

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

Establishing Death in Stranded
Odontocetes (Toothed Whales)

Using Other Mammals:

A Pilot Study

A thesis presented in partial fulfillment
of requirements for the degree of
Master of Science in Zoology
At Massey University

Katherine A. Paul
2003

Acknowledgements

I am extremely indebted to my Supervisors Associate Professor Robin Fordham, Dr Per Madie and Dr Geoff Barnes for all their support and encouragement throughout the study. I am especially grateful for their confidence in me during the more difficult times of the study.

I would also like to thank Gary McDonald of Marineland of New Zealand in Napier and all of his staff, for his willingness to help, and especially for his unlimited access to their precious dolphins; Auckland Zoological Park and their staff, for their assistance and access to their sea lions, Massey University Large Animal Teaching Unit (LATU), Alison Quinn and Robin Whitson for their access and assistance with their cattle; Palmerston North City Council, Alex Davies, Peter Davies, and Alan Nutman who allowed me access during the euthanasia of their dogs; Keith Lapwood for access to the sheep in his physiology laboratories; and Massey University Teaching Hospital for access to their dogs for initial practice of the techniques.

Many thanks to Travis Dombroski, Jane McDermott and Yvette Cottam for their help with the practical parts of the study; to Erica Reid for driving me to Napier and Duncan Hedderly for his assistance with the statistics used in the study.

I am especially grateful to all the support I received from the Ecology Department, Massey University and to all the postgraduates for their advice and encouragement

Lastly I would like to thank my friends and family for all their encouragement and love especially during difficult times.

I

Table of Contents

| | <u>Page</u> |
|--|-------------|
| Title Page | i |
| Acknowledgements | ii |
| Table of Contents | iii |
| List of Figures | vi |
| List of Tables | x |
| Abstract | 1 |
| General Introduction | 2 |
| | |
| Chapter One: Cetacean Strandings | 4 |
| | |
| 1.1 Introduction | 5 |
| 1.2 Definition | 5 |
| 1.3 Strandings of single individuals | 6 |
| 1.4 Multiple and Mass strandings | 7 |
| 1.5 New Zealand Whale strandings | 11 |
| 1.6 Similarities between Species that Frequently Strand | 14 |
| 1.7 The pilot whale (<i>Globicephala spp.</i>) | 18 |
| 1.8 The killer whale (<i>Orcinus orca</i>) | 20 |
| 1.9 Summary | 22 |
| 1.10 References | 23 |
| | |
| Chapter Two: Handling and Health Assessment of Cetaceans at a Stranding | 31 |
| | |
| 2.1 Introduction | 32 |
| 2.2 Conditions of a Typical Stranding | 32 |
| Example One | 32 |
| Example Two | 34 |
| Example Three | 36 |
| 2.3 Summary of examples | 39 |
| 2.4 Current Legislation concerning Cetacean Strandings | 39 |
| 2.5 Health Assessment of Stranded Animals | 41 |
| 2.5.1 Body Condition | 42 |
| 2.5.2 Breathing | 43 |
| 2.5.3 Discharges | 43 |

| | |
|---|-----------|
| 2.5.4 Temperature | 44 |
| 2.5.5 Skin | 44 |
| 2.5.6 Other signs | 45 |
| 2.5.7 Behaviour | 45 |
| 2.6 Current Procedures involving assistance at a Stranding * | 46 |
| 2.7 Guidelines for Euthanasia | 49 |
| 2.7.1 Method of Euthanasia | 49 |
| 2.8 Marine Mammal Stranding Networks | 51 |
| 2.9 References | 54 |
| | |
| Chapter Three: Determining Death in Mammals and Features Affecting this Procedure in Cetaceans | 57 |
| | |
| 3.1 Introduction | 58 |
| 3.2 Measuring Death in Mammals | 58 |
| 3.3 The Effect of Anatomy and Physiology on Determination of Death in Cetaceans | 59 |
| 3.2.1 Bradycardia | 59 |
| 3.2.2 Body Size | 61 |
| 3.2.3 Blubber | 63 |
| 3.2.4 The Skeleton | 65 |
| 3.2.5 Blowhole | 68 |
| 3.2.6 Breath holding Ability and the Lungs | 70 |
| 3.4 Summary of anatomical and physiological features | 74 |
| 3.5 References | 74 |
| | |
| Chapter Four: Arterial Blood Supply in Mammals | 81 |
| | |
| 4.1 Introduction | 82 |
| 4.2 Cerebral blood circulation in mammals | 82 |
| 4.3 Marine mammals (excluding Cetacea and Sirenia) | 85 |
| 4.4 The Rete Mirabile | 86 |
| 4.4.1 Summary Tables | 89 |
| 4.5 Cerebral blood supply in Carnivora | 90 |
| 4.6 Cerebral blood supply in Pinnipedia | 95 |
| 4.7 Cerebral blood supply in Sirenia | 98 |
| 4.8 Cerebral blood supply in Artiodactyla | 101 |
| 4.9 Cetacean Cardiovascular System | 106 |
| 4.9.1 cervico-thoracic vasculature | 110 |

| | |
|---|------------|
| 4.9.2 The internal carotid | 115 |
| 4.10 References | 118 |
| | |
| Chapter Five: Vision in Cetacea | 126 |
| 5.1 Introduction | 127 |
| 5.2 The Cetacean eye | 127 |
| 5.3 Visual Acuity | 133 |
| 5.4 Colour Perception in Cetaceans | 137 |
| 5.5 The Fundus of the Eye | 139 |
| 5.6 The Importance of Vision in Cetacean Lives | 143 |
| 5.6.1 Detection of Predators | 145 |
| 5.6.2 Finding and Capturing Prey | 146 |
| 5.6.3 Social Communication and Interaction | 149 |
| 5.7 Summary | 154 |
| 5.8 References | 155 |
| | |
| Chapter Six: The Retinal Pulse as a method for Determining Death | 165 |
| 6.1 Introduction | 166 |
| 6.2 Study Animals and Methods | 166 |
| 6.3 Results | 173 |
| 6.3.1 Domestic Cattle | 173 |
| 6.3.2 Domestic Dogs | 178 |
| 6.3.3 Sheep | 183 |
| 6.3.4 Seals and sea lions | 185 |
| 6.3.5 Dolphins | 185 |
| 6.4 Discussion | 186 |
| 6.5 References | 189 |
| | |
| General Discussion | 191 |

List of Figures

| | <u>Page</u> |
|---|-------------|
| Figure 1.1 Stranded pilot whale (<i>Globicephala spp.</i>) from the Chatham Islands | 4 |
| Figure 1.2 Pilot whale stranding in New Zealand using people and a low-flying helicopter to herd animals out to sea | 8 |
| Figure 1.3 Sperm whale stranding in the Wellington Region of New Zealand | 9 |
| Figure 1.4 Sperm whale stranding in the Chatham Islands New Zealand | 10 |
| Figure 1.5 Pilot whale stranding in the Wellington Region of New Zealand | 12 |
| Figure 1.6 Map of New Zealand showing the location of the most frequent stranding sites | 13 |
| Figure 1.7 Shark wound healing on a five year old male bottlenose dolphin, Shark Bay Australia | 15 |
| Figure 1.8 Comparison of the short-finned pilot whale (<i>Globicephala macrorhynchus</i>), and the long finned pilot whale (<i>Globicephala melas</i>) | 19 |
| Figure 1.9 Geographical distribution of pilot whales (<i>Globicephala spp.</i>) | 19 |
| Figure 1.10 Geographical distribution of killer whales (<i>Orcinus orca</i>) based on documented records | 21 |
| Figure 1.11 A male killer whale of Patagonia intentionally beaching in order to catch sea lion pups on the shore | 22 |
| Figure 2.1 An air-lifted dolphin | 31 |
| Figure 2.2 False killer whales in the Dry Tortugas, in a tight group formation | 34 |
| Figure 2.3 The Tryphena pilot whales with locals attempting to right those whales that are disorientated. | 36 |

| | | |
|------------|--|----|
| Figure 2.4 | Shortly after the Tryphena whales were refloated, they restranded at this site on the falling tide. | 38 |
| Figure 2.5 | Diagram of examples of different body condition | 42 |
| Figure 2.6 | Examples of emaciated animals not suitable for refloating | 42 |
| Figure 2.7 | A female sperm whale that has drifted in the last stages of a stranding onto a submerged reef. | 44 |
| Figure 2.8 | Examples of how sheets can be used to keep the cetacean cool also note the scooped out mud for easy bucketing of water | 47 |
| Figure 2.9 | Map of the United States showing the four geographical regions that compose the stranding network | 52 |
| Figure 3.1 | Comparison of the blubber between (A) a pinniped and (B) a cetacean | 63 |
| Figure 3.2 | Comparison between different marine mammals, and a 'typical' terrestrial mammal of their different insulation structures | 64 |
| Figure 3.3 | Diagram showing the skeletons of (a) a mysticete and (b) an odontocete | 66 |
| Figure 3.4 | Skeletal systems of some representative marine mammals along with the 'typical' terrestrial mammal | 67 |
| Figure 3.5 | Blowholes of (A) a mysticete and (B) an odontocete | 68 |
| Figure 3.6 | Differences in the nasal passages of (a) mysticete, (b) sperm whale and (c) dolphin | 69 |
| Figure 3.7 | Graph showing lung versus oxygen stores in shallow and deep diving mammals | 71 |
| Figure 3.8 | Diagram showing the morphology of the airways and the alveoli of different mammals | 73 |
| Figure 4.1 | Diagram of the blood supply to the brain in a generalized placental mammal | 83 |
| Figure 4.2 | Diagram of the systemic arteries in the dog (<i>Canis familiaris</i>) | 91 |
| Figure 4.3 | Diagram of the systemic arteries in the dog (<i>Canis familiaris</i>) entering the brain | 93 |

| | | |
|-------------|---|-----|
| Figure 4.4 | Diagram showing the blood vessels supplying the eye in the dog (<i>Canis familiaris</i>) | 94 |
| Figure 4.5 | Diagram showing the blood supply to the brain in Pinnipedia | 97 |
| Figure 4.6 | Diagram showing the blood supply to the brain in Sirenia | 100 |
| Figure 4.7 | Diagram showing the blood supply to the brain in domestic cattle (<i>Bos taurus</i>) | 105 |
| Figure 4.8 | Diagram showing the blood supply to the brain in cetacea | 109 |
| Figure 5.1 | Drawing of a bottlenose dolphin (<i>Tursiops truncatus</i>), binocularly looking at an object | 126 |
| Figure 5.2 | Diagram of a cross section of the eye of a harbour porpoise (<i>Phocoena phocoena</i>) | 127 |
| Figure 5.3 | Anterior part of the eye with surrounding tissue | 129 |
| Figure 5.4 | Diagram showing the comparison of the eye and lens shape of a human, pinniped, and cetacean; optics in air and water | 131 |
| Figure 5.5 | A rod and a cone as found in the retina of <i>Balaneoptera physalus</i> | 137 |
| Figure 5.6 | Diagram of the fundus of a bottlenose dolphin (<i>Tursiops truncatus</i>) | 141 |
| Figure 5.7 | Bottlenose dolphins (<i>Tursiops truncatus</i>) chasing fish onto mud banks in South Carolina | 148 |
| Figure 5.8 | Rotating pairs of Hawaiian spinner dolphins (<i>Stenella longirostris</i>) | 150 |
| Figure 5.9 | Shark bay bottlenose dolphin (<i>Tursiops truncatus</i>) calf spy-hops during play | 151 |
| Figure 5.10 | Examples of cetacean pigmentation patterns (a) beluga <i>Delphinapterus leucas</i> (b) killer whale <i>Orcinus orca</i> (c) spectacled porpoise <i>Phocoena dioptrica</i> | 153 |
| Figure 6.1 | A common dolphin (Kelly) being lifted from its pool | 165 |
| Figure 6.2 | Looking into the eyes of an adult male New Zealand fur seal (Angel) using an ophthalmoscope | 168 |
| Figure 6.3 | An adult male Californian sea lion (Skuttles) at Auckland Zoo | 169 |

| | | |
|-------------|--|-----|
| Figure 6.4 | Looking into the eyes of a common dolphin (Kelly) at Marineland using an ophthalmoscope | 171 |
| Figure 6.5 | Tilting of the dolphin during the procedure to observe a retinal pulse | 172 |
| Figure 6.6 | Relationship of the difference between retinal pulse rate and heart rate and the mean of these two measures | 175 |
| Figure 6.7 | Relationship between retinal pulse rate and heart rate in cattle using a regression line | 176 |
| Figure 6.8 | The predicted heart rate of cattle using the retinal pulse rate | 177 |
| Figure 6.9 | Data set for the time of death in dogs (<i>Canis familiaris</i>) showing the relationship between the two measurements | 180 |
| Figure 6.10 | Relationship between retinal pulse and heart beat in the times of death in dogs (<i>Canis familiaris</i>) | 181 |
| Figure 6.11 | Scatter graph of the entire data set | 182 |
| Figure 6.12 | Scatter graph for the data set excluding the three outliers | 182 |

List of Tables

| | <u>Page</u> |
|---|-------------|
| 4.1 List of Abbreviations for Figure 4.1 | 83 |
| 4.2 Descriptions of the different types of rete mirabile | 89 |
| 4.3 Descriptions of the different vessels from in the rete mirabile | 89 |
| 4.4 List of Abbreviations for Figure 4.5 | 97 |
| 4.5 List of Abbreviations for Figure 4.6 | 101 |
| 4.6 List of Abbreviations for Figure 4.7 | 106 |
| 4.7 List of Abbreviations for Figure 4.8 | 110 |
| 6.1 Mean of the Retinal Pulse Rate (beats/min) and the Heart Rate (beats/min) in live cattle (<i>Bos taurus</i>), and the difference between these scores | 174 |
| 6.2 Table showing the time of cessation of the heart beat and the time of cessation of the retinal pulse in dogs (<i>Canis familiaris</i>) | 178 |
| 6.3 Observational data the time of cessation of the retinal pulse in sheep | 183 |

Abstract

The aim of this study was to investigate and evaluate a new method for determining death in stranded odontocetes (toothed whales). The new method was using the pulsations seen in the retinal blood vessels in the place of the heart rate. The retinal blood vessels can be visualized, using an ophthalmoscope, in the fundus of the eye. Initially the procedure was to be tested using animals at a mass stranding, but there were no suitable strandings that took place during the time of the study.

Therefore other mammal species were used to test the procedure. These mammals were cattle, sheep, and dogs, with additional observational testing carried out on seals, sea lions and dolphins. The mammals were chosen because of their availability and supply.

The results showed that there was a strong relationship between the heart rate and the pulsations measured in the retinal blood vessels. This was expected as the cardiovascular system is connected and pulsations of blood vessels must have originated from the heart. The results using dogs, also indicated that there is a relationship between the cessation of the pulsations in the retinal blood vessels and the cessation of the heart beat. Dogs were used as a benchmark by which all other mammals could be compared.

Therefore this study indicates that it is possible to identify the cessation of the heart using the cessation of the pulsations in the retinal blood vessels

General Introduction

Cetacean (whales, dolphins and porpoises) strandings have been recorded since Aristotle 2000 years ago (Geraci 1978) and have provided intrigue and interest for both scientists and the general public since that time. Strandings can be divided into two categories, single strandings and multiple or mass strandings (Geraci 1978, Robson 1984, Dawson 1985). Single strandings occur in many species throughout the world, and have provided valuable scientific information (Odell 1987). But it is mass or multiple strandings, which can involve hundreds of individuals, that rouse the highest level of interest. This type of stranding happens only in certain parts of the world and regularly involves only certain species (Odell 1987), all of which are social odontocetes (toothed whales) (Geraci 1978).

At a mass stranding where seemingly healthy animals came ashore while still alive, 80% of those animals that strand will not survive (Mazzuca *et al* 1999). Therefore it is very important to be able to make accurate judgements about an animal's state of health in order to improve the overall welfare of the animals at a stranding. Unfortunately the 'usual' methods for determining death in mammals are difficult to apply to cetaceans, because of a number of anatomical and physiological features (Pabst *et al* 1999) that they have. This accurate assessment of their state of health is not a straight forward exercise.

The aim of this study is to investigate and evaluate a new method of determining death using pulsations in the retinal blood vessels. The intention was to examine recently stranded whales, however over two years far fewer than the average number of strandings occurred, and the

one or two that did were not accessible in time. Accordingly the measurement was tested using dogs, sheep and cattle with additional observational testing carried out on seals, sea lions and dolphins. In order to fully understand how this technique can be assessed it is important to understand the complexity of the cetacean cardiovascular and visual systems, and these are compared with those species used to test the procedure.

References

Dawson S. 1985. *The New Zealand Whale and Dolphin Digest*. Brick Row Publishing Co. Ltd. Auckland

Geraci J. 1978. *The enigma of marine mammal strandings*. Oceanus 21: 38-47

Mazduca L., Atkinson S., Keating B. & Nitta E. *Cetacean mass stranding in the Hawaiian Archipelago, 1957-1998*. Aquatic Mammals 25: 105 – 114

Odell D. 1987. *The mystery of marine mammal strandings*. Cetus 2-6

Pabst D., Rommel S., & McLellan 1999. *The functional morphology of marine mammals*. In Reynolds J. & Rommel S. (eds) *Biology of Marine Mammals*. Smithsonian Institution Press. Washington pp 15-72

Robson F. 1984. *Strandings, ways to save whales*. Angus & Robertson Publishers Sydney