

# JCU ePrints

This file is part of the following reference:

**Mangott, Arnold H. (2010) *Behaviour of dwarf minke whales (*Balaenoptera acutorostrata* subsp.) associated with a swim-with industry in the northern Great Barrier Reef.* PhD thesis, James Cook University.**

Access to this file is available from:

<http://eprints.jcu.edu.au/19001>

**Behaviour of dwarf minke whales (*Balaenoptera  
acutorostrata* subsp.) associated with a swim-with  
industry in the northern Great Barrier Reef**

Thesis submitted by

Arnold H. MANGOTT, B.Sc.

in November 2010

for the degree of

Doctor of Philosophy

School of Earth and Environmental Sciences and Business

James Cook University

Townsville

Australia

## STATEMENT OF ACCESS

I, the undersigned, author of this work, understand that James Cook University will make this thesis available for use within the University Library and, via the Australian Digital Theses network, for use elsewhere. All users consulting this thesis will have to sign the following statement:

“In consulting this thesis I agree not to copy or closely paraphrase it in whole or in part without consent of the author and to make proper written acknowledgement for any assistance which I have obtained from it.”

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and I do not wish to place any further restriction on access to this work.

Signature \_\_\_\_\_

Date \_\_\_\_\_

Arnold H. Mangott

## STATEMENT OF SOURCES DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Signature \_\_\_\_\_ Date \_\_\_\_\_

Arnold H. Mangott

## **ELECTRONIC COPY**

I, the undersigned, the author of this work, declare that the electronic copy of this thesis provided to the James Cook University Library is an accurate copy of the print thesis submitted, within the limits of the technology available.

Signature \_\_\_\_\_ Date \_\_\_\_\_

Arnold H. Mangott

## STATEMENT ON THE CONTRIBUTION OF OTHERS

Project support	Graduate Research Scheme	
	- School of Earth and Environment Sciences	\$ 2,160
	- School of Business	\$ 1,451
	Science for Management award (GBRMPA)	\$ 1,479
	School of Business (IRA)	\$ 3,000
	Minke Whale Tourism Monitoring Fund (GBRMPA)	\$ 7,500
	Minke Whale Project Fund	\$ 3,000
	Cod Hole and Ribbon Reef Operator Association in-kind support (berth spaces)	\$45,000
Stipend	Joint Scholarship (2007-2009) Sustainable Tourism CRC & James Cook University	\$39,860
	Fee waiving scholarship, James Cook University	\$55,000
Supervision	Dr Alastair Birtles Professor Helene Marsh A/Prof Peter Valentine	
Assistance with data collection	Dr Alastair Birtles (u/water photos, descriptions of dwarf minke behaviours, u/water whale-swimmer distances, u/water behavioural observations) Susan Sobotzick (u/water video, u/water behavioural observations, identification of individual whales) Jessica Maddams (u/water whale-swimmer distances, behavioural observations)	
Statistical support	Dr Yvette Everingham Dr Stefan Walker Jessica Maddams	
Editorial assistance	Whole thesis: Jessica Maddams References: Jessica Maddams	

## Declaration on Ethics

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement on Ethics Conduct in Research Involving Human* (1999), the *Joint NHMRC/AVCC Statement and Guidelines on Research Practice* (1997), the *James Cook University Policy on Experimentation Ethics, Standard Practices and Guidelines* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (approval numbers H2375 and A1111).

Signature \_\_\_\_\_ Date \_\_\_\_\_  
Arnold H. Mangott

## ACKNOWLEDGEMENTS

First I would like to thank the most important person in my life, my wife and best friend Jess, as all this would not have been possible without her. Thank you so much for giving me the extra strength, encouragement and love I needed during this time. I know for times too often, it was not easy for you dealing with me being stressed, absent and/or preoccupied in my frame of mind. I am very grateful for your patience, understanding and your help in seeing the bigger picture. I truly enjoyed our times together on the boat observing and studying dwarf minke whales. It was your input, thoughts and ideas which helped me a great deal to fine-tune and strengthen my studies and to successfully collect the information needed for this thesis. With your curious spirit to understand the natural world together with your bright mind, dedication to research and attention to detail you are and always will be an amazing role model for me. I will never find the words accurately expressing how wonderful it is to have you by my side – you are truly beautiful my angel.

I am so very grateful to my parents who have always supported me without a question. It must have come as a shock to you, when I came up with the crazy idea to study marine biology, after establishing and proving myself in my promising tourism career. Nevertheless, you listened and tried to comprehend from the start, and supported me with all your means, strength and love. It was amazing having you both visit me here in Australia, it was so very important for me to show you where I am living and what I am doing. Mum and Dad, you are so very special to me, your guidance, advice and wisdom provided me with strength and reassurance throughout my life.

I am equally grateful to both my brothers, Peter and Stefan. I am very lucky to have such great personalities so close to my heart. You both supported my ideas from

the beginning and were always there when I needed you. I am very proud of you both, for what you achieved and how you mastered your life. You always have been an inspiration for me. It has been hard the last couple of years being so far apart, but I hope that there will be times where we all can be closer and are able to spend much more time together.

I am deeply thankful to my supervisors: Alastair Birtles, Helene Marsh, Peter Valentine and the late Peter Arnold. It was a privilege for me working alongside all of you. Thanks so much Alastair for providing me with the opportunity of studying the behaviour of these amazing creatures. Your guidance and wealth of knowledge about these whales helped me greatly in designing the study and achieving the goals we set. I cannot thank you enough for your patience with my Germanic-English and your effort you put in to correct my drafts. Also, I am very grateful for letting me develop my own thoughts and carry out the study independently, but constructively criticising my decisions along the way. It has been a once in a life-time experience for me working with you.

I cannot thank Helene Marsh enough for her willingness to join in as a supervisor in 2006. Your experience, knowledge and professionalism were priceless to this study. The fortnightly meetings with you were always very productive and thought inspiring, and indeed one of the main ingredients to the quality of this work. I also would like to thank you for the countless hours you spent on correcting my verbose sentences and providing me always with timely and constructive feedback. Finishing this work in time would not have been possible without you.

To Peter Arnold, who unfortunately passed away at the beginning of this study. I am very grateful to you, for the amazing input into my Masters thesis and in the initial design of my PhD study. Your love for these whales and your knowledge

about the natural world inspired me in many ways. You are greatly missed and I would have loved to share all the new findings with you. Thank you also to my co-supervisor, Peter Valentine, who although in the periphery brought a wealth of knowledge to this project. Peter, you have been a great guide on the side.

This project was supported by several different agencies and I am very thankful for their interest in my study. I received a joint scholarship from the Sustainable Tourism CRC and James Cook University in 2007, which provided me with the financial freedom in the last 2 ½ years of my study. I am very grateful for the research funds received from the Great Barrier Reef Marine Park Authority, the School of Earth and Environmental Sciences and School of Business. I would also like to thank all the operators and managers (*Undersea Explorer* – Louise Bernstein; *Mike Ball Dive Expeditions* – Mike Ball, Craig Steven and Janine; *Explorer Ventures* – Laurene and John; *TAKA* – Andy and Pam) and crews of the swim-with-dwarf minke whale industry, who provided me with the amazing in-kind support and help to carry out my studies. In particular I would like to give my gratitude to the crew of *Undersea Explorer* - Jaap, Brenden, John Marsden, John Rumney, Qamar, Emily and Claire. It has been amazing working with you with the shared belief to make the world a better place.

I would also like to say a big thanks to all my colleagues, Susan, Matt and Will. It was great working alongside you. Having people around who are dealing with similar problems and issues has proven to be an amazing help. Thanks for reading my drafts, providing me with constructive feedback, cheering me up and being there when I needed you. Great times we had on the way, which I never want to miss. Also, good luck to all three of you, with finishing off your PhDs and your future careers.

I would also like to thank Yvette Everingham and Stefan Walker, for all the statistical advice and help along the way. I learnt a great deal from you both about the statistical world. Also it would not have been possible without the help of all our volunteers. Thanks so much for being interested in my work and the whales. Your effort in this project was priceless and I truly hope that you found it enjoyable and more importantly gained knowledge about the whales in the process.

A special thank you to all of my Key Informants. Without your willingness to participate a crucial aspect of my study, the risk assessment, would not have been possible. You also provided me with many insights into marine mammal behaviour, management and conservation.

Last but not least, I would like to thank my two anonymous reviewers for their interest in my study. Your advice and positive criticism has greatly improved my work.

## PUBLICATIONS ASSOCIATED WITH THIS THESIS

Information from this thesis, which currently is in review or in preparation to be submitted to peer reviewed journals. From information in Chapter 4 the following articles are currently accepted or in review:

**Mangott, A.,** Birtles A. & Marsh, H. (2011) Attraction of dwarf minke whales (*Balaenoptera acutorostrata* subsp.) to vessels and swimmers – management challenges for an inquisitive whale. *Journal of Ecotourism*, xx, xxx-xxx

From information in Chapters 3, and 6 following manuscripts are currently in preparation for submission.

**Mangott, A.,** Birtles A., Marsh, H. & Valentine., P. (in prep.) Who is looking at whom? Exploratory behaviour of dwarf minke whales during swim-with interactions. *Wildlife Research* or the *Journal of Environmental Management*.

**Mangott, A.,** Birtles, A. and Marsh, H. (in prep.) Non-acoustical behaviour repertoire of interacting dwarf minke whales in the northern Great Barrier Reef. *Marine Mammal Science*

**Mangott, A.,** Birtles, A. and Marsh, H. (in prep.) Dwarf minke whale behaviours of concern during swim-with interactions – a risk assessment. *Environmental Conservation or Conservation Biology*

### Related publication

Birtles, A., Arnold, P., Curnock, M., Salmon, S., **Mangott, A.,** Soltzick, S., Valentine, P., Caillaud, A. & Rumney, J. (2008) Code of Practice for dwarf minke whale interactions in the Great Barrier Reef World Heritage Area. Great Barrier Reef Marine Park Authority, Townsville, Australia

## ABSTRACT

A diffuse aggregation of dwarf minke whales occurs in the northern Great Barrier Reef World Heritage Area during the austral winter months. This area coincides with a region heavily used by a large dive and snorkel tourism industry. Over the last two decades a small part of this industry has developed into a swim-with dwarf minke whale industry that has been limited via a permit scheme since 2003. Very little was understood about the whales' behaviour or the response of the whales to the vessels and swimmers. In order to address this knowledge gap, I designed this study with two major aims: (1) to provide detailed insights into the behaviour of dwarf minke whales around tourism vessels and swimmers, and (2) to establish recommendations for the tourism industry and management agencies to provide for discussions on future management and to contribute to the sustainability of this industry.

During my research (2006-2008), I described over 30 distinctive dwarf minke behaviours and provided evidence for the presence of behaviours with potential social and investigative functions. Behaviours with likely social attributes such as *belly presentations* and *bubble releases*, were significantly influenced by a large group size (>6 animals), while investigatory behaviours such as *close* and *very close approaches*, *motorboating*, and *headrises* were positively influenced by the presence of resighted animals. Dwarf minke whales are a predominantly solitary oceanic species. When they form social groups, behaviours which convey information among conspecifics via visual communication (e.g. presenting the white belly or releasing bubbles) may be particularly important. The presence of several investigative behaviours during interactions with vessels and swimmers highlights the inquisitive nature of these whales and suggests that such behaviours are an important part of their ecology (i.e. finding mates, food or avoiding predators).

I also investigated potential agonistic and disturbance displays of dwarf minke whales and provided an indication on the metabolic costs of interacting with humans. The scarcity of agonistic and disturbance responses and the absence of avoidance behaviours, all suggest that the vessels and swimmers have a relatively low impact on the whales. Nonetheless, several behaviours including *close (>1-3 metres)* and *very close ( $\leq 1$  metre) approaches* to human observers and potential agonistic and disturbance behaviours (e.g. *gapes/gulps, jaw claps*) were identified as of potential harm to both the whales and the swimmers.

The investigative nature of dwarf minke whales was further explored by quantifying the distribution of interacting whales around vessels and swimmers and examining if their behaviour changes in interactions with humans over time. Dwarf minke whales voluntarily approached dive tourism vessels and maintained contact for prolonged periods ( $X \pm SE$ , 2006-2008 =  $171 \pm 11$  minutes). These whales showed a highly clumped distribution around the vessel, surfacing more often within a 60 metres radius of the boat than expected and aggregating around swimmers. My results also suggest that dwarf minke whales change their behaviour over time in interactions with humans. Individual whales repeatedly passed very close to the swimmers ( $X=7.08$  metres  $\pm$  SE 0.09 metres;  $N=119$  whales) and significantly decreased their passing distance over the course of an interaction. In both cases, closeness was significantly influenced by group size; the larger the group of whales, the closer individuals approached the observers. Individual dwarf minke whales significantly decreased their passing distance in subsequent interactions and resighted animals approached swimmers significantly closer than unknown individual whales.

The voluntary initiation of contact with humans, the whales' close and prolonged association with the vessel and swimmers, the closeness of their

approaches and the increased familiarity to the stimuli, all suggest a strong exploratory drive of dwarf minke whales. Indeed, the inquisitive behaviour of dwarf minke whales contrasts with the behaviour of most free-ranging marine mammals interacting with humans. These behavioural attributes raise management issues and concerns about the safety of both the whales and the human participants.

I assessed the risk of harm associated with swimming with dwarf minke whales for both, the swimmers and the whales using both, my observational data and the perceptions of Key Informants (marine mammal experts, and members of management and non-governmental organisations). This assessment revealed that most dwarf minke whale behaviours displayed during interactions are of low risk of harm to the swimmers and the whales. Nevertheless, in a fifth of the total observed interactions (n=101) there was at least one whale behaviour present with potential to harm swimmers and/or whales. In addition, I identified 22 occasions from all interactions of the endorsed industry (N=467; 2006-2008) where whales made physical contact with objects (e.g. ropes, dinghy) or swimmers and five (22%) of those incidents were caused by only one individual resighted whale.

The Key Informants perceived the risk of harm to swimmers from the swim with industry as much greater than the risk of harm to the whales. Nonetheless they were concerned about the wellbeing of the whales in the medium to longer term, i.e. the potential of such industries to change the behaviour of the whales and impact on their behavioural budget and fitness. Most Key Informants evaluated the current swim-with dwarf minke whale industry positively; however, they considered that this industry needs continuous monitoring and future research in order to identify any long-term impacts and to address research gaps for adequate management.

I also evaluated the accuracy of data collected by crew on dwarf minke whale behaviours. The crew reported dwarf minke whale behaviours via the Whale Sighting Sheets. I compared these records (presence/absence of behaviour per encounter) with my data. The best fitting commonalities between my observations and data reported via the Whale Sighting Sheets were between *close* ( $>1-3$  metres) and *very close approaches* ( $\leq 1$  metre), *headrises*, *motorboating* and *touching behaviour*. For crew to be able to identify these particular whale behaviours is important for both, cost-efficient longer-term monitoring and the risk management of interactions. I also used a passenger questionnaire (Interaction Behaviour Diary) to evaluate passengers' satisfaction with their whale swims, and to investigate their perceptions about potential harmful dwarf minke whale behaviours. Swimmers were more satisfied when dwarf minke whales approached very close ( $\leq 1$  metre) to them and perceived such close encounters as harmless. Both these reactions pose challenges to the effective management of risks associated with interactions.

This study is the first comprehensive assessment of the behaviour of a baleen whale associated with a tourism industry. It provides a scientific basis for future studies on dwarf minke whales and will be useful for behavioural studies of other baleen whales associated with humans. This study provides specific recommendations to improve the future management of the swim-with dwarf minke whale industry and to ensure the protection of this species.

## Table of Contents

### CHAPTER 1

#### GENERAL INTRODUCTION AND LITERATURE REVIEW.....1

1.1	WHALE WATCHING .....	2
1.2	SWIM-WITH CETACEANS PROGRAMS .....	3
1.3	EFFECTS OF WHALE WATCHING TOURISM ON CETACEANS .....	4
1.3.1	<i>Short-term responses of cetaceans</i> .....	4
1.3.2	<i>Long-term responses</i> .....	6
1.4	LIFE HISTORY AND SOCIAL STRUCTURE OF ODONTOCETES AND MYSTICETES ...	8
1.4.1	<i>Life history - reproduction, feeding and seasonal migration</i> .....	8
1.4.2	<i>Social organisation in odontocetes</i> .....	9
1.4.3	<i>Social organisation in mysticetes</i> .....	11
1.4.4	<i>Challenges with extrapolating findings from odontocetes to mysticetes</i> 12	
1.5	MEASURING BEHAVIOUR.....	13
1.5.1	<i>Research design</i> .....	13
1.5.2	<i>Behavioural sampling techniques</i> .....	15
1.5.3	<i>Sampling methods</i> .....	16
1.6	THE SWIM-WITH DWARF MINKE WHALE INDUSTRY IN THE GREAT BARRIER REEF .....	20
1.7	RESEARCH AIMS AND THESIS STRUCTURE .....	23

### CHAPTER 2

#### GENERAL MATERIAL AND METHODS .....27

2.1	STUDY AREA .....	28
2.2	PLATFORMS OF OPPORTUNITY – THE SWIM-WITH DWARF MINKE WHALE INDUSTRY.....	29
2.3	LEGISLATIVE BACKGROUND.....	30
2.3.1	<i>National Guidelines for Whale and Dolphin Watching</i> .....	32
2.3.2	<i>Code of Practice for swimming with dwarf minke whales</i> .....	33
2.5	WHALE SIGHTING SHEET .....	34
2.5	INTERACTION BEHAVIOUR DIARY .....	35
2.6	STUDY SPECIES – DWARF MINKE WHALES .....	35
2.7	DESCRIPTION OF ENCOUNTERS/INTERACTIONS WITH DWARF MINKE WHALES .....	37
2.8	GENERAL RESEARCH PROTOCOL (2006-2008).....	38
2.9	DEFINITIONS .....	40

### CHAPTER 3

#### NON-ACOUSTIC BEHAVIOURAL REPERTOIRE OF DWARF MINKE WHALES INTERACTING WITH VESSELS AND SWIMMERS IN THE NORTHERN GREAT BARRIER REEF.....41

3.1	INTRODUCTION .....	42
3.2	METHODS.....	46
3.2.1	<i>Partial ethogram</i> .....	46
3.2.3	<i>Context of behavioural occurrences and associations of behaviours</i> ....	48

3.2.4	<i>Limitations</i> .....	49
3.3	RESULTS .....	50
3.3.1	<i>General</i> .....	50
3.3.2	<i>Partial ethogram of interacting dwarf minke whales</i> .....	50
3.3.3	<i>Behavioural occurrences in in-water interactions / encounters</i> .....	63
3.3.4	<i>Potential factors influencing the occurrence of dwarf minke whale behaviour</i> .....	64
3.3.5	<i>Association of behavioural occurrences</i> .....	64
3.3.6	<i>Breathing intervals of individual dwarf minke whales</i> .....	65
3.4	DISCUSSION .....	66
3.4.1	<i>Potential functions of dwarf minke behaviours during interactions with humans</i> .....	67
3.4.2	<i>Potential agonistic, aggressive and disturbance behaviours of dwarf minke whales</i> .....	71
3.4.3	<i>Chapter summary</i> .....	75

## CHAPTER 4

### WHO IS LOOKING AT WHOM? EXPLORATORY BEHAVIOUR OF DWARF MINKE WHALES DURING SWIM-WITH INTERACTIONS AND ASSOCIATED MANAGEMENT CHALLENGES.....76

4.1	INTRODUCTION .....	77
4.2	MATERIALS AND METHODS .....	80
4.2.1	<i>Whale Sighting Sheets 2006-2007</i> .....	80
4.2.2	<i>Ad libitum sampling protocol (2006)</i> .....	81
4.2.3	<i>Adaptive scan sampling protocol (2007)</i> .....	81
4.2.4	<i>Distance measurements of whale passes from the researcher (2008)</i> ....	82
4.2.5	<i>Data analyses</i> .....	83
4.3	RESULTS .....	86
4.3.1	<i>Distribution of dwarf minke whales around vessels and swimmers</i> .....	86
4.3.2	<i>Distance measurements of whale-swimmer passes (2008)</i> .....	88
4.4	DISCUSSION .....	92
4.4.1	<i>Initiation of interactions with vessels and swimmers</i> .....	94
4.4.2	<i>Approaching closer over time</i> .....	96
4.4.3	<i>Concerns arising from the attraction of dwarf minke whales to vessels and swimmers</i> .....	98
4.4.4	<i>Management challenges</i> .....	99
4.4.5	<i>Chapter summary</i> .....	100

## CHAPTER 5

### DWARF MINKE WHALE BEHAVIOURS OF POTENTIAL RISK OF HARM TO SWIMMERS AND/OR WHALES.....102

5.1	INTRODUCTION .....	103
5.2	METHODOLOGY .....	106
5.2.1	<i>Dwarf minke whale behaviours which are of potential harm to swimmers and/or the whales</i> .....	107

5.2.2	<i>Factors contributing to the potential risk of harm.....</i>	107
5.2.3	<i>Occurrence probability of dwarf minke whale behaviours in interactions/encounters.....</i>	108
5.2.4	<i>Key Informant Survey .....</i>	108
5.2.6	<i>Assessment of the risk of harm from dwarf minke whale behaviours ...</i>	112
5.2.6	<i>Limitation to the study .....</i>	113
5.3	<b>RESULTS .....</b>	113
5.3.1	<i>Key Informant Survey .....</i>	113
5.3.2	<i>Occurrence probability of dwarf minke whale behaviours of potential harm to swimmers and/or the whales .....</i>	119
5.3.3	<i>Risk of harm to swimmers or the whales from dwarf minke whale behaviours.....</i>	120
5.3.4	<i>Interactions with dwarf minke whale behaviours of greater harm to swimmers and/or whales.....</i>	122
5.3.5	<i>Dwarf minke whales making physical contact with objects and swimmers.....</i>	122
5.4	<b>DISCUSSION .....</b>	124
5.4.1	<i>Direct risk of harm to swimmers from dwarf minke whales .....</i>	125
5.4.2	<i>Risk of harm to swimmers associated with individual whales.....</i>	126
5.4.3	<i>Risk of harm to swimmers from external factors .....</i>	129
5.4.4	<i>Risk of harm to dwarf minke whales .....</i>	129
5.4.5	<i>Indirect risk of harm to dwarf minke whales .....</i>	131
5.4.6	<i>Risk of harm to the swim-with dwarf minke whale industry.....</i>	132
5.4.7	<i>Chapter summary.....</i>	133

## **CHAPTER 6**

### **MONITORING OF DWARF MINKE WHALE BEHAVIOURS AND INSIGHTS INTO PERCEPTIONS OF PASSENGERS REGARDING BEHAVIOURS OF POTENTIAL HARM.....135**

6.1	<b>INTRODUCTION .....</b>	136
6.2	<b>METHODS.....</b>	139
6.2.1	<i>Occurrences of dwarf minke whale behaviours reported by the endorsed industry using the Whale Sighting Sheet.....</i>	139
6.2.2	<i>Comparison of dwarf minke whale behaviour occurrences in interactions between the Whale Sighting Sheet and researcher observations (2006-2008).....</i>	140
6.2.3	<i>Association of investigatory behaviours with very close approaches (<math>\leq 1</math> metre) of dwarf minke whales to swimmers and/or the vessel. ....</i>	141
6.2.4	<i>Time to the first occurrence of a close approach (<math>&gt;1-3</math> metres) and very close approach (<math>\leq 1</math> metre) by dwarf minke whales to swimmers and the vessel.....</i>	141
6.2.5	<i>Passengers' satisfaction rates and perceptions of management of their in-water interactions .....</i>	142
6.2.6	<i>Passengers' perceptions of dwarf minke whale behaviours and their concerns about swimming with these whales.....</i>	142
6.3	<b>RESULTS .....</b>	143
6.3.1	<i>Behavioural occurrences in in-water interactions / encounters reported via the Whales Sighting Sheets.....</i>	143

6.3.2	<i>Comparison of behavioural occurrences between the Whale Sighting Sheets and researcher observations.....</i>	144
6.3.3	<i>Potential influencing behaviours on the occurrence of very close approaches (<math>\leq 1</math> metre) of dwarf minke whales to swimmers and/or vessel.....</i>	145
6.3.4	<i>Time to the first occurrence of a close approach (<math>&gt;1-3</math> metres) and very close approach (<math>\leq 1</math> metre) of dwarf minke whales to swimmers and the vessel.....</i>	145
6.3.5	<i>Passengers' satisfaction rates and perceived management of their in-water interactions.....</i>	146
6.3.6	<i>Passengers' perceptions of dwarf minke whale behaviours which potentially put either swimmers or whales at risk.....</i>	147
6.3.7	<i>Passenger concerns about swimming with dwarf minke whales.....</i>	148
6.4	DISCUSSION.....	150
6.4.1	Chapter Summary.....	155

## CHAPTER 7

### GENERAL DISCUSSION AND SYNTHESIS.....157

7.1	INTRODUCTION.....	158
7.2	MAJOR RESULTS OF THIS STUDY.....	159
7.3	ADVANCES IN KNOWLEDGE ABOUT DWARF MINKE WHALES.....	165
7.4	IMPLICATION FOR THE CONSERVATION AND MANAGEMENT OF DWARF MINKE WHALES.....	166
7.5	OPTIONS FOR THE MANAGEMENT OF DWARF MINKE WHALES IN THE GREAT BARRIER REEF.....	170
7.6	SPECIFIC RECOMMENDATIONS FROM MY PHD STUDY.....	172
7.7	FUTURE RESEARCH ON THE BEHAVIOUR OF DWARF MINKE WHALES.....	174
7.7.1	<i>Overall population size of dwarf minke whales in the Great Barrier Reef.....</i>	175
7.7.2	<i>Satellite-linked telemetry; daily activity budget, area usage and migratory pathways and destination of dwarf minke whales.....</i>	176
7.8	FINAL REMARKS.....	177

### REFERENCES.....179

## Appendices

<b>Appendix 1:</b>	Whale Sighting Sheet 2009.....	216
<b>Appendix 2:</b>	Akaike Information Criterion (AIC) Index ranking the predictor variables which influence the occurrences of dwarf minke whale behaviours.....	217
<b>Appendix 3:</b>	Letter to the Key Informants outlining the aims and objectives and explaining the conduct, duration and time frame of the anticipated three surveys.....	219
<b>Appendix 4:</b>	Meet the Minkes. Dwarf minke whale interpretive DVD, 2007...	220
<b>Appendix 5:</b>	Key Informant Internet Survey questionnaire – Part 1.....	221
<b>Appendix 6:</b>	Key Informant Interview – Part 2.....	225
<b>Appendix 7:</b>	Key Informant Survey – Part 3.....	229
<b>Appendix 8:</b>	Key Informants’ ratings of dwarf minke whale behaviours of potential harm to swimmers in the assigned distance categories (rating scale from 1 = no risk to 5 = very high risk).....	233
<b>Appendix 9:</b>	Key Informants’ ratings of dwarf minke whale behaviours of potential harm to the whales in the assigned distance categories (rating scale from 1 = no risk to 5 = very high risk).....	234
<b>Appendix 10:</b>	Key Informants’ field of expertise.....	235
<b>Appendix 11:</b>	Marine mammal species on which the Key Informants worked on.....	236
<b>Appendix 12:</b>	Key Informants’ view about commercial tourism operations offering swims with cetaceans.....	237
<b>Appendix 13:</b>	Key Informants’ concerns for the targeted animals in swim-with cetacean industries.....	238
<b>Appendix 14:</b>	Key Informants responses to the question if they have any concerns for the participants (swimmers) in swim-with cetacean industries.....	239
<b>Appendix 15:</b>	Reasons why Key Informants perceived the rated behaviours of high or very high potential to harm swimmers.....	240
<b>Appendix 16:</b>	Reasons why Key Informants perceived the rated behaviours of high or very high potential to harm whales.....	241
<b>Appendix 17:</b>	Interaction Behaviour Diary 2008.....	242

## List of Tables

Table 2.1	Descriptions of swim-with dwarf minke whale endorsed operations (2006-2008); day boat operations shaded.....	31
Table 3.1	Categorisation of the probability of the occurrence of dwarf minke whale behaviours.....	47
Table 3.2	Dwarf minke whale encounters and in-water interactions observed during the research period (June/July) from 2006–2008.....	50
Table 3.3	Descriptions of dwarf minke whale behaviours observed during the research period in June/July 2006-2008.....	51
Table 3.4	Occurrences of dwarf minke whale behaviours in in-water interactions during the research period in June/July 2006-2008.....	63
Table 3.5	Generalised linear model testing the likelihood of the occurrence of dwarf minke whale behaviours in in-water interactions.....	64
Table 3.6	Results of a Generalised Linear Model showing the likelihood (Exp(B)) of the presence of behaviours in an in-water interaction if a particular behaviour occurred (** $\alpha$ level $\leq 0.01$ ; * $\alpha \leq 0.05$ ).....	65
Table 4.1	Outcomes of a Repeated Measures ANOVA testing individual whale passing distance to the observer over time (Beginning, Middle and End Interaction) with the grouping predictor variables of whale group size (1-3, 4-6 and >6 animals), Boat status (Drifting, Stationary) and Wind status (15, 20 knots).....	89
Table 4.2	Outcomes of a Repeated Measures ANOVA comparing the passing distances of five individual whales from their first to their subsequent interaction.....	91
Table 5.1	Risk assessment chart of dwarf minke whale behaviours according to the probability of occurrence and the Key Informants' perceived harm of dwarf minke whale behaviours to the swimmers and/or the whales .....	112
Table 5.2:	Key Informants' views about the swim-with dwarf minke whale industry in the northern Great Barrier Reef .....	116
Table 5.3:	Occurrence probability of interactions featuring dwarf minke whale behaviours of potential harm to swimmers and/or the whales in the assigned distance categories.....	119
Table 5.4	Individual dwarf minke whales exhibiting behaviours of greater risk to harm swimmers.....	123
Table 5.5	Incidents of physical contact between dwarf minke whales and objects and swimmers.....	124
Table 6.1:	Ranked occurrence probabilities of dwarf minke whale behaviours reported by crew via the Whale Sighting Sheets (2006-2008).....	143
Table 6.2	Dwarf minke whale behaviours which significantly influence the occurrence of <i>very close approaches</i> ( $\leq 1$ metres) of the whales to swimmers or vessel.....	145

Table 6.3	Passengers' perceptions why there were/weren't any dwarf minke whale behaviours that potentially put either swimmers or whales at risk of harm.....	149
Table 6.4:	Passengers' concerns about swimming with dwarf minke whales...	150

## List of Figures

Figure 1.1	Diagram of thesis structure.....	26
Figure 2.1	Map of the northern Great Barrier Reef showing the main locations (i.e. Agincourt Reefs, Ribbon Reefs, Cod Hole) where dwarf minke whales are encountered by the tourism industry in the austral winter months (May-August).....	28
Figures 2.2a	Movement pattern (simplified) of dwarf minke whales around <i>Undersea Explorer</i> in drifting in-water interactions.....	38
Figures 2.2b	Movement pattern (simplified) of dwarf minke whales around <i>Undersea Explorer</i> in stationary in-water interactions.....	38
Figure 3.1	Sequence showing a <i>belly presentation</i> by a dwarf minke whale....	55
Figure 3.2	<i>Bubble releases</i> of dwarf minke whales.....	56
Figure 3.3	<i>Headrises</i> of dwarf minke whales.....	57
Figure 3.4	Sequence of a dwarf minke whale <i>pirouetting</i> .....	58
Figure 3.5	<i>Breaching</i> dwarf minke whales.....	59
Figure 3.6	<i>Close (&gt;1-3 metres) and very close approaches (≤1 metre)</i> by dwarf minke whales.....	60
Figure 3.7	<i>Lunging</i> dwarf minke whale.....	61
Figure 3.8	<i>Gulping/gaping</i> dwarf minke whales.....	62
Figure 3.9	Mean breathing intervals (sec ± SE) of twelve individual dwarf minke whales and three cow-calf pairs recorded over the three consecutive research periods (2006-2008).....	66
Figure 4.1	Assigned Areas (defined by distance to vessel) and sectors (based on an imaginary clock face) used for data collection on the distribution of interacting dwarf minke whales around the vessel and swimmers.....	82
Figure 4.2	Proportions of observed surfacing of whales from 20 in-water interactions in 2006 for 1-2 animals (n=170) and >2 animals (n=1656).....	86
Figure 4.3	Observed versus expected frequencies of surfacing dwarf minke whales (per unit effort and unit area) in the three assigned areas ( <i>Inner, Middle</i> and <i>Outer Area</i> ) around the vessel from 18 in-water interactions in 2007.....	87
Figure 4.4.	Observed versus expected frequencies of surfacing dwarf minke whales in the four assigned quarters ( <i>Rope/Swimmer Quarter, Left Quarter, Right Quarter</i> and <i>Opposite Quarter</i> ) in the area closest to the vessel ( <i>Inner Area</i> ) (n=18 in-water interactions).....	88
Figure 4.5	Whale group size dependent changes in mean (±SE) whale-swimmer passing distances (metres) of individual whales ( $m = 20$ ) during the first 90 minutes of in-water interactions (time based categories: ‘Beginning Interaction’, ‘Middle Interaction’, ‘End Interaction’)....	90

Figure 4.6	Changes in mean ( $\pm$ SE) passing distance (m; log <sub>10</sub> transformed) of individual whales (n=5) from their first to their subsequent Interaction.....	91
Figure 4.7	Mean ( $\pm$ SE) passing distances (metres) of non-resighted and resighted whales to swimmers during the first hour of in-water interactions (n=9).....	92
Figure 4.8a	Process of habituation Type I (after Bejder et al., in press).....	98
Figure 4.8b	Process of increased attraction (habituation Type II) as observed In dwarf minke whales.....	98
Figure 5.1:	Key Informants' mean rating of the potential of harm to swimmers (rating scale from 1 = no risk - 5 = very high risk) from individual dwarf minke whale behaviours in the four assigned distance categories.....	118
Figure 5.2:	Key Informants' mean rating of the potential of harm to whales (rating scale from 1= no risk - 5 = very high risk) from individual dwarf minke whale behaviours in the four assigned distance categories.....	118
Figure 5.3	Risk of harm to swimmers from dwarf minke whale behaviours in the assigned distance categories ( $\leq$ 1 metre; >1-3 metres; >3-6 metres; >6 metre) with respect to the occurrence probability of the behaviour in interactions and the potential of harm (consequences) perceived by Key Informants.....	121
Figure 5.4	Risk of harm to dwarf minke whales from their behaviours in the assigned distance categories ( $\leq$ 1 metre; >1-3 metres; >3-6 metres; >6 metre), with respect to the occurrence probability of the behaviour in interactions and the potential of harm (consequences) perceived by Key Informants.....	121
Figure 6.1	Comparison of the occurrences of dwarf minke whale behaviours between my behavioural observations and the Whale Sighting Sheets over the research period of 2006-2008.....	144
Figure 6.2:	First occurrences of <i>close</i> (>1-3 metres) and <i>very close approaches</i> ( $\leq$ 1 metre) of dwarf minke whales to swimmers or the vessel in interactions (researcher observations).....	146
Figure 6.3	Comparison of passengers' satisfaction between interactions where very close approaches of dwarf minke whales were present (n=215) or absent (n=216).....	147