

# **Boat Preference and Stress Behaviour of Hector's Dolphin in Response to Tour Boat Interactions**

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submitted in partial fulfilment  
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By  
Georgia-Rose Travis

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Dolphins are increasingly coming into contact with humans, particularly where tourism is involved. It has been assumed that such contact causes chronic stress on dolphin populations. This study examined relatively naive populations of Hector's dolphins and their interaction with various watercrafts. Dolphins in New Zealand have been observed using theodolites and boat-based observations over the last two decades, particularly on the east side of the South Island at Akaroa, which is situated on the coast line of Banks Peninsula. This research was undertaken using shore-based theodolite tracking to observe boat activity around the coast of Lyttelton and Timaru and their associated Harbours. Observations were made mostly over two periods each of six months duration and included the months October through to March during the years 2000-2001 and 2001-2002. Observations made during a third period in 2005 were also incorporated for some of the analyses. Field investigations using a theodolite included more than 376 hours/site/season and recorded dolphin behaviour both with and without the presence of tour boats. Of primary interest were the tours, which ran regular trips to observe *Cephalorhynchus hectori* in their natural habitat.

Hector's dolphins at both Lyttelton and Timaru were consistently observed with particular boat types and not with other types of water craft. Dolphins at Timaru exhibited a greater range of behaviours than those at Lyttelton. Stress-related behaviours such as an increase in swimming speed to open ocean and grouping behaviour were only observed in the presence of boats. Other potential stress behaviours, such as head slaps and repeated tail slaps, were only performed in the absence of boats. Observations implied that some generic dolphin behaviours, which

often indicate stressed individuals may not apply to Hector's dolphins, and therefore question the assumption that all dolphin species behave in similar ways. We suggest that low-level tourist boat activity is not placing undue stress on the population.

In addition to theodolite observations, tour boat based observations of Hector's dolphin were undertaken and behaviour at each site recorded for a focal animal. Tour boat-based observations concentrated on determining any preference to bow, stern, portside and starboard sides of the vessel. Dolphins consistently showed a preference in direction of approach and departure from tour vessels with a strong tendency to the bow of the boat, and least with the stern. These results were similar irrespective of site or vessel.

Behaviour data were also collected from tour boat vessels over 48 trips/season/site and the data divided into transitional behaviour groups, which included stress behaviours, association / interaction behaviour and neutral behaviour. Behavioural count and time data were collected to reflect the number of times and duration of behaviour occurrence, particularly in relation to transitional behaviours. Determining the presence of stress in Hector's dolphins varied between the data sets and indicated that time is a necessary factor when attempting to determine whether an individual or a general population is genuinely stressed.

Quadrant preference and swimming direction in relation to the Black Cat were observed over six years, and both count and time data were collected with regard to behaviour. The results were consistent with preference in quadrant being expressed towards the bow of the boat and least with the stern. The count data suggested no significant impact on Hector's dolphin behaviour in the presence of the Black Cat over time, where time data indicated there was a transition over the years from neutral behaviour in the second year of tour boat activity, to positive behaviour in the third year of boat-activity and finally avoidance behaviour in the seventh year of tour boat activity at Lyttelton Harbour in response to the presence of the Black Cat.

**Keywords: Hector's dolphin, tour boats, behaviour, stress, theodolite, boat-based observations**

# Contents

Contents .....	iv
Tables.....	xi
Figures.....	xi
Plates.....	xviii
Chapter 1 – An Introduction to <i>Cephalorhynchus</i> Species and Stress .....	1
1.1 Characteristics and Biology.....	1
1.2 Stress .....	5
1.3 An Overview of Stress Responses in Cetaceans.....	10
1.3.1 Stress Behaviours Exhibited by Dolphins as a Result of Environmental Contamination in the Form of Pollutants and Toxins. ....	11
1.3.2 Stress Behaviours Exhibited by Dolphins as a Result of Fishing Operations.....	13
1.3.3 Stress Behaviours Exhibited by Dolphins as a Result of Specific Habitat and Climate Factors .....	14
1.3.4 Stress Behaviours Exhibited by Dolphins as a Result of Noise in the Environment .....	16
1.3.5 Dolphin Mortality Resulting from Boat-Dolphin Collisions .....	18
1.3.6 Stress Behaviours Exhibited by Dolphins as a Result of Wildlife Tour Operator Activity ...	18
1.3.7 Stress Behaviours Exhibited by Dolphins as a Result of Dolphin Research Programmes ....	19
1.3.8 Stress Behaviours Exhibited by Dolphins as a Result of Dolphin-Boat Interactions .....	21
1.4 An Introduction to Banks Peninsula.....	22
1.4.1 An introduction to Lyttelton and Timaru.....	27
1.4.2 Why Study Hector’s Dolphins at Lyttelton and Timaru? .....	28
1.4.3 Why Monitor the Effects of Both Boat and Human Presence on Hector’s Dolphin Behaviour?.....	30
1.4.4 Banks Peninsula Marine Mammal Sanctuary .....	32
1.5 Methods to be used in this research.....	32
1.5.1 Boat-Based Research.....	33
1.5.2 Boat-Based Research.....	34
1.6 Overall Objectives .....	35
1.7 Specific Aims .....	35
Chapter 2 - Non-invasive Observations of Tour Boat Association and Behaviour of <i>Cephalorhynchus hectori</i> at two New Zealand Harbours.....	36
2.1 Abstract .....	36
2.2 Introduction .....	37
2.3 Methods .....	40
2.3.1 Recording observations .....	42

2.4 Results .....	44
2.4.1 Dolphin Sightings.....	45
2.4.2 Ocean Plots – Lyttelton .....	46
2.4.3 Ocean Plots – Timaru .....	46
2.4.4 Sightings With and Without Boats .....	51
2.4.5 Behaviour in the Presence and Absence of Boats.....	52
2.5 Discussion.....	54
2.6 Conclusion.....	56
2.7 Further Study .....	57
2.7.1 Technical Advancement of Theodolite Equipment Which Presents Future Research Opportunities .....	57
2.7.2 Packages and Programmes Designed for Recording Theodolite Obtained Data .....	59
2.7.3 Further Development and Applications of Theodolite Technology.....	61
2.7.4 Further Opportunities for Study.....	62
Acknowledgements .....	63
Chapter 3 - Behaviour Changes in <i>Cephalorhynchus hectori</i> as a Result of Tour Operator Presence .....	64
3.1 Abstract .....	64
3.2 Introduction .....	65
3.2.1 Stress as a Result of Interacting Factors .....	65
3.2.2 Definition of Stress.....	66
3.2.3 Behaviours Used to Determine Stress .....	67
3.3 Aims .....	67
3.4 Objectives.....	68
3.5 Methods .....	68
3.5.1 Categories of Behaviours.....	79
3.5.2 Count Data.....	81
3.5.3 Time Data .....	82
3.6 Results .....	84
3.6.1 Count Data: Number of dolphins.....	84
3.6.2 Count Data: Number of observations .....	85
3.6.3 Count Data – Negative and Positive Stress, Association and Neutral Behaviour (NPAN) ...	91
3.6.4 Count Data: Avoidance, Positive Behaviour and Neutral Behaviour (APN).....	94
3.6.5 Time Data: Stress, Association and Neutral Behaviours (SAN).....	96
3.6.6 Time Data: Negative and Positive Stress, Association and Neutral Behaviours (NPAN)...	101
3.6.7 Time Data: Avoidance, Positive and Neutral Behaviour (APN). .....	104
3.7 Count Data: Summary and Discussion of Results for Each Category .....	108
3.7.1 Count Data: Stress, Association and Neutral Behaviour (SAN).....	108
3.7.2 Count Data: Negative and Positive Stress, Association and Neutral behaviour (NPAN)....	112
3.7.3 Count Data: Avoidance, Positive and Neutral behaviour (APN).....	113

3.7.4 Time Data: Stress, Association and Neutral Behaviour (SAN) .....	114
3.7.5 Time Data: Negative and Positive Stress, Association and Neutral Behaviour (NPAN) ....	115
3.7.6 Time Data: Avoidance, Positive and Neutral Behaviour (APN) .....	116
3.8 Count Data: Comparison Between SAN-NPAN-APN Results .....	117
3.8.1 Overall Comparison of Results - Black Cat versus Caroline Cat .....	117
3.8.2 Black Cat Season 1 versus Black Cat Season 2 and Caroline Cat Season 1 versus Caroline Cat Season 2 .....	118
3.8.3 Black Cat versus Caroline Cat Using x-x Behavioural Transitions .....	120
3.8.4 Black Cat versus Caroline Cat Using Behavioural Transitions x+x-x+x .....	122
3.9 Time Data: Comparison Between SAN-NPAN-APN Results .....	123
3.9.1 Overall Black Cat versus Caroline Cat .....	123
3.9.2 Black Cat versus Caroline Cat Using Behavioural Transitions x+x-x+x .....	125
3.10 Adaptation .....	126
3.10.1 Associative and Non-associative Learning .....	127
3.10.2 Habituation .....	128
3.10.3 Sensitisation .....	128
3.11 Relation to Other Studies .....	129
3.12 Conclusion .....	132
3.13 Further Research .....	133
<b>Chapter 4 - Approach Quadrant Preference Exhibited by Hector's Dolphin Towards Tour Boats at Lyttelton and Timaru .....</b>	<b>135</b>
4.1 Abstract .....	135
4.2 Introduction .....	135
4.3 Aims .....	139
4.4 Objectives .....	140
4.5 Methods .....	140
4.5.1 Statistical Tests Applied to Each Set of Data .....	145
4.6 Results .....	146
4.6.1 Trips and Observations over Both Seasons .....	146
4.6.2 Mating, Calving and Weaning Periods .....	148
4.6.3 Preference to Quadrant .....	150
4.6.4 Preference in Swimming Direction in the Presence of Tour Operator Vessels .....	153
4.7 Discussion .....	155
4.7.1 Mating, Calving and Weaning Periods .....	155
4.7.2 Preference to Quadrant .....	156
4.7.3 Preference in Swimming Direction in the Presence of Tour Operator Vessels .....	158
4.7.4 Efficiency of and Justification for Using Non-parametric Tests .....	158
4.8 Conclusion in relation to Trips and Observations over Both Seasons .....	159
4.8.1 Mating, Calving and Weaning Periods .....	159
4.8.2 Preference to Quadrant .....	159

4.8.3 Preference in Direction in the Presence of Tour Operator Vessels.....	160
4.9 Difficulties and Challenges .....	160
4.9.1 Quadrants.....	160
4.9.2 Observations .....	161
4.9.3 Volunteers.....	161
Acknowledgements .....	162
<b>Chapter 5 – Behavioural Response of Hector’s dolphin Towards Tour-Boats and a Recreational Yacht Over One Breeding Season .....</b>	<b>163</b>
5.1 Abstract .....	163
5.2 Introduction .....	163
5.3 Aims .....	164
5.4 Objective .....	165
5.5 Methods .....	165
5.6 Results .....	166
5.6.1 Quadrant and Swimming Direction .....	166
5.6.2 Count and Time Data per month (APN).....	169
5.6.3 Count Data: Avoidance, Positive and Neutral Behaviour (APN).....	169
5.6.4 Time Data: Avoidance, Positive and Neutral Behaviour (APN) .....	171
5.7 Discussion.....	171
5.8 Conclusion.....	177
5.9 Further Research.....	177
<b>Chapter 6 – Behavioural Response of Hector’s Dolphin Towards Boats Over Several Breeding Seasons .....</b>	<b>179</b>
6.1 Abstract .....	179
6.2 Introduction .....	179
6.3 Aims .....	181
6.4 Objectives.....	181
6.5 Methods .....	182
6.5.1 Statistical Tests: Quadrant Count Data .....	183
6.5.2 Behaviour Count Data .....	183
6.5.3 Time Data .....	184
6.6 Results .....	184
6.6.1 Quadrant and Swimming Direction .....	184
6.6.2 Count Data: Oct-Dec 2000, 2001 and 2006.....	187
6.6.3 Count Data Results: Individual Behavioural Transitional Changes Within the Three Categories Avoidance, Positive and Neutral Behaviours as Exhibited by Dolphins at Lyttelton (APN) .....	190
6.6.4 Time Data: Oct - Dec 2000, 2001 and 2006 .....	193
6.7 Discussion.....	196

6.7.1 Preference to Quadrant and Swimming Direction Exhibited by Dolphins at Lyttelton Using Count Data.....	196
6.7.2 Individual Behavioural Transitional Changes Within the Three Behaviour Groups Avoidance, Positive and Neutral Behaviour as Exhibited by Dolphins at Lyttelton Using Count Data (APN).....	198
6.7.3 Individual Behavioural Transitional Changes Within the Three Behaviour Groups Avoidance, Positive and Neutral Behaviour as Exhibited by Dolphins at Lyttelton Using Time Data (APN).....	199
6.8 Overall Conclusion.....	200
6.9 Further Research.....	201
6.9.1 Education of Tourists.....	201
6.9.2 Ongoing Monitoring.....	202
<b>Chapter 7 – Issues Central to Behaviour Research, Improvements and Recommendations Regarding Voracity of Research and Analysis .....</b>	<b>203</b>
7.1 Introduction .....	203
7.2 Difficulties and Improvements .....	204
7.2.1 Fieldwork is Problematic.....	205
7.2.2 Lack of Control.....	205
7.2.3 Problems Measuring and Possible Bias in Recording Dolphin Behaviour.....	206
7.2.4 Variable Factors.....	207
7.2.5 Ethogram .....	210
7.2.6 Environmental Impact Assessment.....	211
7.2.7 Finance .....	211
7.2.8 Problems with Terms.....	212
7.3 Other Issues to Consider.....	212
7.3.1 Anthropomorphism.....	212
7.3.2 Captive versus Wild Population Studies.....	217
7.4 Main Conclusions.....	218
7.4.1 Data Collection and Analysis .....	221
7.5 Further Study .....	222
7.5.1 Stress.....	222
7.6 What Does This Study Add? .....	223
7.7 A Way Forward .....	224
Acknowledgements .....	224
References .....	225
<b>Appendix A.....</b>	<b>257</b>
A1.1 Existing Legislative Framework.....	257
A1.2 Resource Management Act (1991).....	257
A1.2.1 Part 1 – Short Title and Commencement.....	258
A1.2.2 Part 2 – Outlines the Purpose of the Act.....	259



A1.2.3 Parts 3 Onward – Responsibilities Under the Act.....	259
A1.2.4 Part 9 – Water Conservation Orders .....	260
A1.2.5 Part 12 – Enforcement Orders.....	260
A1.2.6 Part 13 – Hazardous Substances .....	261
A1.3 Obligations Under the Marine Mammal Protection Act (1978) and Marine Reserves Act (1971) .....	261
<b>Appendix B: Theodolite Instruction Manual .....</b>	<b>263</b>
B1.1 Observation Manual.....	263
B1.2 Quick Reference Section – Theodolite Set-up, Overview for Trained Team Leaders .....	263
B1.2.1 To Level the theodolite .....	263
B1.2.2 To Set a Zero Reference.....	264
B1.2.3 Recording Observations.....	265
B1.3 Section 1 - Theodolite Use / Recording Data / Down Loading Information / Cleaning Data and Theo.exe and T-Trak Use .....	266
B1.3.1 Set-up Tripod .....	266
B1.3.2 Hooking up the Palmtop to the Theodolite: .....	266
B1.3.3 To Level the Theodolite .....	266
B1.3.4 Examples of 3 digit codes to enter before making a mark .....	269
B1.3.5 To Finish and Pack up for the Day.....	269
B1.3.6 How to Transfer Data From the Palmtop to the Laptop, Clean up Data and Sort by Parameters .....	270
B1.3.7 Cleaning Up Theo Data Files in WORD.....	272
B1.3.8 Using T-trak .....	273
B1.3.9 Station Files .....	273
B1.4 Section 2 - Behaviour Codes and Boat Codes.....	274
B1.4.1 Behaviour Codes.....	274
B1.4.2 Watercraft Codes .....	274
B1.5 Section 3 - Emergency Numbers .....	275
B1.6 Section 4 - Volunteers Personal Emergency Information .....	275
<b>Appendix C .....</b>	<b>276</b>
C1.1 Behaviour Data Sheet .....	277
<b>Appendix D .....</b>	<b>279</b>
D1.1 Count and Time Data Used in Analysis.....	279
<b>Appendix E .....</b>	<b>298</b>
E1.1 Advert, Volunteers Wanted for Dolphin Research.....	298
E1.1.1 Experience Required .....	298
E1.1.2 Team Leaders .....	299
E1.1.3 Training.....	299
E1.2 Theodolite Observations .....	300

E1.2.1 Boat-Based Observations .....	300
E1.2.2 Personal Behaviour .....	301
E1.2.3 Associated Costs .....	301
E1.2.4 Vacancies .....	301
E1.2.5 Contact Details .....	302
<b>Appendix F - Statistical Tests .....</b>	<b>303</b>
F1.1 Statistical Tests Applied to Each Set of Data: .....	303
F1.1.1 Kruskal-Wallis Test.....	303
F1.1.2 Wilcoxon / Mann-Whitney Test.....	304
F1.1.3 Average/Mean.....	305
F1.1.4 Efficiency of and Justification for Using Non-Parametric Tests .....	306
<b>Appendix G .....</b>	<b>307</b>
G1.1 A report to outline the number of successful observations of Hector’s Dolphin at Lyttelton Harbour, Christchurch, New Zealand between October – December 2005.....	307
<b>Appendix H .....</b>	<b>313</b>

# Tables

Table 1: Hector’s dolphin behaviours recorded and their definitions.....	43
Table 2: Watercraft categories by size and type of motion. ....	44
Table 3: The mean number of Hector’s dolphin sighted with various watercraft at Lyttelton and Timaru over two years’ observations.....	52
Table 4: List of behaviours observed in the presence and absence of the Black Cat at Lyttelton and the Caroline Cat at Timaru.....	53
Table 9: Total number of Hector’s dolphin observations for combined seasons per site for stress, association and neutral behaviours (SAN). ....	85
Table 10: Total number of Hector’s dolphin observations per season for the Black Cat in relation to stress, association and neutral behaviours (SAN).....	86
Table 11: Total number of Hector’s dolphin observations per season for the Caroline Cat in relation to stress, association and neutral behaviours (SAN). ....	86
Table 12: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviours which make up the stress, association and neutral behaviour category (SAN). ....	87
Table 13: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviours which make up the ‘stress’ group within the stress, association and neutral behaviour category (SAN).....	90
Table 15: Total number of Hector’s dolphin observations for combined seasons per site for negative and positive stress, association and neutral behaviours (NPAN). .....	91
Table 16: Total number of Hector’s dolphin observations per season for the Black Cat in relation to negative and positive stress, association and neutral behaviours (NPAN). ....	92
Table 19a: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviour which make up the ‘negative stress’ category (NPAN). ....	93
Table 19b: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviour which make up the ‘positive stress’ category (NPAN). ....	93

Table 23a: A brief summary of the behaviour transition results including the number of changes within each transitional group behaviour and whether that change was an increase ‘>’ or decrease ‘<’ in the overall number of transitional behaviours for a particular season .....	95
Table 23b: A brief summary of results for the APN category .....	95
Table 29: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviours which make up the stress, association and neutral behaviour groups (SAN) .....	100
Table 36: Total number of observations per season per site for the individual transitional behaviours which make up the negative and positive stress, and association and neutral behaviour groups (NPAN).....	103
Table 37: The total duration of time, in hours and the percentage of time, per site, that dolphins spent exhibiting avoidance, positive and neutral behaviour (APN). ....	104
Table 38: The total duration of time, in minutes and the percentage of time, per site, per season, that dolphins spent exhibiting avoidance, positive and neutral behaviour (APN). .....	105
Table 43a: A brief summary of results showing P-values for the categories of behaviour SAN, NPAN and APN .....	107
Table 43b: Results showing how many transitional behaviours within each category changed and whether the change was an increase ‘>’ or decrease ‘<’ in the transitional behaviour observed, and the season which the change occurred: S1; Season 1, S2; Season 2 .....	107
Table 44: An example of how data was tabulated after completion of each day’s trips. ....	142
Table 45: Kruskal-Wallis and Friedman Test for significance when testing the mean number of dolphin observations per quadrant per period: mating, calving and weaning, and calculating Zars Statistical test for $Q$ for the Black Cat and Caroline Cat. ....	149
Table 46: Kruskal-Wallis and Friedman Test for significance when testing the mean number of dolphin observations per quadrant based on two seasons observations, and calculating Zars Statistical test for $Q$ for the Black Cat and Caroline Cat...	152
Table 47: Kruskal-Wallis and Friedman Test for significance when testing the percentage of dolphin observations per direction of swimming: swimming	

towards, away and with the vessel based on two seasons' observations, and calculating Zars Statistical test for $Q$ for the Black Cat and Caroline Cat.....	154
Table 48 (following page): Kruskal-Wallis and Friedman Test for significance when testing the mean number of dolphin observations per month versus quadrant and swimming direction in the presence of the Henrietta, and a test on the Sum of Ranks using Zars Statistical Test for $Q$ for both quadrant and swimming direction. ....	167
Table 49: The number of occurrences and mean duration of time that avoidance, positive and neutral behaviour were observed (APN). ....	170
Table 50: Average number of times a dolphin was observed with Q1, the bow, Q2, starboard side, Q3, the stern, and Q4, portside of the Black Cat .....	185
Table 57: Chi-Square test results in relation to the number of dolphin observations versus month per season.....	187
Table 58: Chi-Square results in relation to the number of times a dolphin was counted exhibiting avoidance, positive and neutral behaviour per season (APN) .....	189
Table 59: Results in relation to the number of times a dolphin was counted exhibiting avoidance, positive and neutral behaviour per month, per season, per site (APN). ....	190
Table 60: Total number of Hector's dolphin observations per season per site for the individual transitional behaviours which make up the avoidance, positive and neutral behaviour groups (APN) .....	192
Table 61: Total amount of time spent exhibiting avoidance, positive and neutral behaviour (APN) .....	193
Table 62: Total amount of time, in seconds, and average amount of time per month per season spent exhibiting avoidance, positive and neutral behaviour (APN) ..	194
Table 66: Individual transitional behaviours within each category avoidance, positive and neutral behaviour (APN) .....	195
Table 5: Total number of observation periods and actual number of dolphins observed per month per site over two seasons.....	279
Table 6: Total number of observation periods and actual number of dolphins observed per site per season .....	280
Table 7: Total number of observation periods and actual number of dolphins observed per site over two seasons. ....	280

Table 8: Number of observations per site per month per season for the Black Cat and Caroline Cat.....	281
Table 14: Count Data: Number of times negative and positive stress, association and neutral behaviour occurred per month, per season at Lyttelton and Timaru (NPAN).....	282
Table 17: Total number of observations per season for the Caroline Cat in relation to negative and positive stress, association and neutral behaviours (NPAN).....	283
Table 18: The initial transitional behaviours within the negative behaviour group within the NPAN category.....	283
Table 20: Total number of observations per site in relation to negative avoidance, positive, and neutral behaviour (APN).....	283
Table 21: Total number of observations per season for the Black Cat in relation to avoidance, association and neutral behaviours (APN).....	284
Table 22: Total number of observations per season for the Caroline Cat in relation to avoidance, association and neutral behaviours (APN).....	284
Table 24: Total duration of time, in minutes, dolphins spent exhibiting stress, association and neutral behaviour at Lyttelton and Timaru (SAN).....	284
Table 25: Average amount of time in minutes dolphins spent exhibiting stress association and neutral behaviour at Lyttelton and Timaru (SAN).....	285
Table 26: A General Linear Model (GLM) test investigating the average amount of time in minutes dolphins spent exhibiting stress behaviour (SAN).....	286
Table 27: A General Linear Model (GLM) test investigating the average amount of time in minutes dolphins spent exhibiting association behaviour (SAN).....	287
Table 28: A General Linear Model (GLM) test investigating the average amount of time in minutes dolphins spent exhibiting neutral behaviour (SAN).....	288
Table 30: The duration of time in minutes that dolphins exhibited negative and positive stress, association and neutral behaviour at Lyttelton and Timaru over two seasons (NPAN).....	288
Table 31: The mean duration of time in minutes per month dolphins spent exhibiting negative, positive, association and neutral behaviours (NPAN).....	289
Table 32: A General Linear Model (GLM) test investigating the occurrence of negative stress versus site, season and month (NPAN).....	290
Table 33: A General Linear Model (GLM) test investigating the occurrence of positive stress versus site, season and month (NPAN).....	291

Table 34: A General Linear Model (GLM) test investigating the occurrence of association behaviour versus site, season and month (NPAN).....	292
Table 35: A General Linear Model (GLM) test investigating the occurrence of neutral behaviour versus site, season and month (NPAN).....	293
Table 39: Mean time, in minutes per month, that dolphins spent exhibiting avoidance, positive and neutral behaviour at Lyttelton and Timaru (APN).....	294
Table 40: A General Linear Model (GLM) test investigating the occurrence of avoidance behaviour v site, season and month (APN).....	295
Table 41: A General Linear Model (GLM) test investigating the occurrence of positive behaviour versus site, season and month (APN).....	296
Table 42: A General Linear Model (GLM) test investigating the occurrence of neutral behaviour versus site, season and month (APN).....	297
Table 51: Kruskal-Wallis test results in relation to the average number of dolphin observations versus quadrant.....	313
Table 52: Friedman Test results in relation to the average number of dolphin observations for all seasons versus quadrant.....	313
Table 53: Average number of times a dolphin was observed swimming away, a/w, swimming towards, t/b, and swimming with, s/w the Black Cat.....	314
Table 54: Kruskal-Wallis test results in relation to the average number of dolphin observations versus swimming direction.....	315
Table 55: Friedman Test results in relation to the average number of dolphin observations versus swimming direction.....	315
Table 56: Critical values of $Q$ for non-parametric multiple comparison testing. Used to determine significance in quadrant preference and swimming direction preference.....	316
Table 63: A General Linear Model (GLM) test investigating the occurrence of avoidance behaviour over six years, versus season and month, for the Black Cat at Lyttelton (APN).....	316
Table 64: A General Linear Model (GLM) test investigating the occurrence of positive behaviour over six years, versus season and month, for the Black Cat at Lyttelton (APN).....	317
Table 65: A General Linear Model (GLM) test investigating the occurrence of neutral behaviour over six years, versus season and month, for the Black Cat at Lyttelton (APN).....	317

# Figures

Figure 1: Map of the eastern coastline of the South Island of New Zealand with the two study areas, Lyttelton and Timaru highlighted. Insert of New Zealand North and South Islands .....	23
Figure 2: Topographic map of Lyttelton Harbour. The arrow marks the theodolite site .....	26
Figure 3: Topographic map of Timaru Harbour. The arrow marks the theodolite site	26
Figure 4: The Black Cat tour boat which operates within Lyttelton Harbour. Photo shows the inlet as viewed from Lyttelton Quay.....	27
Figure 5: Caroline Bay viewed from the inlet port of Timaru.....	28
Figure 6: A view looking towards Lyttelton Harbour from the theodolite observation site situated at Lyttelton Quarry. The theodolite site is marked by an arrow. ....	41
Figure 7: Timaru Harbour as viewed from the ocean looking towards the observation point at Washdyke. The theodolite site is marked by an arrow. ....	41
Figure 9 (previous page): Plot of Hector’s dolphin presence in Lyttelton Harbour to 2 km from the theodolite station .....	48
Figure 10 (previous page): Plot of Hector’s dolphin presence in Timaru Harbour up to 2 km from the theodolite station .....	50
Figure 11: Total number of Hector’s dolphin sighted with and without tour boat presence over two seasons at Lyttelton and Timaru .....	51
Figure 12: Schematic diagram showing the four quadrants used to mark dolphins approach and departure from the vessel.....	70
Figure 13: Hector’s dolphin jumping, as taken from the Black Cat at Lyttelton Harbour.....	72
Figure 14: Hector’s dolphin grouping, as taken from the Black Cat at Lyttelton Harbour.....	72
Figure 15: Hector’s dolphin coming up to breathe as taken from the Black Cat at Lyttelton Harbour.....	73
Figure 16: Hector’s dolphin swimming as taken from the Black Cat at Lyttelton Harbour.....	73



Figure 17: An interaction plot based on Log time (minutes) versus avoidance behaviour for Hector’s dolphins observed in the presence of the Black Cat (BC) at Lyttelton and the Caroline Cat (CC) at Timaru (APN).....	97
Figure 18: An interaction plot based on Log (time) versus association behaviour for Hector’s dolphins observed in the presence of the Black Cat (BC) at Lyttelton and the Caroline Cat (CC) at Timaru (APN). .....	98
Figure 19: An interaction plot based on Log (time) versus neutral behaviour for Hector’s dolphins observed in the presence of the Black Cat (BC) at Lyttelton and the Caroline Cat (CC) at Timaru (APN). .....	99
Figure 20: An example of a circular data sheet designed and used to mark dolphin direction and position relative to the tour boat.....	142
Figure 22: Percentage of dolphin observations per quadrant over two seasons for the Black Cat (BC) at Lyttelton and Caroline Cat (CC) at Timaru.....	150
Figure 23: Percentage of dolphin observations per swimming direction over two seasons for the Black Cat and Caroline Cat .....	153
Figure 26: The total number of observation periods during Season 1, 2 and 3 (1999, 2000 and 2006 respectively) at Lyttelton as observed aboard the Black Cat. ....	188
Figure 24: Equation employed in order to complete Zars Statistical Test for $Q$ for quadrants .....	314
Figure 25: Equation employed in order to complete Zars Statistical Test for $Q$ for swimming direction.....	316

# Plates



Hector's Dolphin (Black Cat Group, 2005).



Hector's Dolphin Pod (Black Cat Group, 2005).



Theodolite observations at Timaru



The Black Cat tour-boat at Lyttelton

# Chapter 1 – An Introduction to *Cephalorhynchus* Species and Stress

## 1.1 Characteristics and Biology

The three orders of the class Mammalia contain marine mammals Cetacea, Carnivora and Sirenia with sizes ranging from 1 kg, with the largest being the blue whale weighing about 100,000 kg. Habitats are varied from particular seas, open ocean, coastal shores to freshwater lakes and rivers. All extant Cetacea and Sirenia normally spend their entire lives in water. However, the Carnivora marine mammals are semi-aquatic, for example, fur seals (*Arctocephalus* sp., *Callorhinus* sp.), seas lions including the New Zealand sea lion (*Phocartos hookeri*), sea otters (*Enhydra lutris*) and the walrus that are able to haul themselves on to land (National Research Council, 1994).

The Hector's dolphin, *Cephalorhynchus hectori*, is the smallest member of the family Delphinidae and is New Zealand's only species of *Cephalorhynchus*, although the North Island population has been found to be genetically different from those of the South Island (Pichler *et al.*, 1998). The North Island Hector's dolphins are now considered a sub-species on the basis of genetic and skeletal differences as determined by Dr Alan Baker (2002). It has been renamed Maui's dolphin in view of Te Ika a Maui, which represents the indigenous Maori name for the North Island (WWF, 2007). Its scientific name is *Cephalorhynchus hectori maui* and it represents the world's rarest marine dolphin with an estimated population of between 100 and 111 individuals (Slooten, 2000; Slooten *et al.*, 2006a) and having a coastal habitat of some five nautical miles from shore (Dawson and Slooten, 1998).

*C. hectori* are endemic to New Zealand (DoC, 1988) and occur throughout the New Zealand coastline, but particularly on the east and west coast of the South Island (Slooten and Dawson, 1994; Slooten and Dawson, 1996). The most reliable site to observe Hector's dolphins is Akaroa harbour, Banks Peninsula, where mothers and calves can often be sighted together (Slooten and Dawson, 1996).

Hector's dolphins are characterised by non-aggressive behaviour, and a unique round dorsal fin. They inhabit shallow waters usually less than 10 km from shore, where they dive for no more than two minutes at a time to catch food, including squid (*Loligo duvaucelii*), flatfish (*Asterorhombus cocosensis*), sprats (*Sprattus antipodum*) and yellow-eyed mullet (*Aldrichetta forsteri*). Hector's dolphins have a comparatively low reproductive rate for dolphins, and short lifespan of about 20 years, which means that females produce only 4 - 6 calves in a lifetime (Slooten, 1991; Dawson, 2002). The calves vary in length between 60 - 75 cm when born. Adults grow to 1.4 m in length and are unique in that the species possesses the highest brainweight/bodyweight ratio of any dolphin (1.7). This ratio is greater than that found in any primate and is near to that of a human (1.9; Slooten and Dawson, 1996), likely indicating a very sociable and intelligent mammal.

Hector's dolphins have been reported to rarely bow ride, but in contrast are also reported to frequently swim in the wake of and alongside passing boats with a preference to stationary vessels or vessels moving at less than 10 knots (Slooten and Dawson, 1994). In the presence of fast-moving vessels, Hector's dolphins are reported to dive in order to avoid interaction. Mothers with calves have been observed to be shy and seldom approach boats, with the exception of busy ports (Slooten and Dawson, 1994). Other studies have shown that dolphins increase swimming velocity away from boats (Bejder *et al.*, 2006), change swimming direction, in that dolphins swim towards open waters and away from boats (Lemon *et al.*, 2006) and that the distance between individual dolphins within a pod decreases with boat presence (Bejder *et al.*, 1999; Bejder *et al.*, 2006a; Martinez *et al.*, 2002). Dolphins also became less interested in the boat the longer it were present (Bejder *et al.*, 1999; Martinez *et al.*, 2002). Theodolite tracking showed that Hector's dolphin had clear preferences to certain types of boat than others (Nichols *et al.*, 2001).

Hector's dolphins are sociable and curious animals, and as with all animals their behaviour is dependent on context. For example, jumps can represent play, excitement or a display of aggression. Blowing bubbles can be a sign of aggression but also plays a role in sexual behaviour and play (Slooten, 1994). Accordingly observations need to be made carefully to determine the motivation behind behaviours. To determine the function of behaviour it is necessary to set the context by observing what the behaviour was immediately prior to and after the behaviour of interest was recorded. For example, if the behaviour prior to jumping reduced the distance between individuals and the behaviour immediately after was a change in swimming direction towards open waters, then this may be recorded as avoidance behaviour. Clear indications of avoidance behaviour in existing literature are: increase in swimming velocity (Bejder *et al.*, 2006), swimming direction, in that dolphins swim towards open waters and away from boats (Lemon *et al.*, 2006) and a reduction in distance between individual dolphins within a pod (Bejder *et al.*, 2006). As such, an increase in swimming speed away from the vessel and grouping behaviour are characteristic signs of stress in cetacean species within the Order Cetacea. Stress in this context relating to physiological changes as indicated by increased swimming speed, coupled with a change in behaviour, in this instance dolphins exhibiting avoidance behaviour, otherwise seen as swimming away from a boat. The reason stress responses are important to monitor is that under extreme cases they can lead to mortality.

Both the South Island Hector's dolphin *C. hectori hectori* and the North Island subspecies, (*C. h. maui*), are listed as being in danger of extinction. The Maui's dolphin is listed as an endangered species (Slooten and Taylor, 2000), and *C. hectori* have recently been listed as a threatened species (DoC, 1999a), so any threat to their reproduction or survival needs to be investigated in order to ensure their survival for future generations, or there is a genuine risk of the species becoming extinct.

The Department of Commerce in the United States of America requested that the California grey whale (*Eschrichtius robustus*) be removed from the endangered list with effect from 7<sup>th</sup> January, 1993 as it recovered from severe exploitation (NAMMCO, 1992). However, other species are not as fortunate. For example, the Yangtze River dolphin (*Lipotes vexillifer*) suffered a decline in number due to the stress of boat traffic and associated noise which interfered with sonar location of food

(National Research Council, 1994). Since 1999, population numbers continued to decrease. During 2005 an extensive search by 30 scientists over an area of 3500 km over 45 days failed to locate one dolphin. The last verified sighting of the Yangtze River dolphin was in September 2004 (Lovgren, 2006). They were officially declared "functionally extinct" on December 13, 2006 by the Whale and Dolphin Conservation Society (WDCS) (National Geographic News, 2006; WDCS, 2008).

The endemic Chilean dolphin, *Cephalorhynchus eutropia* was reported to be in danger of extinction in 1994 (National Research Council, 1994) and is now listed in the International Union for Conservation of Nature and Natural Resources Red List of Threatened Species (IUCN) under category 'DD'. This is Data Deficient, meaning that there is insufficient population and distribution data to determine any risk of extinction (IUCN, 2006). The same DD category has been assigned to three of the four *Cephalorhynchus* species: *Cephalorhynchus commersonii*, *Cephalorhynchus eutropia*, and *Cephalorhynchus heavisidii*. *Cephalorhynchus hectori* are listed as endangered due to 'facing a very high risk of extinction in the wild in the near future' and on the basis of 'observed estimates, inferred or suspected reduction of at least 80% over the last 10 years or three generations whichever is the longer, based on actual or potential levels of exploitation and an estimated continuing decline of at least 25% within three years or one generation, whichever is longer' (IUCN, 2006). Exploitation is referred to in relation to tour activity such as 'swim with dolphins', and excursions to view dolphins in their natural habitat.

Perrin (1988) stated that "no cetacean species has been driven to extinction by human endeavours". This statement would clearly not stand for all cetacean species today. What is important is that research investigates the effect of human interaction and activity such as tour operations on the behaviour of the wildlife of interest and that clear terms and definitions are used in order to determine any real threats or changes to the wellbeing of the animal of interest. One of the most widely used words in research is stress, but often it is not clearly defined, hence confusion over its exact meaning may be misinterpreted.

## 1.2 Stress

The history of stress research has been summarised by many authors (Moberg, 1985; Chrousos and Gold, 1992; Chrousos *et al.*, 1988; Johnson *et al.*, 1992), and others have pointed out that stress is always present in daily life, or as Selye (1974) put it “only absent from life after death”. Waples and Gales (2002) state that ‘not only is stress present in daily life, but that it is an important factor in both the individual and the group lives of all social animals.

Robert Sapolsky, in particular has undertaken extensive studies in regard to the effect of stress on animals, specifically in regard to physiological change. Sapolsky showed that stress can increase the rate of aging and result in a greater susceptibility to the risk of heart-attack in humans (Sapolsky, 2004). He has also shown that stress has a detrimental effect on rodent brains, in that, learning and memory abilities are reduced (Sapolsky, 1996). Many of his studies have focused on changes to the hippocampus in response to stress in laboratory animals (Meaney *et al.*, 1988; Zaidel *et al.*, Sapolsky, 1996; Sapolsky, 2001; Dinkel *et al.*, 2004) and hormonal changes (Krey *et al.*, 1984; Sapolsky and Pulsinelli, 1985; Yehuda and Sapolsky, 1997). Although much of Sapolsky’s work on stress, hormones and physiological changes has taken place in the laboratory, he has also undertaken extensive research in the field. Much of Sapolsky’s research has shown that stress can have detrimental effects on animals, although other research has shown that high stress hormones do not necessarily prevent a dominant individual within a social population, such as birds, dogs and mongooses, from having off-spring (Morell, 1996).

Sapolsky’s recent research includes social culture of non-humans, such as baboons (Sapolsky, 2006). Although Sapolsky’s work on stress is extensive it is based on land mammals. For the purpose of discussing stress in later chapters, in relation to behavioural changes in dolphins in response to stress, stress will be discussed in view of studies undertaken on a broad range of cetacean species. In view of the wide ranging effect that stress can have on a particular species, a discussion which includes the responses in regard to stress in other marine mammals would be more appropriate than human, baboons and rodent responses to stress. That is not to say that some

stress responses are not similar across species, but as will be outlined later, stress can be species specific, gender specific and vary between sites. For this reason, discussions will focus on marine mammal stress but in light of Sapolsky's hormonal investigations, will also include information about physiological and hormonal changes which take place in stressed cetacean species. What is clear is that stress is present in the lives of all organisms and that it has an affect on animals'. What is not always given in reports and literature is a clear definition or a context for the use of the word "stress".

The term "stress" is often used ambiguously to describe a broad range of conditions that affect the behaviour and/or the physiological condition of an organism. Due to its wide use the term is easy to misinterpret. In order to determine the impact of stress whether detrimental or otherwise, to an organism, a definition of the actual term is required and its actual meaning should be made clear where it is used. This should prevent, or at least minimise, incorrect interpretation.

According to the Oxford English Dictionary (Soanes and Stevenson, 2006), stress is defined as 'a state of mental, emotional, or other strain'. The term stress also refers to a human action that causes an adverse effect on the wellbeing of an individual animal or a potential adverse effect on a population of animals (National Research Council, 1994). Chrousos and Gold (1992) take the Greek idea that 'balance or harmony' is required for an organism to survive, and then define stress as 'a state of disharmony or threatened homeostasis'. Another definition is given as 'stress is a condition caused by factors impairing an animals' well-being by forcing its systems into oscillary instability and altering normal oscillatory performances (homeostasis)' (Myrick and Perkins, 1995). All of these definitions allude not only to an internal change in response to a stressful situation but seem to imply that this change is detrimental in that it causes 'strain' (Oxford Dictionary, 2001), an 'adverse effect' (National Research Council, 1994), or 'disharmony' (Chrousos and Gold, 1992), and that overall stress forces systems into oscillary instability (Myrick and Perkins, 1995). It seems to be a common misconception that stress is always detrimental (Barton, 2002). In some situations this may be true, but not in all.



Creel (2001) attempted to alleviate the problem with the word 'stress' and its different meanings amongst biologists. He suggested using the word 'stressor' and 'stress response' in place of the word stress, where the stressor can be any stimulus which evokes a physiological response (Creel, 2001). However, he warned that simply changing the use of words may still not alleviate all confusion. Any energetically-demanding situation can be considered to be a stressor, which may also present inaccuracy. He gives an example of birds who may find migrating stressful due to the physiological responses required, but at the same time an individual is able to prepare for the stressful event. Such events are not then categorised as 'stressors' but as 'difficult'. Therefore, difficult conditions or events, such as migrating or reproducing, are difficult events and not considered stressors. Stressors are an event that provokes a physiological stress response and are the result of an unpredictable or uncontrollable situation (Creel, 2001).

Hans Selye, (Selye, 1973 in Barton, 2002), broadly defined stress as the "non-specific response of the body to any demand" but in earlier works Selye (1936) developed a stress theory called the General Adaptation Syndrome, which outlines three phases of stress. The theory is based on adrenal gland function in response to stimuli to which there are three phases. In order of occurrence these are the alarm phase, adaptation phase and adrenal exhaustion phase. The theory was recently referred to by Reilly (2002), who states in a response to an administrative report that the National Marine Fisheries Service in the USA fails to acknowledge various levels of stress in their reports (Sisson and Edwards, 2000). He then goes on to outline the three phases:

1. Alarm Phase where a threat is perceived resulting in a rapid physiological response by both the nervous and endocrine systems.
2. Adaptation or Compensation phase which occurs after prolonged exposure to the stressor, resulting in either adaptation to or compensation for the presence of the stressor.
3. Maladaptation Phase which results from a stressor being of such duration and intensity that adaptation or compensation is impossible. If the stressor then persists or it is severe enough an animal may in the worst case scenario develop illness, become susceptible to disease and infection, experience

immune response decline and subsequently die (National Marine Fisheries Service, 2002).

The adaptive mechanism, in fish for example, facilitates the return to a normal homeostatic state after stress hormones have been released and the flight or fight response triggered (Barton, 2002). Stress is explained as an adaptive mechanism, which allows fish to cope with a real or perceived stressor, but which also extends to humans and marine mammals (Barton, 2002). The return to a normal homeostatic state is therefore reliant on a suite of adaptive responses (Barton, 2002). Furthermore, Cannon and De La Paz (1911) demonstrated that both physical and emotional stimuli can elicit the same response within an organism and where stressors are present over a short period of time an organism returns to its normal homeostatic state without any long term detrimental effects. Short-term behavioural changes are considered to be adaptive because the physiological responses cease quickly whilst resolving the stressful condition (Creel, 2001). In such cases adaptive behaviour can be seen as a positive stress response. However, if short-term stressors persist and become long-term stressors then serious pathological symptoms can result, such as loss of reproductive capability, reduced immune response and muscle wasting (Creel, 2001), thus becoming detrimental to the animal.

Chronic or repeated acute stress has been shown to have severe effects on animal immune responses, reproductive function and growth (Moberg, 1991; Rivier and Rivest, 1991; Chrousos and Gold, 1992; McEwan *et al.*, 1997). The pathway to such severe responses begins with the persistent presence of a stressor. Stressors illicit an immediate physiological response by activation of the hypothalamic-pituitary-adrenal axis, which in turn releases the stress hormones glucocorticosteroids (Curry, 1999). It was Cannon and De La Paz (1911) who made the link between the adrenal gland and stressors, and who identified this interaction to be responsible for the 'fight or flight' response to threat. If an organism should have a response to a stimuli or stressor which causes a flight or fight response, it could be argued that this is a positive effect so long as the stressor is not present for an extended period of time and the animal has some control over escaping the stimulus. What is deemed an extended period may vary for each organism that themselves have different tolerances resulting in moving

through the alarm, adaptation and maladaptation phases at different rates of different stress intensities.

Acute stressors include situations involving fear or a perception of danger, pain and forced exercise as a result of unavoidable situations in which an animal perceives it has lost some or all control (Myrick and Perkins, 1995). The physiological changes which occur as a result of acute stressors such as endocrine changes, cardiovascular and respiratory as well as overall metabolic changes in fishes have been shown to effect changes in growth, disease resistance and behaviour. These changes then have the potential to affect survivorship (Barton, 2002). However, caution is required because stress hormones or increase in respiration or heartbeats can also indicate pleasurable activities such as play or survival such as hunting, as well as avoidance and fear (Dawkins, 2006).

Changes in growth, physiological responses and behaviour are also influenced by other factors. Other factors which may cause a change in behaviour include environmental factors such as temperature, climate, time, light, nutritional state, colour of environment, disease, water quality, toxin presence and contaminants, all of which effect stress responses in fish with the latter appearing to exasperate stress responses (Barton, 2002). Physiological responses are also evident in other species, such as killer whales (*Orcinus spp.*) (Akamatsu, *et al.*,. 1993), bottlenose dolphins (*Tursiops truncates*) (Bejder *et al.*,2006a), Orang-utans (*Pongo pygmaeus*) (Birke, 2002), red howler monkeys (*Alouatta seniculus*) (de la Torre *et al*, 1999), and various bird species (Dooling, 2005). Although environmental factors can have a modifying effect on both magnitude and duration of the stress response, these factors cannot always be measured or fully accounted for in any interpretation, hence biological significance is often difficult to address (Barton, 2002).

A repeated stressor could also lead to sensitisation or habituation. Repeated exposure to stress in juvenile rainbow trout is reported to have resulted in a general habituation to the repeated stressor even when the stressor became acute (Barton, 2002). Other factors causing stress are developmental stages of growth. A consistent increase in stress responses are seen in andromous salmonid fish as they develop appearing particularly sensitive to physical disturbances during smolt (Barton, 2002). This could

cause disruption to physiological processes needed for smolt, reproduction or growth as shown in mammals and birds, who respond to stress by inhibiting physiological processes which are not needed for immediate survival (Creel, 2001). As physiological processes can be difficult to monitor in wild animals, the most common effect of human disturbance is frequently measured in terms of an animal's change in observed behaviour (Beale and Monaghan, 2004 in Lemon *et al.*, 2006)

Cetaceans have been shown to have a clear repertoire of behavioural responses to different stressors which will be discussed further in later sections.

### **1.3 An Overview of Stress Responses in Cetaceans**

Cetaceans respond to threats such as tour boats and research vessels by displaying vertical avoidance, for example, increasing dive duration or changing swimming direction (Ng and Leung, 2003; Lemon *et al.*, 2006) or increasing swimming velocity (Kruse, 1991; Williams *et al.*, 2002; Lusseau, 2003). Delphinids may change breathing patterns (Janik and Thompson, 1996), and dolphin groups become more compact with erratic speeds and directions of travel (Bejder *et al.*, 1999; Bejder *et al.*, 2006b). An increase in swimming speed under water and swimming acceleration away from boats followed by a single leap or porpoise has also been observed for other stressful situations, for example, biopsy pole samples being taken from dolphins (Bilgmann *et al.*, 2007). Helicopter flights are known to influence movements in terrestrial mammals and are used for dolphin-watching at elevations of 700-1000 feet at which dolphins are reported to react to their presence with increase in swimming speeds (Norris *et al.*, 1978). Dolphins caught in nets when rounded up in order for fleets to capture tuna exhibit hyperactivity, rapid swimming, diving and charging at the nets and were also observed sinking tail first into heaps on the net floor, as well as laying in 'morose' postures on the surface of the water (Myrick and Perkins, 1995). The greatest effect that stress can have is for the stress to be so great that it results in mortality. A lack of oxygen causes physiological changes and results in death. Dolphins have been recorded as dying from asphyxiation within fishing nets and calves being left abandoned. A report in January 2007 showed that the yellowfin tuna industry caused mortality in 14 dolphin species (20 stocks) of which three populations

were significantly depleted. These populations are presently showing no indication of recovering at expected rates (Noren *et al.*, 2007). The report provides evidence that mortality in nursing calves is an important factor in the lack of population recovery, specifically when lactating mothers are captured and killed by purse-seine nets, and calves are left to fend for themselves (Noren *et al.*, 2007). Behaviours such as these have been deemed examples of dolphins responding to stress situations.

Stress can be the result of many stressors, not only commercial fishery or tour boat operations. Stressors in the environment include toxins (Marsili *et al.*, 2001), contaminants (Reddy *et al.*, 2001), pollutants (Gachal *et al.*, 2006), anthropogenic activities (Clark *et al.*, 2006), commercial pursuits (Myrick and Perkins, 1994), and also physical, climatic or geographical factors present within a specific area (Wursig and Green, 2002).

### **1.3.1 Stress Behaviours Exhibited by Dolphins as a Result of Environmental Contamination in the Form of Pollutants and Toxins.**

The bottlenose dolphin (*Tursiops truncatus*), was proposed as a species which could be used to measure the health of the marine environment specifically in relation to marine toxins and pollutants which can accumulate by bioaccumulation in blubber and tissue samples (Mancia *et al.*, 2007). A study investigating stress due to the presence of chemicals in the environment, in this case, polycyclic aromatic hydrocarbon (PAH) showed that free-ranging Mediterranean cetaceans suffer from chemical stress (Marsili *et al.*, 2001). Blubber samples from live fin whales (*Balaenoptera physalus*) in the Ligurian Sea and striped dolphins (*Stenella coeruleoalba*) in the Ionian Seas showed that concentration levels varied over the sampling period, but that both species suffered from increases in PAH (Marsili *et al.*, 2001), yet had species specific responses, indicating that the response of one cetacean to what may be considered a stressor may not be reflected by the same response in another species. This is further discussed in the next section, 1.4.2.

Chemicals and toxins present in the environment can also result in stress. The US Navy investigated the effects of contaminants on dolphins (*Tursiops truncatus*) by looking at dolphin immune systems, neurologic responses and reproduction (Reddy *et al.*, 2001). The dolphins studied lived in a netted area and were monitored for levels of organochlorine (OC) contaminants present in the surrounding water. Tests were done on blubber, blood and milk with calf mortality being a main focus in the study (Reddy *et al.*, 2001). The study showed that the mean concentration of  $\Sigma$ DDT was more than three times greater in dolphins whose calves died when compared to dolphins whose calves survived beyond six months. The mean  $\Sigma$ PCB levels were greater than two and a half times higher in females whose calves did not survive (Reddy *et al.*, 2001), indicating that toxins and contaminants have a stress effect and that survivorship of offspring is compromised.

Pollution and environmental deterioration in the river dolphins' habitat have resulted in them being listed as an endangered species around the world (Gachal *et al.*, 2006). The Indus river dolphin, (*Platanista minor*), in particular has been at risk since the 1970s (Gachal *et al.*, 2006). This species predominantly inhabits the turbid waters of the Indus River which has high contamination levels, and is also close to the pollution source (Gachal *et al.*, 2006). These factors along with the high metabolic ability of the river dolphin indicate that this species is at great risk from environmental contamination, especially from heavy metals (Gachal *et al.*, 2006). Another species under threat is a population of Indo-Pacific humpback dolphin (*Sousa chinensis*), which inhabits the polluted oceans surrounding Hong Kong. This species, at this location, are also at risk from contamination from fish which have polychlorinated biphenyls (PCBs) and organochlorine pesticides present in their tissues.

Petroleum effects on dolphins have also been studied. As well as leading to a long-term coating of the body surface, oil also affects physiological processes in cetaceans. The filtering ability of baleen whales is reduced when petroleum is present in the environment where they inhabit (Rainer, 1983). However, bottlenose dolphins were shown to be only slightly affected after oil immersion and digestion in regard to

measurements made relating to hematological, plasma chemistry or histopathological factors, although localised skin damage was recorded (Rainer, 1983), again indicating that responses to factors within the environment can also be species specific. The study showed that while marine mammal species tend to be grouped together due to their life habits, their susceptibility to petroleum toxicity is much less general, and showed species-specific responses (Rainer, 1983).

As well as fish stocks being contaminated, as evident in Hong Kong, cetacean tissue from many species have also been identified as being contaminated (Teuten *et al.*, 2006). The blubber of marine mammals present around the coast of New England was found to contain three novel halogenated organic compounds (Teuten *et al.*, 2006). The blubber of the Atlantic white-sided dolphin (*Lagenorhynchus acutus*), the bottlenose dolphin (*Tursiops truncatus*), the common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), the harbor porpoise (*Phocoena phocoena*), the beluga whale (*Delphinapterus leucas*), the fin whale (*Balaenoptera physalus*), grey seal (*Halichoerus grypus*), harp seal (*Phoca groenlandica*) as well as their potential food source (*Loligo pealei*) all had concentrations of halogenated organic compounds as high as 2.7 µg/g (lipid weight) (Teuten *et al.*, 2006). Such chemicals can have a detrimental effect on liver function and other physiological processes (Teuten *et al.*, 2006), and indicates that pollution is a genuine risk factor on at least a physiological level which then leads to behavioural stress responses (Rainer, 1983; Gachal *et al.*, 2006; Teuten *et al.*, 2006).

### **1.3.2 Stress Behaviours Exhibited by Dolphins as a Result of Fishing Operations**

Activities such as fishing, especially within the tuna industry, have been proven to be stressful to dolphins (Clark *et al.*, 2006). Studies on mortality due to net entanglement represent some of the few cetacean studies which actually define different levels of stress. A study on beach-stranded Atlantic bottlenose dolphins defined categories of stress where dolphins were deemed acutely stressed if mortality arose from net

entanglement, boat strike, or an acute infection (Clark *et al.*, 2006). Dolphins that suffered or died from a long-term disease or injury were deemed chronically stressed (Clark *et al.*, 2006). The results of this study indicated that chronic stress in bottlenose dolphins' result in an increase in adrenal mass, and cortex to medulla ratio, as well as epinephrine-producing cells which subsequently result in an increased thickness of the medullary band (Clark *et al.*, 2006). As with much research, the immunological and physiological results of stress were recorded but behavioural responses neglected. Further immunological results were found in a study on dolphins used to catch yellowfin tuna (Myrick and Perkins, 1994). Chasing dolphins and confining dolphins using nets was shown to generate stress. Examination of 262 cortices of male spinner and spotted dolphins that died due to being chased and confined by nets showed that stress caused lipid depletion and hyperemia, and in all cases darkening of the cortex and that the spotted dolphins became stressed as they were being chased, which acted as the trigger starting the physiological processes leading to cortical darkening (Myrick and Perkins, 1994). The study seems to indicate that the spotted dolphin becomes stressed during chase, in that the physiological processes outlined which lead to the darkening of the cortex are put in to action as chase commences, where this was not stated for the spinner dolphin possibly indicating that physiological responses may be species specific also.

### **1.3.3 Stress Behaviours Exhibited by Dolphins as a Result of Specific Habitat and Climate Factors**

Factors within a specific dolphin habitat and surrounding environment, including climate change, may also have an influence on dolphin behaviour. A study of the immunobiology in the bottlenose dolphin, in response to environmental stress and infections showed an increase in stress hormones in bottlenose dolphins in response to environmental stressors (Mancia *et al.*, 2007). The Costa Rica Dome is part of an east–west thermocline ridge associated with the equatorial circulation, where surface currents flow cyclonically around, and the seasons are influenced by large-scale wind patterns (Fielder, 2002). The characteristics of the Dome provide a unique biological habitat in which phytoplankton and zooplankton biomass is greater than in the surrounding tropical waters (Würsig and Greene, 2002). The physical and biological



characteristics of the Dome affect the distribution and feeding of marine mammals which include whales and dolphins (Würsig and Greene, 2002). Stressors may be present should boat traffic, including tour boats, disturb the food source in an effort to provide tourists with a dolphin-watching experience. This would be particularly important where there are either spatial or seasonal variations in food sources which dolphins may follow. The minke whale (*Balaenoptera acutoroshala*), for example, shows spatial and seasonal variations in diet according to local availability of prey (Robinson, 2007). The distribution of fin whales (*Balaenoptera physalus*) and minke whales (*Balaenoptera acutorostrata*) were also investigated in the Bay of Fundy, Canada and indicated that whale distribution could be influenced by ocean depth, bottom topography and fine scale oceanographic features that facilitate foraging (Ingram, 2007).

Climate has also been shown to influence behaviour. Ocean climate variation has been shown to alter the behaviour of bottlenose dolphins in the Moray Firth (Robinson, 2007), United Kingdom and in Johnstone Strait in Canada (Lusseau, 2004b). Group size varied at both locations over time in response to large-scale ocean climate variation. When less food became available, dolphin group size decreased, suggesting that climate variation may influence social organisation due to subsequent changes in food stock availability. A genetic study of the four *Cephalorhynchus* species suggested that coastal, depth-limited odontocetes are susceptible to population fragmentation, isolation and long-distance movements which results from climatic change (Pichler *et al.*, 2001). On the basis of genetic testing all four species of *Cephalorhynchus* are thought to have originated in South Africa, but dispersed as a response to climatic change, with some populations following the West Wind Drift that lead to the colonisation of New Zealand waters (Pichler *et al.*, 2001). The Chilean and Commerson's dolphins are then thought to have speciated along the two coasts of South America from which genetically isolated populations arose from secondary radiations giving rise to *C. hectori* in New Zealand waters (Pichler *et al.*, 2001).

### **1.3.4 Stress Behaviours Exhibited by Dolphins as a Result of Noise in the Environment**

Lyttelton is a larger Harbour than Timaru and has significantly more traffic, of which much is represented by tankers, container ships and cruise vessels, which would contribute to any underwater noise. Research into the effect of noise on behaviour has been undertaken for some cetacean species and was found to be variable not only across species but also within species (Würsig and Richardson, 1997). The difference in vessel traffic within Lyttelton and Timaru Harbours may also be a factor in influencing dolphin behaviour. Research in western Hong Kong which is home to the Indo-Pacific humpbacked dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*) indicated that both species are not very sensitive to sounds below 300 Hz. Underwater engine sounds are therefore restricted to 110 dB re 1  $\mu\text{Pa}^2/\text{Hz}$  at frequencies above 300 Hz to a distance no greater than 300 m. Tankers navigating the waters are permitted to operate within this spectrum and were found to produce less than 110 dB re 1  $\mu\text{Pa}^2/\text{Hz}$  even at distances of 200 m or less (Würsig and Greene, 2002). However, no research has yet been undertaken on these dolphins in order to determine whether the noise spectrum permitted inhibits feeding which is predominantly acoustically based, communication within pods or between individuals or result in stress (Würsig and Greene, 2002).

Noise in the marine environment can be the result of aircraft such as helicopters, private and commercial ships, tourist boats, marine industrial activities, seismic exploration, oil exploration, sonars, explosions, and ocean acoustics studies (Akamatsu *et al.*, 1993; Baines, 1993; Evans, 1996; Würsig and Richardson, 1997; Stone, 2003; McIwem, 2006). Noise can inhibit natural response behaviours as they can mask important natural sounds to which dolphins would normally respond, and it is suggested that noise can result in hearing impairment or stress if it is sufficiently loud or prolonged (Würsig and Richardson, 1997). Overall, it has been determined that sounds associated with boat approach have a lesser effect on behaviour than those which have high pulsed sounds such as seismic survey pulses (Baines, 1993; McCauley, 1994; Würsig and Richardson, 1997). However, the study showed that with repeated exposure cetaceans habituate to persistent noise, but at the same time an

increase in sensitivity occurs. These effects were noted over a short-term and any long-term effect on individuals and for many populations are either not known or very little is known (Würsig and Richardson, 1997). Behavioural reactions of cetaceans to man-made disturbances, such as noise, have been shown to vary, with behaviour relating to attraction, or association with a vessel indicated by bow riding, through to what can be considered neutral behaviour as shown by an apparent unresponsiveness through short-term changes in behaviour such as swimming away from a vessel to long-term displacement (Hammond *et al.*, 1995; Würsig and Richardson, 1997; Cox, 2004).

Construction projects within the humpbacked dolphin's habitat were shown to cause disturbance which was indicated by an increase in swimming speed away from the construction area (Jefferson, 2000). Human-related causes of mortality include entanglement in fishing nets and vessel collisions. Some environmental contaminants (especially the heavy metal mercury and the pesticide DDT) were found in high levels in some dolphins, and preliminary evidence suggests that these may be affecting the health of the animals, in particular changing behaviour from foraging to avoidance thus using more energy which may impact on dolphins by reducing overall energy stores and potentially reducing biological fitness (Jefferson, 2000). A change from foraging or resting behaviour to either interaction with tour boats in the form of bow riding, or avoidance behaviour in the form of swimming away at speed from the tour boat, results in the expenditure of energy, the possible depletion of energy stores and possibly reduced reproductive output. Research and long-term monitoring of the population must continue for management strategies to be evaluated and refined (Jefferson, 2000). Overall, the population of hump-backed dolphins that occurs in Hong Kong waters appears to be viable and should be able to survive with appropriate conservation efforts (Jefferson, 2000). An investigation to determine individual factors which constitute stress within their habitat would serve to assist in such conservation measures. The same can be said for the area of the east coast of the South Island in regard to protecting both the habitat and conservation of resident wildlife, specifically Hector's dolphin.

### **1.3.5 Dolphin Mortality Resulting from Boat-Dolphin Collisions**

In boat-dolphin interactions there is a risk of dolphin and boat collisions, and where avoidance behaviour is exhibited resulting in a greater expenditure of energy, the possible reduction in overall fitness. The first reported collision between a tour operator and a spinner dolphin, (*Stenella longirostris*), was recorded this year (2007) in Brazil, where the dolphin sustained extensive injuries (Camargo *et al.*, 2007). Boat and dolphin collisions have increased the mortality rate of many marine mammals to such an extent that dolphin collisions are now recognised in Australia as a high risk factor that are now included in marine management issues, especially in relation to the Dugongs (*Dugong dugon*) (Sakamotoi *et al.*, 2006). Another cetacean prone to collision with boats is the sperm whale (*Physeter macrocephalus*) in the Canary Islands which has an habitat where large numbers of fast moving vessels are present (Delory, 2007). Collisions are made more likely due to sperm whales ceasing vocalisations at times when they are vulnerable, such as at the surface of the water, making them difficult to detect (Delory, 2007).

Apart from collisions, vessel traffic presence has also been suggested to have contributed to the Southern Resident Killer Whales becoming endangered (Bain *et al.*, 2006). During 2003 and 2004 theodolite observation were employed at sites along San Juan Island in order to determine behaviour responses of Killer Whales to boat traffic (Bain *et al.*, 2006), especially swimming speed and display behaviours. The study showed that Killer Whales swam further distances and had increased rates of display behaviour when boats were present or distance between the Killer Whale and boat decreased, resulting in expending energy, and reducing foraging time, which in turn may also result in reduced energy acquisition (Bain *et al.*, 2006).

### **1.3.6 Stress Behaviours Exhibited by Dolphins as a Result of Wildlife Tour Operator Activity**

Research on Tursiops spp. in Doubtful Sound, New Zealand, established that boat interactions with dolphins affect the behavioural budget of the overall dolphin population, and that dolphins were more sensitive to interactions with boats when at

rest and to a lesser extent when socialising (Lusseau and Higham, 2004). Bottlenose dolphins in the Bay of Islands are reported to be most frequently exposed to dolphin-watching tourism (Constantine *et al.*, 2004). The study on bottlenose dolphins and behaviour in response to boat presence was found to differ with boat number, where resting behaviour decreased as boat numbers increased (Constantine *et al.*, 2004). However, it was reported that dolphins engaged in more milling behaviour in the presence of permitted dolphin-watching boats compared to non-permitted boats (Constantine *et al.*, 2004). A recent study looked at the behavioural changes in bottlenose dolphins at two fjords in New Zealand, of which each was exposed to different levels of tourism activities (Lusseau, 2004a). The study showed that dolphins were more likely to travel after an interaction with a vessel, but that overall the behavioural budgets of the populations were unchanged even though individual behavioural budgets were significantly altered during interactions with boats (Lusseau, 2004a). However, the study determined that dolphins at both sites exhibited avoidance behaviour in the presence of the boats and if boat presence persisted in that, dolphin-boat interactions were more frequent than 68 minutes apart, the result was that dolphins exhibited avoidance behaviour not only in relation to the vessel, but relative to the area the vessel was within (Lusseau, 2004a). It is not only tour boats that affect dolphin behaviour and can stimulate stress or avoidance responses, research vessels in the quest to study dolphins and build a knowledge base have also been shown to affect behaviour.

### **1.3.7 Stress Behaviours Exhibited by Dolphins as a Result of Dolphin Research Programmes**

Research into overall effects on dolphin health are hampered by the fact that many species of cetacean are listed as endangered so any affect or change in genetics due to environmental or other pressures over time are difficult to assess (Mancia *et al.*, 2007), as too are populations of dolphins that appear similar like the North and South Island Hector's dolphin which have been shown to be genetically different (Pichler *et al.*, 1998). The Hector's dolphin populations found on the North Island, the west coast of the South Island, and the east coast of the South Island show a marked segregation of maternal lineages, which amongst cetacean species is very unusual, especially

across such a small geographic range (Pichler *et al.*, 1998). It is thought that there are at least eight separate populations of hump-backed dolphins (*Sousa chinensis*) along the coast of southern China, but preliminary genetic work has shown only equivocal evidence of population separation from dolphins in the Xiamen area when in fact there may be more variation to be discovered (Jefferson *et al.*, 2000). The problem with trying to determine if one population is genetically different from another or even if behaviour differs from one population to another is that often the methods needed to reach the conclusion are invasive and can themselves result in stress for the dolphin. For example, the coastal Heaviside's dolphin (*Cephalorhynchus heavisidii*) has a limited inshore distribution off the west coast of southern Africa and after being fitted with satellite-linked GPS transmitters showed avoidance of the capture site (Elwen *et al.*, 2006). However, genes have been found to influence behaviour of other mammals. Genetic research showed that rats have clear heritable reactions in regard to different emotional reactivity, including stress, to the same environmental stimuli, and that this heritable trait was passed down to the eight generations studied (Stead *et al.*, 2006). Another study found that genes influenced eating behaviour in humans, and that these genes also passed down through generations, but was gender specific (Keski-Rahkonen *et al.*, 2004). Daily motor activity has been found to be hereditary in mice, dependant the presence of specific chromosomal groups (Sans-Fuentes *et al.*, 2005). In regard to dolphins genomic DNA has been shown to act as a template as well as a primer which can lead to self-amplification of satellite DNA (Buntjer *et al.*, 1998) which is a highly repetitive element of delphinids (Arnason *et al.*, 1984; Widegren *et al.*, 1985) and species-specific (Buntjer *et al.*, 1998). Although not investigated in this thesis, it is possible that genetic variation in Hector's dolphins is an influencing factor in behavioural variation to the same stimulus or stressor, in this case, the behaviour of dolphins towards the presence of boats at Lyttelton and Timaru.

The type of research conducted appears to determine whether or not dolphins exhibit stress, as other research has stated that research vessels have no effect on dolphin behaviour. Bottlenose dolphins in Doubtful Sound, New Zealand, showed an increase in vertical avoidance of boats (Lusseau, 2003b). However, this response was only observed in boats other than the research vessel which is stated not to have a significant effect on the diving pattern of the dolphins, but dolphins did avoid tour boats by exhibiting vertical avoidance, shown by an increase in the mean length of

diving time. There were also gender differences in that dolphins started to react before tour-boats were in visual contact, with males responding more promptly than females (Lusseau, 2003b). These studies indicate that conducting research also effects dolphin behaviour and that the behaviour can be species specific and also vary between individuals and genders. Other studies have found similar results (Wade, 1998; Bräger, 1999; Nichols *et al.*, 2001a). In addition, Hector's dolphin calf mortality is an increasing concern in regard to both boat presence (Stone and Yoshinga, 2000) and fisheries (Pichler and Baker, 2000; Slooten *et al.*, 2000; Starr, 2000; Baird and Bradford, 2000).

### **1.3.8 Stress Behaviours Exhibited by Dolphins as a Result of Dolphin-Boat Interactions**

It is clear that many dolphin studies have shown that dolphins exhibit both horizontal, swimming away from the vessel, and vertical avoidance, prolonging the length of dive duration, in order to create distance between themselves and vessels (Hammond *et al.*, 1995; Würsig and Richardson, 1997; Cox, 2004; Constantine *et al.*, 2004; Lusseau, 2004a; Bain *et al.*, 2006; Lusseau, 2006). Dolphin behaviour, specifically swimming movement of dolphins, becomes increasingly erratic during interactions with all types of vessels, and noted behavioural effects increase when boats are more intrusive (Lusseau, 2006). David Lusseau's studies have outlined the impacts of interaction with boats, specifically behavioural responses, but have also shown that the effects can be minimised if vessels respect guidelines in place which govern marine based tour operations (Lusseau, 2006). However, the most recent research, reports that even though eco-tourism or cetacean-watching tours are the main focus at main coastal locations, the effect of tour activities on individuals and populations of cetaceans remain largely unknown, in particular with regards to biological significance (Lusseau, 2004a), in particular with regards to reproductive fitness. The difficulties determining conclusive results from data collected decades ago appear still to be similarly problematic today.

Studies in the past have concluded that the effects of marine mammal tourism were unclear, and that seems to have persisted to some extent through to today. Lusseau

(2003a) studied bottlenose dolphins in Doubtful Sound and used Markov chains to determine behavioural changes with the presence of tour boats. The study was conducted over a 14-month period at the end of which it was determined that resting behaviours were disrupted by boat interactions, and that dolphins were more likely to travel away after an interaction with a boat, but that overall the behavioural budget of the population was not significantly affected. He concludes that the bottlenose dolphin population in Doubtful Sound appears to be able to sustain the present level of boat interactions due to these interactions being low in intensity (Lusseau, 2003a), but there are still large gaps in knowledge with regard to long-term behavioural changes although there have been advances in this regard within the last decade (Bejder, 2006a/b; Lusseau *et al.*, 2007). For example, the result of studies on bow riding dolphins indicate that behavioural, physiological and morphological factors make wave-swimming an economical form of high-speed travel for dolphins, which use much less aerobic energy than they would if swimming without wave riding (Williams *et al.*, 1992). Whether bow riding or wave riding is in fact energetically advantageous is hard to substantiate in the absence of physiological data for exercising cetaceans (Williams *et al.*, 1992), and it could be argued that if bow riding or wave riding is energetically beneficial it would be a behaviour in common to all or most cetaceans, but there are accounts of certain cetacean species, which appear not to engage in bow riding. For example, the Hong Kong hump-backed dolphins have been reported to rarely ride wave on the bow of boats (Jefferson, 2000).

## **1.4 An Introduction to Banks Peninsula**

Dominated by a highly diverse and dynamic eco-system, Banks Peninsula is subject to both commercial and recreational water based activities, as too is much of the coast of both the North and South Islands of New Zealand. Monitoring the varied effects of commercial and recreational activity on the behaviour of resident marine animals is a complex undertaking, but is possible with the effective use of research which includes population and behaviour studies, monitoring and mapping methods to determine changes and effects on population assemblages, and population dynamics within inhabited areas. The endemic and threatened species *C. hectori* are heavily exploited



by humans. Watercraft use around coastal areas resulting in the encroachment on the lives of animal inhabitants requires monitoring.

The Banks Peninsula District in New Zealand spans from Sumner Head to the Rakaia River, and incorporates both Lyttelton and Akaroa Harbours (see Figure 1). Situated south of the Rakaia is the Timaru District which incorporates Timaru Harbour. The endemic and threatened Hector's dolphin, inhabits these harbours as well as being present along this stretch of coastal water. Dominated by a highly dynamic ecosystem, as well as being subject to human recreational activity and commercial operations, both Banks Peninsula and Timaru are popular tourist venues as well as attracting locals. The variety of activity available enables individuals or groups to encounter nature at close quarters using either recreational watercraft or commercially-run trips. While proving educational, this also creates management and conservation issues for the species of interest.

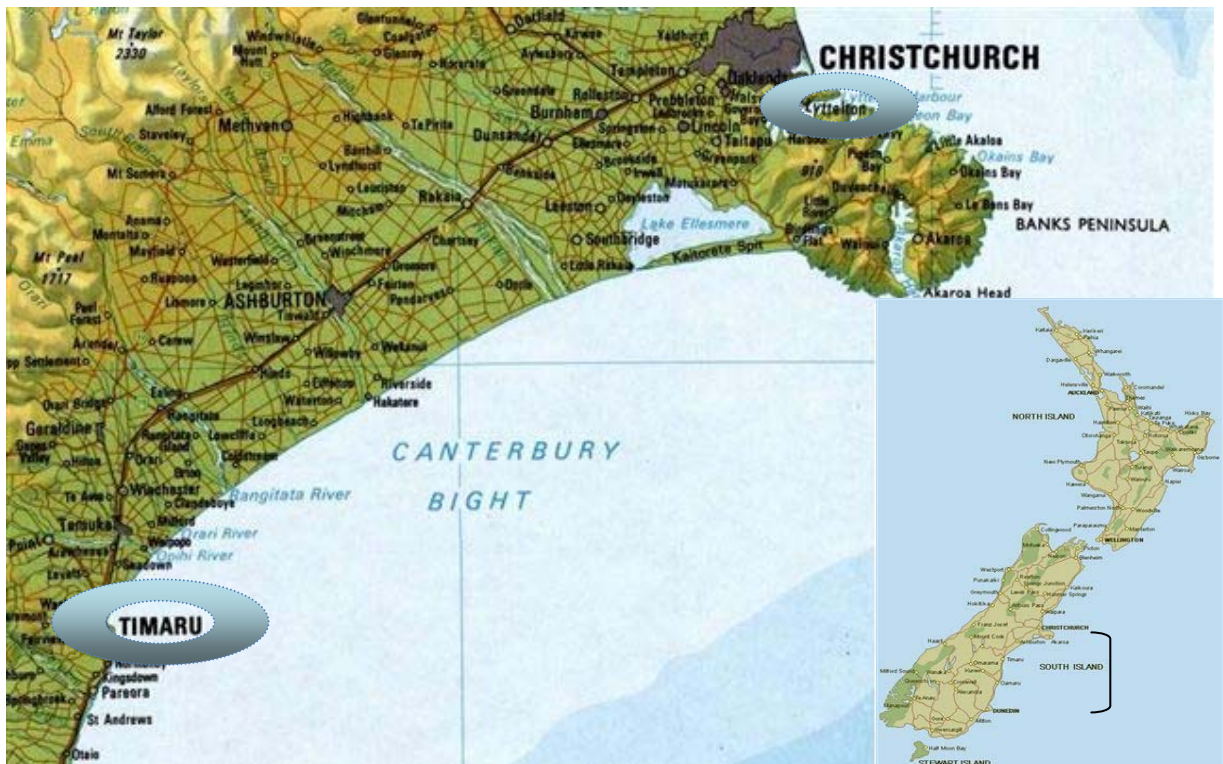


Figure 1: Map of the eastern coastline of the South Island of New Zealand with the two study areas, Lyttelton and Timaru highlighted. Insert of New Zealand North and South Islands (TopoNZ, 2007).

Different ocean-based activities, such as scuba diving, kayaks and eco-tours, produce varied responses and also result in behavioural developments and changes within species. Although not always negative, these activities can in turn lead to the detrimental susceptibility of vulnerable species. Observing and dealing with the many activities which take place around Banks Peninsula is a complex undertaking, but it is achievable with the effective use of research, legislation, population studies and mapping methods in order to monitor effects of activities in relation to behavioural changes, population, general species mix and changes in areas inhabited.

Both the number of tour operators and the number of eco-tours conducted at Akaroa Harbour, the South Island's most popular tourist spot for marine mammal interaction, have increased within the last decade. Specifically, tourist numbers tripled in the last 15 years. In respect to Canterbury there is an estimated increase in tourist visitors forecast of 3.7% annually up until 2008. This amounts to 4.3 million visitors, bringing revenue of 2.3 billion NZ\$ for the Canterbury region alone (Christchurch City Environmental Trends, 2003). More business ventures are being established advertising "dolphin watch" or "swim with the dolphin" experiences. As well as dolphin experience tours, other tours are offered which include fishing, harbour cruises and bird watching. Other recreational eco-tour activities include snorkelling, sea kayaking and SCUBA gear hire in order to observe marine wildlife in its natural habitat. In addition, private boats venture into the harbour with the main focus of either observing or swimming with Hector's dolphins.

Eco-tourism is now a very popular and growing industry. In addition to the tour operators in Akaroa Harbour, dolphin experience operators, these are tours offering swim with the dolphins, or dolphin spotting tours, are now established at Lyttelton Harbour and on the coast around Timaru. The Black Cat, which began operations at Akaroa, now operates at Lyttelton Harbour. These tours commenced in November 1999 and are generally fully booked, especially during the summer months. In addition to Black Cat tours, Sea Tours New Zealand operates a 'Dolphin Adventure' tour and Lyttelton Harbour Cruises operate wildlife cruises and other excursions including trips to Diamond Harbour, Ripapa Island and Quail Island. Furthermore, dolphin experience tours have now extended around the coast to Timaru. Although

not well advertised or as popular as Akaroa eco-tours, the potential for growth is evident in the growth of both Akaroa and Lyttelton tour operators.

Hector's dolphin and human interactions can be experienced within Akaroa Harbour, Lyttelton Harbour and Timaru either by booking a tour through a commercial operator or by private excursions organised by individual boat owners. The potential effect of these activities on the behaviour of Hector's dolphins at Akaroa Harbour has been investigated (Stone, 1992; Stone *et al.*, 1995; Stone *et al.*, 2000), but many aspects still remain largely unknown and, therefore, require investigation. This is particularly true in the case of Lyttelton Harbour (Figure 2) and Timaru Harbour (Figure 3), where, although there have been transect surveys in order to determine populations (Dawson *et al.*, 2000; DuFresne *et al.*, 2001), there have been no reported behavioural investigations conducted. Transect surveys showed that Hectors dolphin populations were greater on the west coast of New Zealand than the north, south and east coasts combined. There were no Hectors dolphin estimates of abundance before 1984 when estimates and survival rates began to be investigated (Slooten *et al.*, 1988; Slooten and Dawson, 1992; Martien *et al.*, 1999; Burkhart and Slooten, 2003). Population abundance, as calculated using aerial transects, was investigated between Motunau and Timaru (Dawson *et al.*, 2000) and between Timaru and Long-Point (DuFresne *et al.*, 2001). Population estimates between Farewell spit and Kahurangi Point were 74 dolphins with a combined population estimate for the north, south and east coasts of 1882 individuals, and where the west coast population was the greatest with an estimated abundance of 5388 dolphins (Slooten *et al.*, 2002).





Figure 2: Topographic map of Lyttelton Harbour. The arrow marks the theodolite site (TopoNZ, 2007).

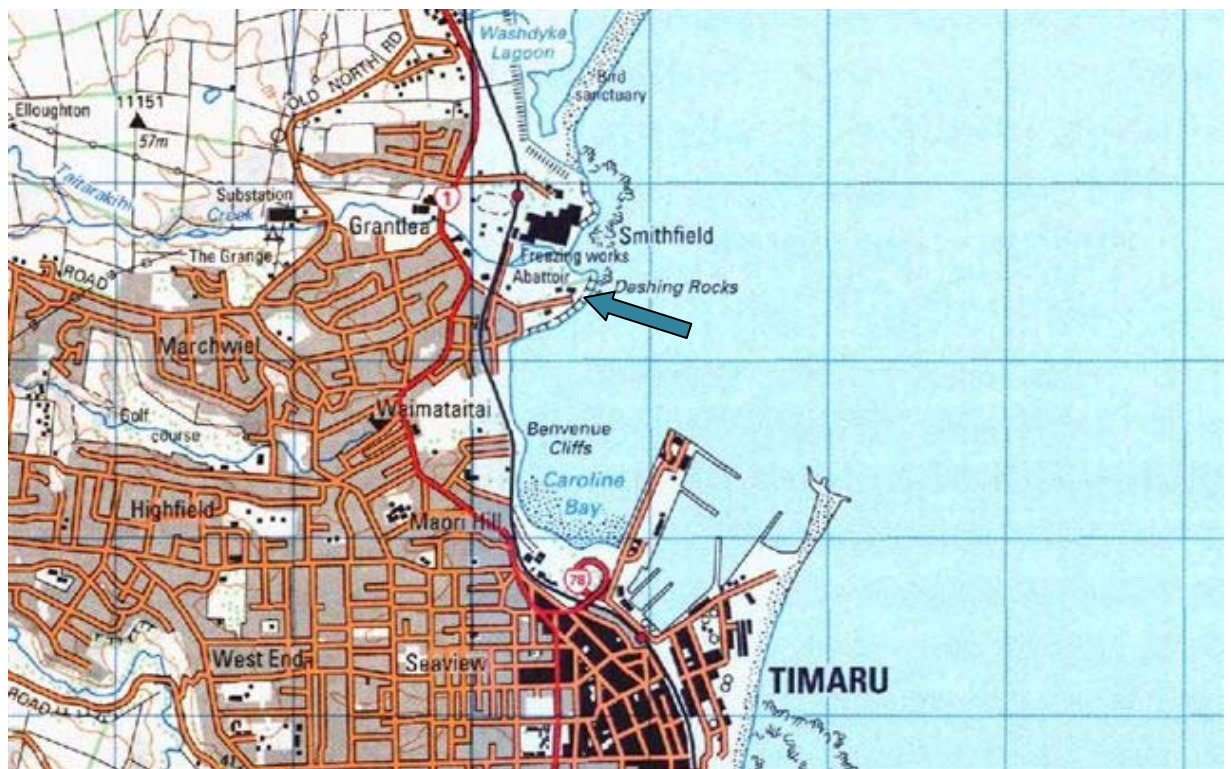


Figure 3: Topographic map of Timaru Harbour. The arrow marks the theodolite site (TopoNZ, 2007).

### 1.4.1 An introduction to Lyttelton and Timaru

As eco-tours become increasingly popular, so too does Lyttelton Harbour (see Figure 4), as it presents an opportunity to take part in many activities that allow close encounters with Hector's dolphin. The inlet port of Lyttelton has a population of 228 people, while Lyttelton itself has a population of 3078 people (Statistics NZ, 2006a). Lyttelton Harbour is easily accessible from Christchurch City and the surrounding population in the Canterbury region of 521832 (Statistics NZ, 2006a). As well as operating as a port and working docks, wildlife cruises operate from Lyttelton Harbour, which also has historical value. In particular, there are two islands within the Harbour, Quail Island and Ripapa Island, both of which can be visited by ferry from Lyttelton launch wharf. The main attraction of Quail Island is its flora and fauna, whereas Ripapa Islands principle area of interest is historical (Braithwaite, 1988). The tourist attractions are therefore varied and bring into Lyttelton many individuals who may be seeking both historical information and natural wildlife experiences.



Figure 4: The Black Cat tour boat which operates within Lyttelton Harbour. Photo shows the inlet as viewed from Lyttelton Quay.

The city of Timaru is 163 km south west of Christchurch, located at the southern end of the Canterbury Bight. Timaru derived its name from a corruption of the word 'temaru', meaning 'the place of shelter' (Dymock, 1994), where whalers operated into the late 1830s (McLaughlan, 1995), taking up to 70 tonnes of oil in one whaling



season (Tod, 1982). The port initially suffered from poor facilities and deep-water berthage, and large vessels could not confidently use the port until well into the 20<sup>th</sup> century (McLaughlan, 1995). Prior to European settlement the area of Timaru was occupied by the Ngai Mamoe who were driven south by the Ngai Tahu from the north. Timaru was the result of a merger between William, George and Robert Rhodes who owned land, and the government who also owned land. Timaru District now has a population of 42870 (Statistics NZ, 2006b), with residents at the inlet port of Caroline Bay (see Figure 5) numbering 33 (Statistics NZ, 2006c).



Figure 5: Caroline Bay viewed from the inlet port of Timaru.

#### **1.4.2 Why Study Hector's Dolphins at Lyttelton and Timaru?**

The Department of Conservation (DoC), considered the Hector's dolphin population at Timaru to be relatively naïve, in comparison to the population at Lyttelton which had been subject to tours for a year prior to the commencement of this study. It must be remembered that although Hector's dolphin behaviour may be similar at different locations due to genetic and physiological traits, there may be some differences based on geological and habitat differences and previous encounters with watercraft that have not been recorded, observed and therefore cannot be accounted for.

A major problem with assessing the behaviour of Hector's dolphin, in Lyttelton and Timaru, is that there is no baseline from which to determine pre-tourism dolphin

behaviour. Many studies have been conducted investigating the response of Hector's dolphins to boats but what dolphin behaviour was like prior to the presence of tour boats is unknown at these sites. This was a primary reason for choosing the observation sites for this study.

Both Lyttelton and Timaru have larger human populations than Akaroa, which has only 912 permanent residents (Statistics NZ, 2006a). Unlike the dolphin population at Akaroa, the dolphin population at Timaru remains largely undisturbed by commercial tour operators conducting regular dolphin experience based tours, and so presents an opportunity to observe behaviours as yet unchanged by multitudes of operators and human interaction other than through non-targeted port activity. Using a theodolite allowed behavioural observations to be recorded both in the presence and absence of boats. It may be possible to use observations from this site as a baseline from which it may be possible to deduce the context and change in behaviour, if any, present when Hector's dolphins are subject to both boat and human presence. As tourism commenced at Timaru very recently, at the end of 1999, the dolphins are in an earlier stage of human interaction than those at Akaroa, and as Lyttelton Harbour dolphin excursions commenced in 2000 these dolphins are in an early stage of human interaction between that of Akaroa and Timaru.

It is possible that the data obtained at Timaru is representative of baseline data with regard to behavioural responses to tour boats and that the response at Lyttelton are representative of transitional behaviour changes between what would be observed at Timaru and what would be observed elsewhere, where dolphin-tours are already established. However, studies show that there may be site-specific differences in response to a changing environment in regard to the presence of dolphin tours. For example, studies of Hector's dolphin in Porpoise Bay show that it took four years for a dramatic change in behaviour (Bejder 2006a/b) and in the Bay of Islands dolphins changed their response in the presence of swimmers, in three years (Constantine, 2004).

Hector's dolphins are not the only dolphin where gaps exist in knowledge. There are still other dolphin species for which there is little basic biology available. For example, the Indo-Pacific hump-backed dolphin (*Sousa chinensis*) has not been

significantly studied and any detailed biology is unknown and long term studies are absent (Jefferson, 2000).

### **1.4.3 Why Monitor the Effects of Both Boat and Human Presence on Hector's Dolphin Behaviour?**

It is important to monitor the effects of both tour boat presence and other boat presence so that an overall and combined effect on Hector's dolphin behaviour can be determined. Monitoring of individual dolphins and overall group dynamics is therefore required. The information derived from such research will provide details about Hector's dolphin behaviour in response to various boat presences. To date this information is absent from Lyttelton Harbour and Timaru.

Any analysis or interpretation of data obtained from research of this type would give an indication of whether there are problems, in regard to the frequency or presence of dolphin based tour-operations, that need to be addressed. In turn this would ultimately allow decisions to be made about whether there is a need to introduce further control measures or tighten existing regulations governing commercially organised dolphin tours and private excursions.

The non-conformity of some operators and/or their passengers to the regulations governing dolphin experience activities place additional pressures on Hector's dolphin populations. A review of the regulations governing dolphin and human interaction and their enforcement is also necessary. There were 70 instances over a year recorded at Kaikoura where boats did not conform to the conditions and regulations governing dusky dolphin tour activities as outlined in the Marine Mammal Protection Act (MMPA), 1992 (Barr and Slooten, 1999). Any non-conformation to regulations is a major concern and suggests that more stringent regulations or monitoring of conformity to the regulations governing dolphin tour activities is needed. This should be a major priority not only for the dusky dolphin population at Kaikoura but also for Hector's dolphins at Akaroa. Hector's dolphins have been declared a threatened species (DoC, 1999a), and, therefore, require protection to maintain their population and ensure their wellbeing. For these reasons it is essential to determine whether tour



operators conform to regulations and guidelines governing dolphin experience tours wherever the operation.

There is a major concern over the wellbeing of Hector's dolphins. Some of these concerns are related to the conduct of commercial tour operators providing dolphin experience tours, and the conduct of private boat operators. As a result, both Timaru and Lyttelton Harbours are becoming subjected to increasing pressure from commercially organised eco-tours and, additionally, private excursions. Excursions to see dolphins at Lyttelton Harbour have also increased. The fear is that activity of this nature and increasing pressure may alter the behaviour of Hector's dolphins within a habitat that was initially regulated to protect them. A marine mammal sanctuary was established around Banks Peninsula in December 1988 to protect Hector's dolphins against mortality due to net entanglements (Voller, 1992; Dawson and Sooten, 1993). However, the complete effects of tourism are not yet known.

To date there are no accurate figures depicting the number of Hector's dolphins present in Akaroa Harbour, although estimates vary between 1000-4000 individuals (Voller, 1992; Dawson and Sooten, 1993). There have been no estimates made of the individual populations at either Lyttelton or Timaru. Until reliable data are obtained, the existing population of Hector's dolphin must be protected against human interaction situations which have the potential to induce stress or alter behaviour in such a way that it is detrimental to their biology and population dynamics. This is particularly important because Hector's dolphins have a low reproductive output and short life span (DoC, 1988; Sooten, 1991), hence any decline in biological fitness due to stress from eco-tour operators may have long-lasting effects as shown in bottlenose dolphins in Shark Bay (Bejder *et al.*, 2006b).

A change has already been observed in Hector's dolphin behaviour at Akaroa (Stone, 1992; Stone *et al.*, 2005), which is supported by local resident observations (pers. comm., Bob Meikle, September 1999. Resident of Timaru), and DOC employees working in close proximity to the dolphins (pers. comm., Alistair Hutt, September 1999, retired from DoC at Akaroa), in that dolphins appear to be attracted to tour boats and spend an increasing amount of time interacting with them. Any change in behaviour at Lyttelton or Timaru is as yet un-investigated.

The word eco-tour suggests an activity which does not disrupt the natural environment, or alter the behaviour or dynamics of the wildlife present allowing animals to thrive in a relatively undisturbed, naturally changing habitat. However, there has been little research to determine if this is in fact the case in Lyttelton or Timaru Harbours. The eco-tour activities offered at Akaroa and Lyttelton Harbours not only subject dolphins to disturbance from boats, but also from swimmers and divers.

#### **1.4.4 Banks Peninsula Marine Mammal Sanctuary**

Established in 1988, the marine sanctuary serves to protect Hector's dolphins from mortality caused by commercial fisheries and other human activity. The sanctuary follows the coastline from the Rakaia mouth to Sumner Head and spans four nautical miles out to sea. It covers an area of 1140 km<sup>2</sup> (Gabites Porter Consultants, 1995). It serves as an important breeding site which DoC actively protects. However, on-board boat-based observations at both sites and field notes (Travis, 2000; 2001) referencing revealed disregard for the Marine Mammal Sanctuary and the Resource Management Act, 1991 (RMA), and the Marine Mammal Protection Act, 1978 (MMPA) which govern it (Appendix A).

### **1.5 Methods to be used in this research**

To protect both the dolphins and the industries which are based around them, it is necessary to monitor dolphin wellbeing, by finding ways to measure stresses, recording reproductive success and any behavioural changes that may occur over time which are related to human interaction as well as population numbers. A combination of non-invasive cliff-top methods and boat-based observations can reveal important information about dolphin behaviour, in particular preference to water craft and whether tour boat presence has an affect on behaviour.

### 1.5.1 Boat-Based Research

One difficulty in studying dolphins is in observing individuals without affecting their behaviour. Using a land-based theodolite represents a non-invasive method which can be used to observe marine mammals without changing their behaviour as a result of them being aware of the researcher's presence. Theodolites have been utilised in ocean-based research since the 1950s and their use as a research tool has been growing steadily, particularly within the last decade. In this time, theodolites have proven to be successful tools which can be used world-wide to monitor, record and observe not only cetacean behaviour, but also other marine mammals. For example, Vergani and Stanganelli (1986) used theodolite tracking to observe elephant seals *Mirounga leoni* in Argentina to determine population distribution. The feeding behaviour and movements of dolphins have been recorded using theodolites in Mexico (Acevedo, 1991), Portugal (Harzen, 2002) and the USA (Gailey, 2001). In Mexico, theodolite tracking was used to determine bottlenose dolphin distribution. Sea birds, which were thought to be associated with bottlenose dolphins feeding, were found to exhibit their own feeding patterns separate to those of bottlenose dolphins, although seabirds were also influenced by the same prey movements (Acevedo, 1991).

New Zealand's Hector's dolphin, *C. hectori*, is one of the smallest and most threatened of the world's dolphin species. Their inshore habitat regularly brings them into contact with boats and a significant tourist industry based around taking passengers to observe the dolphins has developed. The potential effects that these human-dolphin interactions may have are particularly important to Hector's dolphins in relation to their biology and life cycle as they have low reproductivity and relatively short lives (DoC, 1988). Energy spent exhibiting avoidance behaviour may well deplete energy stores and may reduce overall fitness, which over time may be reflected in a decrease in population numbers due to reduced breeding fitness.

### 1.5.2 Boat-Based Research

Dusky dolphins in Argentina, Tasmania and New Zealand have been observed in association with seabirds (Wirsig and Wirsig, 1979; Gill *et al.*, Brager, 1998; 2000; Hawke and Dobinson, 2001; Hawke, 1994). Dusky dolphins (*Lagenorhynchus obscurus*) at Kaikoura have an association with the white-fronted tern (*Sterna striata*) (Hawke and Dobinson, 2001). Associations also exist between seas birds and Hector's dolphins (Hawke, 1994; Brager, 1998). Dusky dolphins at Kaikoura have been observed exhibiting behaviours which include slow swimming in all directions, jumping, an increase in swimming speed, and diving for periods of varying duration in the presence of seabirds (Hawke and Dobinson, 2001). The behaviours exhibited by Dusky dolphins in the presence of seabirds include an increase in swimming speed and could be accompanied with swimming away from a boat, and would indicate avoidance behaviour by the definitions outlined in this thesis. Although Hector's dolphins were observed at Lyttelton Harbour with seabird rafts, they were never observed, during the course of this study purely as dolphin seabird associations, but rather as dolphin seabird and recreational fishing boat associations. On all occasions that Hector's dolphins were observed with seabirds a local fishing boat, the Minerva, was also present. As the tour boat, the Black Cat remained at distance from the Minerva focal animal sampling which may have otherwise have skewed the results can be confidently ruled out, as dolphins were too far away to be observed exhibiting particular behaviours. However, caution would be best advised in any interpretation of results where seabird and dolphin associations were observed, especially where tour boats or other vessels are in the vicinity. In such instance avoidance behaviour as inferred by an increase in swimming speed and directional swimming away from a vessel may not be a result of boat presence but a response to prey presence and seabird-dolphin associations, which ultimately is linked to a food source.

Observations made from fishing boats such as the Minerva at Lyttelton would allow data collection without increasing the number of boats within the Harbour and may prove useful in providing more details about dolphin seabird interactions and associations as well the type of prey or catch dolphins and seabirds are mutually

attracted to, without causing potentially more disturbance by introducing research or tour boat presence.

## **1.6 Overall Objectives**

To identify any stress-induced behaviour on Hector's dolphin as a result of human interaction using watercraft.

## **1.7 Specific Aims**

The primary aims are to investigate stress:

- What are the stress behaviours, if any, that arise from the interaction between Hector's dolphin and tour boats?
- To give evidence of stress-induced behaviour arising from the interaction between Hector's dolphin and tour boats.
- Recommendations for future research and the identification of any key issues material to the role in managing potential human induced adverse impacts on Hector's dolphin.

# **Chapter 2 - Non-invasive Observations of Tour Boat Association and Behaviour of *Cephalorhynchus hectori* at two New Zealand Harbours**

## **2.1 Abstract**

Hector's dolphin (*C. hectori*) is one of the smallest and most threatened dolphin species. Because much of its natural range is inshore and includes easily accessible harbours, a significant tourism industry has developed around boat tours to observe the dolphins. There is currently little understanding about the interactions between Hector's dolphin and boats and whether there are management issues to consider (Bejder *et al.*, 1999; Martien *et al.*, 1999; Brager *et al.*, 2002; Stone *et al.*, 2005).

Observing dolphins is a complex task and often the only method available is to observe from boats. However, there are occasions when it is necessary to observe dolphin behaviour in the absence of boats. Non-invasive, shore-based theodolite observations of interactions among Hector's dolphin were made at two New Zealand Harbours, Lyttelton and Timaru. Of primary interest were behavioural responses to tour-boat operator presence, which run regular trips to observe Hector's dolphin in their natural habitat and responses at sites where there have only been a few (Lyttelton) and no (Timaru) previous tour operations.

Observations implied that some generic dolphin behaviours which imply stressed individuals may not apply to Hector's dolphins and; therefore, questions the assumption that all dolphin species behave in similar ways. The dolphins at both sites were consistently observed with some boat types, for example, small commercial craft, recreational power, kayaks and commercial fishing vessels respectively, but were not observed with large commercial ships, dredges, trawlers and jet skis. Dolphins at Timaru exhibited a greater range of behaviours than at Lyttelton. The stress-related behaviours identified by an increase in swimming speed to open ocean and an increase in grouping behaviour were observed at both sites, and only in the presence of boats, particularly large commercial boats. Other potential stress behaviours, such as head slaps and repeated tail slaps, were only performed in the absence of boats. It is suggested that low-level tourist boat activity is not currently placing undue stress on the population.

Keywords: *Cephalorhynchus hectori*, stress, tourism, Timaru, Lyttelton

## **2.2 Introduction**

Previous studies on cetaceans indicate that boat presence can be stressful to both whales and dolphins (Hammond *et al.*, 1995; Würsig and Richardson, 1997; Cox, 2004; Constantine *et al.*, 2004; Lusseau, 2004a; Bain *et al.*, 2006; Lusseau, 2006a/b). A characteristic sign of stress in cetaceans is exhibited by avoidance behaviour. Pryor and Shallenberger (1991) indicated that the most common reaction of cetaceans to boat presence was an increase in swimming velocity towards open ocean. This behaviour has been observed in both killer whales (*Orcinus orca*) and beluga whales (*Delphinapterus leucas*). Killer whales in particular exhibit an increase in speed when boat proximity is within 400 m and their swimming velocity was 1.4 times faster when a boat was present (Kruse, 1991). The beluga whale also increased swimming velocity in response to boat presence, although the amount was not quantified (Kruse, 1991). Other whale species also exhibit this response to boat presence. For example, bowhead whales (*Balaena mysticetus*) significantly increase swimming speed when boats approach (Richardson *et al.*, 1985), and humpback whales (*Megaptera*

*novaeangliae*) in Alaskan waters swim faster when boats are present (Baker *et al.*, 1983).

Dolphins show similar behavioural responses to the same stimuli. Bottlenose dolphins increase swimming velocity and change direction so that they swim away from boats (Irvine *et al.*, 1981). Spotted dolphins in the Eastern Tropical Pacific swim away from boats when detecting their presence. In addition, both species ‘bunch together’ to form a tight group and head towards open waters when exposed to capture in purse-seine nets (Pryor and Shallenberger, 1991). They also exhibit agitated behaviour, which include head slaps, tail slaps, thrashing and a change in breathing patterns to sharp ‘puffs’ (Pryor and Shallenberger, 1991; Stone *et al.*, 1992). These behaviours have been attributed to signs of fear and stress. Research on New Zealand’s Hector’s dolphins has shown similar effects. For example, Bejder and Dawson (1999) observed a significant increase in Hector’s dolphin avoidance behaviour and also in the proximity of dolphins to one another when exposed to a dolphin watch tour boat. Boat presence also serves to enhance communication throughout the pod as observed in the spotted dolphin, bottlenose dolphin and various whale species (Weilgart, 1984; Sjare and Smith, 1986; Glockner and Smith, 1986; Pryor and Shallenberger, 1991; Erbe, 2002).

Other behavioural changes by cetacean species in response to boat presence have been observed. For example, undisturbed, killer whales show no preference in swimming direction but when disturbed they favour a course which allows them to escape the narrow Johnstone Strait and enter the open waters of the Queen Charlotte Strait (Kruse, 1991). Kruse (1991) also showed that swimming velocity is positively correlated with the number of boats operating within 400 m of the whale. Different whale species show marked differences in their response to different types of boat. For example, killer whales did not respond differently to boats of varying size or motor type, whereas beluga whales responded differently to outboard-powered vessels and boats with diesel engines.

Information on reactions of dolphins to boat and engine type is important in managing dolphin populations, particularly with regard to tour operator activity which specifically targets dolphins and moves into their close proximity. There may also be



long-term effects on dolphin populations and individuals with continued exposure to boats. These include reduced biological fitness (expenditure of energy, survival and productivity) due to the disturbance of resting periods and the expenditure of energy while exhibiting avoidance behaviour (West *et al.*, 2002; Constantine *et al.*, 2004). Determining which vessel provokes the least behavioural change or exhibition of avoidance behaviour may give an indication of which vessels are best to employ for commercial trips.

Bejder and Dawson (1999) used a theodolite to observe Hector's dolphins in Porpoise Bay, New Zealand. Bejder and Dawson (1999) showed that Hector's dolphins were attracted to tour operator vessels, but that the longer the boat was present the fewer encounters of Hector's dolphins were experienced. This study also showed that the level of tour operator activity within Porpoise Bay was not having any undue affect, but that the potential for increased activity gave cause for concern.

A major problem for cetacean research is when there is no baseline from which to determine 'normal' dolphin behaviour. Studies relating to dolphin behaviour often work on a hypothesis gained from pilot studies, previous observations or local knowledge (Bel'kovich and Agofonov, 1978). Alternatively, long-term studies can relay changes in behaviour, which may occur over time as well as the benefits of long-term observation programmes, but may themselves lack an initial baseline (Wells, 1998). Many studies have investigated the response of dolphins to boats or changes in behaviour over time, but what dolphin behaviour was like prior to the presence of a boat or other changing factors remains unknown in many cases.

The Hector's dolphin population at Timaru, New Zealand, in 1999 remained largely undisturbed and presented an opportunity to observe behaviours, as yet, little impacted by targeted tourism. The population at Lyttelton Harbour was also relatively naïve with respect to tourist pressure, but the port of Lyttelton is a main route for large cruise ships, commercial ships and containers. It may be possible to use observations from both sites as a baseline to compare the context and change in behaviour, if any, when Hector's dolphins are subject to both boat and human presence. Monitoring of individual dolphins and the overall group dynamics is required. Studies at Akaroa, which has had intensive tour boat activity for a number of years, have suggested a

change in Hector's dolphin behaviour due to an increase in tourism (Stone and Yoshinaga, 2000). What is sought in this study is an indication of whether any change in Hector's dolphin behaviour occurring at either Lyttelton or Timaru, which could be attributed to the introduction of dolphin focused tourism at both sites.

## **2.3 Methods**

Lyttelton Harbour is a deep crater formed by a volcanic eruption, and has been made much larger than it was initially due to major erosion (McLaughlan, 1995). It is 12 km south east of Christchurch (Dymock, 1994). Lyttelton Harbour extends 14 km from its eastern entrance, to the north side of Banks Peninsula and southwest as far as Governors Bay (McLaughlan, 1995). As well as operating as a port and working docks, wildlife cruises operate from the jetty. Extensive views in and out of the harbour can be viewed from a now redundant quarry (Figure 6). The city of Timaru is 163 km south west of Christchurch, located at the southern end of the Canterbury Bight. Along the coastline there are wildlife walks including the Washdyke walkway which has views into and out of Timaru Harbour (Figure 7).

Using theodolite tracking, dolphin sightings were plotted on ocean charts, at both Timaru and Lyttelton. Boat preference was also determined along with types of behaviour associated with the presence and absence of boats. As the theodolite had a view of 1000 m a boat was deemed to be absent if there were 1000 m between a vessel and a dolphin. Using focal animal sampling, known negative stress behaviours, such as grouping behaviour and an increase in swimming speed, were identified and recorded by marking longitude and latitude co-ordinates. A SOKKIA theodolite (30X, objective aperture - 45 mm, minimum focus - 0.9 m, field of view (at 1000 m) - 1 degree, 30 minutes, or 26 m and resolving power - 3", which gave a range of observations within the harbours and to the heads of up to 2 kilometres) connected to a Palmton PC running the DOS programme T-trak, was used to observe dolphins. A manual was written outlining the procedures to be followed for making observations and volunteers trained accordingly (see Appendix B).



Figure 6: A view looking towards Lyttelton Harbour from the theodolite observation site situated at Lyttelton Quarry. The theodolite site is marked by an arrow.



Figure 7: Timaru Harbour as viewed from the ocean looking towards the observation point at Washdyke. The theodolite site is marked by an arrow.

Observations were made over two days at each site per week for the months October – March 2000-2001 and 2001-2002. The first season began in October 2000 and ended March 2001 and the second season from October 2001 through to March 2002. The

time, date and longitude and latitude co-ordinates were recorded, along with boat types (Table 2), and whether dolphins were present or absent. The theodolite was used to constantly scan the harbour for dolphins, whilst two other observers also scanned the harbour, one using binoculars and one without binoculars. Dolphin behaviour was also recorded both in the presence of boats and in the absence of boats. The theodolite was used to track focal animals and record their behaviour.

Once a dolphin was sighted it was tracked using the theodolite until it disappeared. If several dolphins appeared at one time, the nearest dolphin to the line of sight of the theodolite was marked and followed until it disappeared. Tracking dolphins using a theodolite proved to be difficult, due to the distance over which observations were made, as well as dolphin behaviour in general. For example, it was not possible to track dolphins once they dived. Most observations, therefore, resulted in only one or two location points. However, the data obtained allowed dolphin presence within the harbours to be plotted on ocean charts. Once a focal animal was out of observational view, another dolphin was marked. It was not possible to mark all individual dolphins within a particular group or mark all groups simultaneously, if more than one group were present, due to using only one theodolite. For focal animals that were able to be tracked over time, behaviour data was recorded along with the type of vessel it was associated with.

### **2.3.1 Recording observations**

Both longitude and latitude co-ordinates in relation to the zero reference point were recorded. The time in hours, minutes and seconds of each observation were automatically recorded and downloaded to the palmtop in the field and later transferred to a desktop. An observation period was represented by a continuous amount of time that dolphins were observable. For each observation the following information was recorded: observation period, whether a dolphin or boat was observed, number of dolphins seen, dolphin behaviour (Table 1), and boat type (Table 2). Details about weather and any unusual events of the day were also recorded.

Table 1: Hector's dolphin behaviours recorded and their definitions.

<b>Behaviour</b>	<b>Definition</b>
Bow riding	Swimming at the front of a moving boat which includes surfing or riding on the wave created by the bow of the vessel
Jump/Breach	A leap out of the water, then falling back in to the water head first and sometimes sideways
Group Together	Decreasing proximity within 2 meters of each other, thus forming a tighter group
Milling	Swimming in one direction in a circular motion
Logging	Either laying motionless in the water or slight movement from side to side, as a floating log would do when being moved by waves
Porpoising	Surfacing often only with partial emergence in order to breathe
*Swimming	Movements around the boat in any direction other than directly to or directly away from the boat*
Swim away from boat	Swimming away from the boat at an angle that cannot be considered with or parallel to the vessel
Swim towards boat	Swimming directly to the boat
> swim speed away from boat	Swimming away from the boat at a speed which increases
Tail slap	Lifting the tail out of the water and slapping it down as to cause a splash
Head slap	Lifting the head out of the water and slapping it down as to cause a splash

\*Swimming represents a dolphin that is neither swimming with, away from or towards the vessel, and where the distance from the boat was more than five metres. Swimming also includes swimming in random directions, and changing direction quickly as not to be able to conclusively state direction. This includes sudden movements in direction to and away from the boat, but without commitment, that is not in any one particular direction. Swimming closer than five metres would be recorded as swimming with the boat. Five metres were chosen as dolphins are generally closer than five metres to a boat when swimming and jumping at the bow. Dolphins were observed swimming with the boat at distances of 1 m - 5 m but the ability to see or hear short breaths or long breaths diminished with distance, hence the tendency was to observe dolphins closest to the boat, for the ease of recording breaths and increases in speed which are more difficult to see at greater distances. At both

cliff-top sites, dolphins closest to the theodolite observation site could clearly be heard. An increase in swimming speed was recorded where an obvious and significantly observed increase in speed of an individual dolphin or group of dolphins was observed.

Table 2: Watercraft categories by size and type of motion.

<b>Category</b>	<b>Size of Vessel and Type of Motion</b>
1	Tour operator vessels
2	Small commercial vessels: boats carrying containers and of a size smaller than a dredge
3	Large commercial vessels: boats carrying containers and of a size larger than a dredge
4	Commercial fishing vessel: a range of sizes
5	Small recreational fishing vessels: usually smaller than commercial vessels
6	Recreational power boats: small fast moving power boats including jet skis.
7	Dredges and trawlers: large and slow moving vessels clearing channels for other boat traffic
8	Kayaks, dinghies and small yachts using engines
9	Yachts and dinghies moving under sail

## 2.4 Results

Observations collected from field investigations using a theodolite span more than 376 hours per site, per season. This equated to 92 hours per month over six months conducted at each site.

### 2.4.1 Dolphin Sightings

There was no significant difference in the average numbers of dolphin sighted between years at each site (Lyttelton, ANOVA  $P = 0.72$ ; Timaru, ANOVA  $P = 0.69$ ). Combined seasons data for each site showed there was also no significant difference between the sites (ANOVA  $P = 0.95$ ). The month of greatest dolphin observations, where the dependent variable was mean number of dolphins per month, at Lyttelton was January, and at Timaru during November (Figure 8). There was also no significant difference between the number of morning and afternoon sightings at each site (ANOVA;  $P = 0.27$  and  $P = 0.80$  respectively) combined over the two seasons.

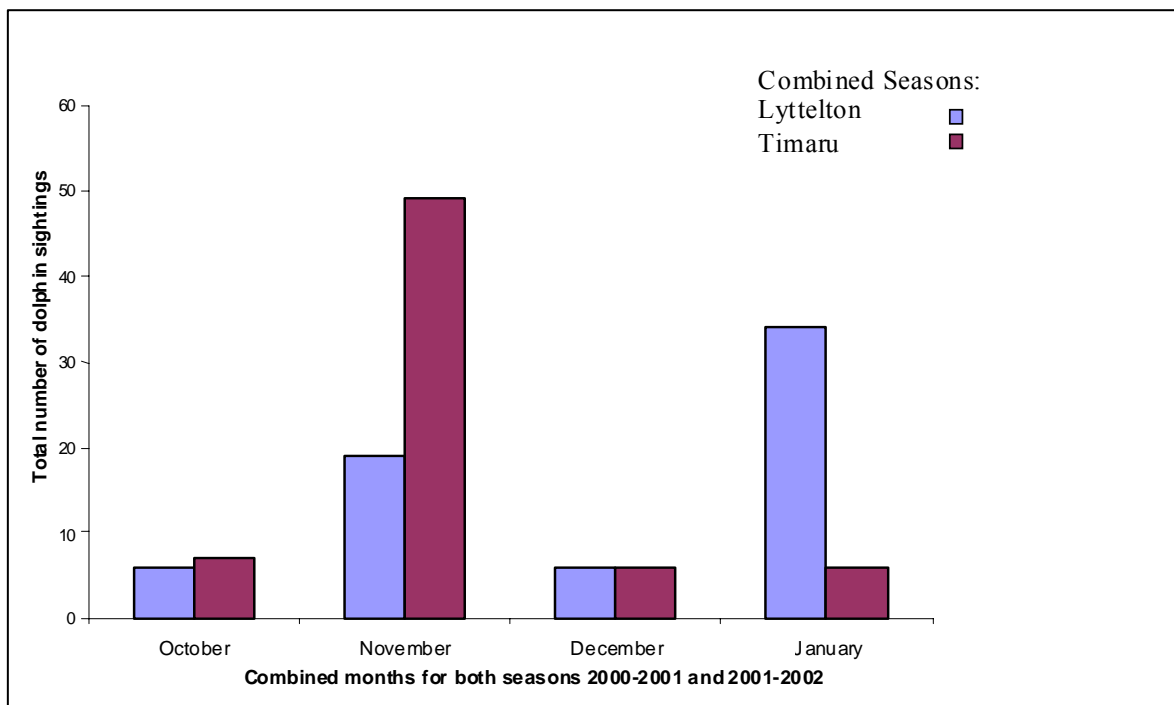


Figure 8: The total number of Hector's dolphin sightings for two seasons at Lyttelton and Timaru. There were more dolphin sightings in November at Timaru and more dolphin sightings at Lyttelton in January than any other month, but overall the numbers of dolphins/month sightings were not significantly different between sites.

## **2.4.2 Ocean Plots – Lyttelton**

At Lyttelton, dolphin presence was found to be most frequent and clustered to the south of a channel which is maintained at 11.7 m by a dredge ( $43^{\circ}36.5'S$   $172^{\circ}46.2'E$ ) between Livingstone and Camp Bays (Figure 9). Dolphins were also observed in an area lying immediately below the theodolite station between Battery Point ( $43^{\circ}36.2S$  and  $172^{\circ}44.7'E$ ) and Golan Bay, as well as within Golan Bay itself ( $42^{\circ}35.9'S$  and  $171^{\circ}45'E$ ). The depth at both these sites is 6 m. On a single occasion a dolphin was observed at the entrance of Livingstone Bay, which has a depth of approximately 6 m.

## **2.4.3 Ocean Plots – Timaru**

Dolphin presence at the site in Timaru was also found to be clustered. More clusters were recorded at Timaru than were observed at Lyttelton. The centre of the two main observed clusters situated at  $43^{\circ}21.8'S$ ,  $170^{\circ}15.8'E$  and  $43^{\circ}22.3'S$ ,  $170^{\circ}15.6'E$  out towards open ocean, with a depth of approximately 4 m (Figure 10).

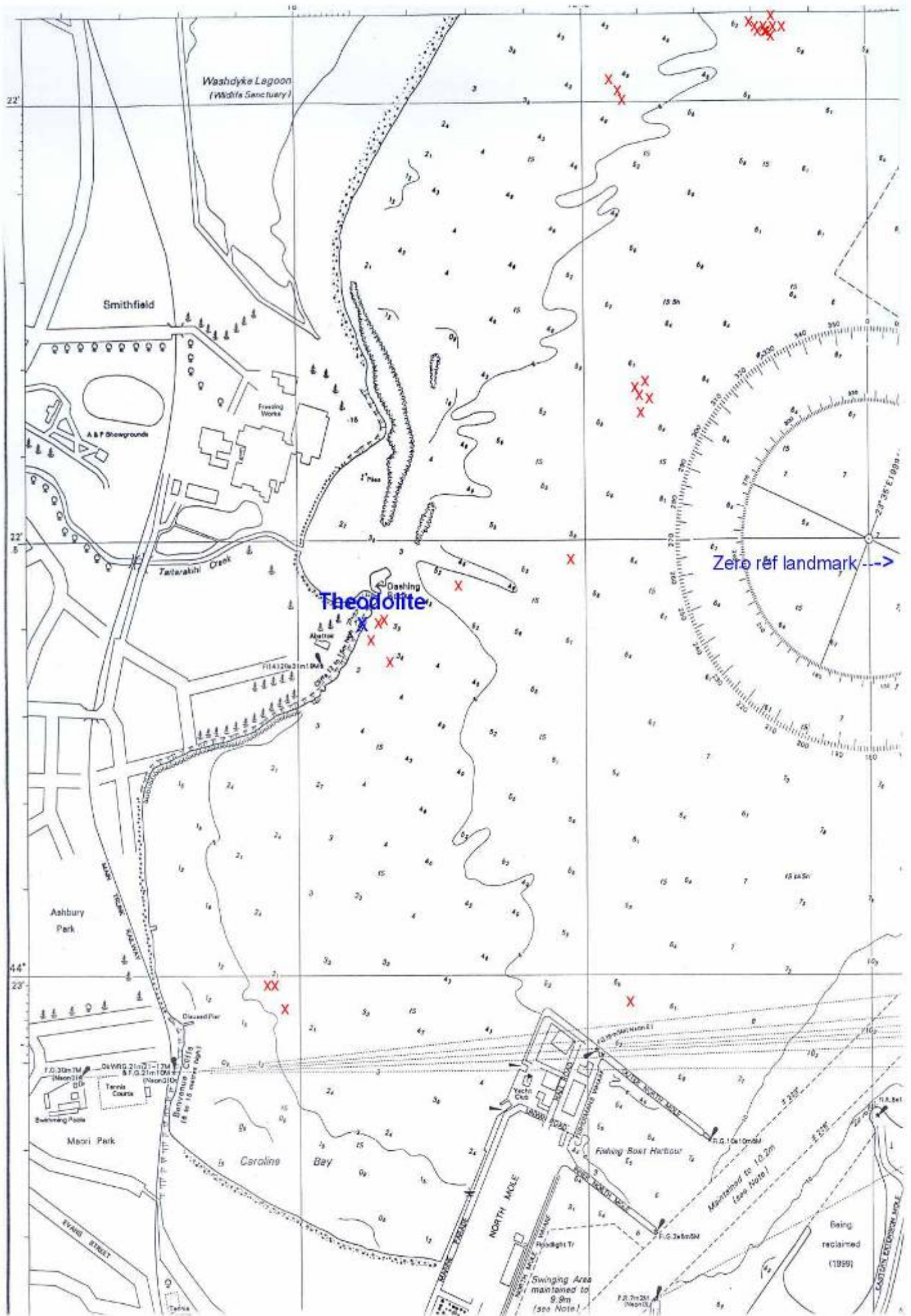




Figure 9 (previous page): Plot of Hector's dolphin presence in Lyttelton Harbour to 2 km from the theodolite station. Each ten observations are plotted and signified with a red cross. The blue crosses indicate the theodolite station and zero reference point.

*Sourced from Land Information New Zealand data. Crown Copyright Reserved.*

Scale: 1: 25 000 m.



Theodolite

Zero ref landmark -->

Figure 10 (previous page): Plot of Hector's dolphin presence in Timaru Harbour up to 2 km from the theodolite station. Each ten observations are plotted and signified with a red cross. The blue crosses indicate the theodolite station and zero reference point.

*Sourced from Land Information New Zealand data. Crown Copyright Reserved.*

Scale: 1: 25 000 m.



More clusters of dolphins were present in Timaru and Lyttelton, and these were observed over more ocean area than observed at Lyttelton. The clusters varied in areas of depth from 2 m within Caroline Bay to 5 m near open ocean. On one occasion a dolphin was observed near to the entrance of the harbour where ocean depth is 6 m. The channel at Timaru is maintained at 10.2 m by the dredge, but no dolphins were observed near the channel. The majority of sightings were observed near the coast line, such as near Dashing Rocks (43°22.6'S, 170°15.3'E) and within Caroline Bay (44°23'S, 170°14.9'E), as well as near the Harbour opening.

#### 2.4.4 Sightings With and Without Boats

There were no significant differences between the number of dolphin sightings with and without boats either between seasons (Season 1, ANOVA P=0.81; Season 2, ANOVA P = 0.57) or sites (Lyttelton ANOVA P = 0.867; Timaru ANOVA P = 0.210) (Figure 11). However, the number of dolphins observed at each site with and without boat presence was significantly dependent on site (ANOVA P = 0.03). There were more dolphins sighted at Timaru than at Lyttelton without boat presence, but more dolphins sighted at Lyttelton than Timaru with boat presence.

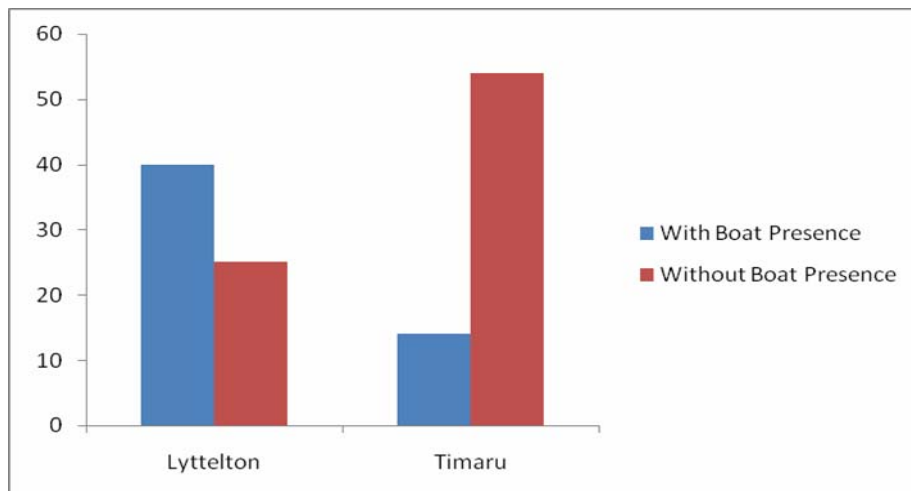


Figure 11: Total number of Hector's dolphin sighted with and without tour boat presence over two seasons at Lyttelton and Timaru. The greatest number of dolphins were seen in Timaru during boat absence, but the greatest number of dolphin sightings were made with boat presence at Lyttelton.

At both sites, Hector’s dolphins were observed with several boat categories (Table 3). Dolphins were not observed to be associated with large commercial ships, dredges or trawlers. They were observed with tour boats and recreational power craft but not jet skis. Dolphins did not associate with commercial fishing ships, yachts under sail, kayaks, dinghies, and small recreational powerboats. No sightings were made with large commercial tankers, the dredge, large groups of recreational education boats or trawlers. Group size also seemed to vary between boat categories with larger groups of dolphins being found near tour boats and small commercial vessels.

Table 3: The mean number of Hector’s dolphin sighted with various watercraft at Lyttelton and Timaru over two years’ observations. Bold figures indicate the type of watercraft that had the greatest number of dolphin observations overall at each site.

	<b>LYTTELTON</b>	<b>TIMARU</b>
<b>Tour Operator</b>	<b>5.1</b>	<b>3.5</b>
<b>Small commercial</b>	3.75	2.75
<b>Recreation power</b>	3	1
<b>Kayak, Dinghy</b>	1.5	0
<b>Large commercial</b>	0	0
<b>Jet skis</b>	0	0
<b>Dredge</b>	0	0
<b>Trawler</b>		
<b>Commercial fishing</b>	1.5	1.6
<b>Yacht under sail</b>	0	0
<b>Fishing recreation</b>	0	0

#### **2.4.5 Behaviour in the Presence and Absence of Boats**

In the absence of vessels at both sites, dolphins were observed to swim, porpoise, and exhibit logging behaviour (Table 4). In the absence of boats at Timaru dolphins also exhibited head slaps, jumps, milling and tail slaps. At Timaru, logging behaviour was also combined with twisting seaweed around in addition to tossing it in the air and diving to retrieve it as it sank. Milling and jumping along with head and tail slaps

were not observed at Lyttelton. ‘The lack of milling behaviour at Lyttelton may indicate dolphins are more stressed at Lyttelton than at Timaru, whereas the lack of jumping behaviour, head and tail slaps may indicate the opposite, that dolphins are less stressed at Lyttelton. Behaviour observed in context may assist in indicating which situation applies. This is investigated further in the next chapter (see Chapter 3).

Table 4: List of behaviours observed in the presence and absence of the Black Cat at Lyttelton and the Caroline Cat at Timaru. Bold letters indicate behaviours in common to both sites overall in respect to tour boat presence and tour boat absence at each site.

<b>Behaviour</b>	<b>Lyttelton</b>		<b>Timaru</b>	
	<b>With boat presence</b>	<b>Boat absent</b>	<b>With boat presence</b>	<b>Boat absent</b>
Bow riding	<b>Y</b>	n/a	<b>Y</b>	n/a
Jump/breach *	<b>Y</b>	N	<b>Y</b>	Y
Grouping together *	<b>Y</b>	<b>N</b>	<b>Y</b>	<b>N</b>
Milling	<b>N</b>	N	<b>N</b>	Y
Logging	<b>N</b>	<b>Y</b>	<b>N</b>	<b>Y</b>
Porpoise	<b>Y</b>	<b>Y</b>	<b>Y</b>	<b>Y</b>
Swimming	<b>Y</b>	<b>Y</b>	<b>Y</b>	<b>Y</b>
Swimming away	<b>Y</b>	n/a	<b>Y</b>	n/a
> speed to open ocean *	<b>Y</b>	<b>N</b>	<b>Y</b>	<b>N</b>
Tail Slap *	<b>N</b>	N	<b>N</b>	Y
Head Slap *	<b>N</b>	N	<b>N</b>	Y

\* Behaviours which have been interpreted as an exhibition of stress or avoidance behaviour where boats are present in previous studies of dolphins. Y indicates that a particular behaviour was observed, where N indicates that a particular behaviour was not. n/a indicates a behaviour that was not-applicable, for example a dolphin is not able to ‘swimming away’ from a boat or bow ride if boats are absent.

Dolphins at Timaru exhibited a greater range of behaviours than at Lyttelton. However, many of the behaviours, such as tail slaps, head slaps, and jumping, were observed for solo dolphins close to Dashing Rocks at Timaru, where the various solo dolphins sighted, remained for a number of hours. At this site solo dolphins were also observed to mill and twist seaweed around their bodies, dive with it and then surface, logging with it still attached. This behaviour was not observed with the theodolite at Lyttelton. An increase in swimming speed to open ocean and grouping behaviour were observed at both sites, and only in the presence of boats.

Some behaviours indicative of stress, such as an increase in swimming speed towards open ocean and grouping together, were observed only when boats were present (Kruse, 1991). Tail slaps and head slaps, which have been deemed indicative of stress due to the presence of boats, were only observed at Timaru and only in the absence of boats.

## **2.5 Discussion**

As eco-tours become increasingly popular, so too does the increase in frequency of interactions between boats and dolphins. The sites chosen for this study represented an opportunity to examine Hector's dolphin populations in areas where dolphins were only just starting to be subjected to increasing interactions with tour boats. Dolphins were equally likely to be observed at both sites. Statistical analysis showed that there were no more chance of sighting a dolphin at one site over the other, although there was a difference in months relating to the greatest number of observations at each site, where January was the month of greatest dolphin observations at Lyttelton and, November was the month of greatest dolphins observations at Timaru. This may be due to respective breeding or calving periods at each site. Overall there were more dolphins sighted without boat presence at Timaru and more dolphins sighted with boat presence at Lyttelton, again, possibly a reflection of the amount of time tour-operations had been conducted, where the dolphins at Lyttelton had become accustomed to the presence of the Black Cat, compared to the relatively naive population of Hector's dolphin at Timaru.



The clusters of dolphin observations at both Lyttelton and Timaru as seen on the ocean charts may be a reflection of the physical, biological and anthropogenic characteristics of the individual Harbours for which Hector's dolphin may have preferred sites. This appears to be the case as shown by the clusters of observations using theodolite tracking. Hector's dolphins exhibit clear preference to location within each harbour, with a greater number of clusters being present at Timaru than at Lyttelton. This may be a reflection of the dolphins at Timaru being less accustomed to the presence of the Caroline Cat than the dolphins at Lyttelton where the Black Cat had been operating for a year longer.

The simple finding that dolphins did interact at each site with boats and that this induced a subset of behaviours tells us little. We need to know if interactions with boats add a chronic stress to the dolphin population. Although the indicator behaviours of stress used in this study have been taken from existing literature they cannot necessarily be deemed to be the result of stress, but nevertheless they formed a basis from which to build the definitions and parameters for this study. Observations of increased swimming speed, short breaths and grouping behaviour do not seem to fit definitions as laid out in existing literature with regard to negative stress. During observations, dolphins swam away from certain watercraft at speed presumably in an attempt to escape, but also exhibited an increase in swimming speed towards other types of watercraft, as well as jumping and taking short breaths. Simultaneously with an increase of speed, jumping and short breaths they swam with or along side watercraft. Therefore, definitions of stress behaviour in dolphins may be species-specific and may need to be placed in context. For example, head and tail slaps, generally thought of as stress-related behaviours, were only observed in the absence of boats and only exhibited by solo dolphins.

A distinction between avoidance behaviour and fear, and behaviour related to play, interest and high energy interaction needs to be made. Stress in Hector's dolphin may fit the descriptions in the general literature under certain specific conditions but cannot be applied at all times. During interaction with tour boats Hector's dolphin increase speed whilst simultaneously taking short breaths and often grouped together. In addition, behaviours that one dolphin exhibits is often exhibited by other dolphins in the group, so two or more individuals are observed jumping together, increasing

speed together and changing direction as a group. As a behavioural trait this may be better described as social chasing or foraging behaviour, or excitement rather than stress, or, alternatively “positive stress”. The same behaviours may be exhibited with the presence of jet skis or fast-moving recreational vessels, but rather than be an indication of excitement or positive stress be indicative of negative stress, which can be determined not only by an increase in swimming speed, grouping behaviour and short breaths but also swimming away from the vessel. Tail slaps and head slaps shown in previous literature to be stress traits can also be viewed in this way. It is not only the behaviour that requires analysis, but the context in which it occurs.

## **2.6 Conclusion**

Theodolite observations are particularly useful in that they allow observations of dolphins without the need for disturbing them and subsequently risk changing their behaviour. For this study theodolite observations were valuable in that they provided information about dolphin behaviour both in the presence and absence of not only tour boats but a variety of other watercraft.

From a management perspective, there is often pressure to limit or regulate boat interactions with dolphins. In this study of two relatively naïve populations, there was no evidence that Hector’s dolphins were avoiding boats in the usual range of those used by tour operators. Behaviours associated with stress in dolphins were not generally seen in the presence of tour boats: the Black Cat at Lyttelton and the Caroline Cat at Timaru. Although tour operations had been conducted at Lyttelton for a year prior to those at Timaru, analysis showed that there was no more chance of sighting a dolphin at Timaru, where the population was newly exposed to tour operator activity, than at Lyttelton, nor was there a significant difference in sighting a dolphin in the morning or afternoon, suggesting that dolphins at either site were stressed with the presence of the respective tour boats. It is important to note that this study was focused on short-term monitoring and does not suggest that there may not be more subtle long term effects from dolphins associating with boats or that this would not change if trips were to become more frequent or longer in duration.

## **2.7 Further Study**

### **2.7.1 Technical Advancement of Theodolite Equipment Which Presents Future Research Opportunities**

The benefit of using a non-invasive method with which to observe animals has become more recognised and as a result has increased its use. Theodolites themselves have become more sophisticated, as too have the programmes that are being developed to record observations, making them an ideal tool to use to make non-invasive observations. Packages that can be utilised alongside theodolites vary from very basic to more advanced.

Non-invasive methods were employed as part of a study investigating behavioural change in the Hawaiian spinner dolphin (*Stenella longirostris*) and showed that the dolphins exhibited spatial differences throughout the day, feeding offshore at night and moving to protected shallow waters during the early morning when they are reported to rest (Delfour, 2007). However, as dolphin based tour operations increased in the local vicinity no real impacts on overall dolphin behaviour were able to be determined (Delfour, 2007). This was primarily due to the study being conducted over three years and including only one month per year; August 2001, 2002 and 2003. I would argue that dolphin behaviour is too complex to be studied over one month per year and three months of observations over a total of 36 months are insufficient to derive any real conclusions with regard to indicting any impacts on dolphin behaviour. Longer term studies should be conducted in order to take in to account the many variables which exist when studying both individual behaviour and social groupings, especially within a habitat which has growing interest for tour operators.

Minke whales in Moray Firth, Scotland (*Balaenoptera acutorostrata*), have been reported to forage for food in the presence of birds rafts, in particular, kittiwakes (*Rissa tidactya*), herring gulls (*Larus argeniatus*), and guillemots (*Uria aalge*) (Robinson, 2007). These birds compete for schooling mackerel (*Scomber scombrus*). Water temperature, and oceanographic changes have been correlated with the migration patterns of mackerel indicating that seasonal and spatial distribution

patterns of the minke whale are possibly directly related to the migration pattern of schooling mackerel, which in turn attract specific bird species and subsequently minke whales (Robinson, 2007). Dusky dolphins (*Lagenorhynchus obscurus*) at Kaikoura in New Zealand have also been reported to have an association with bird species, in particular, the white-fronted tern (*Sterna striata*) (Hawke and Dobinson, 2001). Associations between Hector's dolphin and bird species are also documented (Brager, 1998), but where associations between White-fronted Terns (*Sterna striata*) and Hector's dolphins (*Cephalorhynchus hectori*) were observed only during spring and early summer (Brager, 1998). The number of birds present was found to be positively correlated with dolphin group size and be restricted by the presence of fish species (Brager, 1998). Brager (1998), and Hawke and Dobinson (2001), agree that these associations constitute facultative commensalism and may be advantageous during the breeding season when energetic demands are high.

In view of reported associations between dolphin and bird species which appear to relate directly with schooling fish populations further research using these associations would be useful in regard to Hector's dolphin movements. The clusters of Hector's dolphins as observed using non-invasive theodolite methods from cliff tops at Lyttelton and Timaru (Chapter 2) could be a response to concentrations of Hector's dolphin prey. It would be interesting to plot Hector's dolphin movements month by month in order to determine if clusters of observations exist in particular vicinity for a particular month and whether the pattern of movement occurs and whether such a pattern is related to fish migrations within each Harbour.

In addition, an alternative non-invasive research method would be the simulation tool used in a study to prevent boat and dolphin collisions in the Canary Islands (Delory, 2007). This would be useful in indicating the presence and location of Hector's dolphin that would otherwise be invisible beneath the waters surface, and provide invaluable information about dolphin movements at depth, as well as preventing collisions with watercraft. Simulations currently show a detection range of the order of one kilometre (Delory, 2007), which would be useful in recording dolphin behaviour at distance where dolphin clusters are already known to be present as well as provide information about the presence of dolphins in areas which cannot be seen by looking directly down into water.

## **2.7.2 Packages and Programmes Designed for Recording Theodolite Obtained Data**

The most basic programme to record theodolite data was called Wolitzky's Program after the man who developed it (Gailey and Ortega-Ortiz, 2002). It was a basic HP Desk Calculator which could calculate distances and speeds of bottlenose and dusky dolphins in the South Atlantic (Wursig, 1978). In 1990, a new programme was created by R. Cipriano called T-trak. This programme was the one employed during the pilot study for this research. T-trak uses a basic MSDOS operating system and enables the calculation of distance and swimming speeds of dolphins, but its downfall is that it is only able to run using a basic cartesian co-ordinate system. This was one of the reasons that T-Trak was modified for this study and used to collect data based on longitudinal and latitude co-ordinates for which it is ideally suited.

In 1992, Harold Mills (Cornell University) created a new program which he called Aardvark. This was designed to run on a Macintosh operating system and had wider parameters than T-trak. Aardvark permitted focal animal sampling, collection of orientation data, environmental, distance and speed data collection. It was also designed to run on more modern co-ordinate system such as UTM or Lat. Long. Binary. It also supported the use of both the Topcon and Sokkia model theodolites. However, the data from both T-trak and Aardvark programmes are viewable as text only and cannot be exported or imported into other packages directly for analysis or plotting.

This study collected data using a slightly modified version of Cipriano's T-trak programme, but Aardvark was employed briefly in the second season as a comparison before returning to T-trak primarily in order to standardise methods for both seasons. During the second season correspondence was also entered into with an Australian researcher who was designing a new programme for use with a theodolite, in order to investigate if it could be used in this study.

The programme CYCLOPS was created in Australia by Eric Kniest (2000). CYCLOPS runs in Windows and can utilise imported scanned maps of the area of

observation. Like the basic programmes, it allows distance and speed calculations from data, but it also has the capability of collecting additional data. For example, environmental, group, and real-time data, but again the data collected is only viewable as text. Like Aardvark it runs on a more sophisticated co-ordinate system than T-trak but also supports the use of a greater variety of theodolite models, such as Leica, Sokkia, Nikon and Topcon. An advantage of CYCLOPS is that the programme can record behaviours, and the programmes parameters can be changed. Eric Kniest rewrote part of the programme in order to add more behaviour codes for my study, although CYCLOPS was not used as the principle data collection program.

A more recent development has been Pythagoras, a Window-based programme which uses Visual Basic Programming language allowing more efficient use and rendering it suitable to run with more modern day applications, such as Excel. Unlike the programme's proceeding it, Pythagoras runs using Microsoft Access as the programme's database and it has the capability to exhibit data in several ways, rather than text only. Data collected can be exported or imported to Excel, Access, Text, MATLAB, MapInfo and Surfer making the transfer of data, data input, and subsequent analysis much more efficient. Importing data directly into an application such as Excel would also reduce human data entry errors. Pythagoras also possesses the ability to use GIS maps, non-fixed data, and can record behavioural data as well as provide the basic distance, and speed calculations of the more basic programmes. Furthermore it can be used for focal animal sampling, the collection of group data, and to record environmental details.

Although more sophisticated programmes are becoming available, and allow more aspects to research, the basic programmes still allow for valuable data collection. My study utilised T-trak which had some small modifications in its application to enable recordings of the location of *C. hectori* and their association with certain types of watercraft. It was also used to observe behaviour with and without watercraft presence. The data collected were in text form, but could be transferred to a data file and then later copied into an Excel file. However, dolphin positions had to be manually plotted and some data extrapolated and entered for relevant analysis. In comparison this is a lengthy process that Pythagoras could have done much more efficiently. However, even though T-trak is not as sophisticated as Pythagoras, it still

provides a basis from which to work and collect data which on analysis can show preference of dolphins to particular sites and watercraft. If undertaking research from fresh, the attraction of using a Windows-based package with increased parameters and analysis possibilities would be appealing, along with a more sophisticated model of theodolite, which would reduce some aspects of human error, either in old MSDOS based programmes or manual theodolite set-up.

### **2.7.3 Further Development and Applications of Theodolite Technology**

As theodolite models now exist which are highly sophisticated and can be computerised to perform specific functions, it would be advantageous to apply these to dolphin research as well as to consider their use in other animal research. Computerised theodolites are able to record data itself, leaving the operator free to undertake a different task (Anon, 1999). Other theodolites require little manual setting up or levelling. The Vera Larsen Laser theodolite possesses an automatic levelling laser (Birss, 1997), which reduces the human error factor when levelling the theodolite during initial theodolite set-up. One such theodolite was used in 1996 to determine whether Auckland's Sky Tower was in fact leaning. It was concluded after several weeks of laser theodolite readings that the Sky tower is in fact perfectly straight (The Sunday Star Times, 1996).

The New Zealand Police in 1999 began using similar computerised theodolites equipped with infra-red beams in order to pinpoint areas of interest at crime scenes and crashes. This application produces a map which is to scale and resembles an aerial photograph once complete. This could prove particularly useful in cetacean research to produce accurate movements of dolphins and represent this on an aerial like photograph, thus showing dolphin presence at particular locations to accuracy that many researchers continue to struggle with.

A local company, Trimble, recognised the growing need and applicability of theodolites in an ocean-based area and designed their own packages for data collection. They created a satellite GPS-based programme which allows real-time

monitoring of cetaceans. This programme is Windows-based and works at optimum capacity when applied to laser systems and optical type theodolites (Birss, 1997). The main advantage of a GPS satellite-based system is that observations can be made in any weather and also in the dark (Armstrong, 1996). A problem with cetacean research is that even if equipped with night vision, there remains the limitation with weather: a problem that this more up to date technology can overcome. As it uses the Windows-based operating system, it means that more than one programme can be running at any one time, so data, in theory, could be analysed as it is collected. This package was initially engineered for use in Trimble's navigation Marine Survey Systems, but it could be manipulated to serve researchers in cetacean studies (Armstrong, 1996). The same programmes and technology that are used in building construction and destruction can also be used in ecological and conservation. Previously, Trimble technology provided GPS systems for use in the Gulf War (Birss, 1997), but with some modifications, the same systems could be used to aid research and benefit conservation and add knowledge to areas of habitat, home ranges and behaviour.

#### **2.7.4 Further Opportunities for Study**

Trimble's navigation Marine Survey Systems could also be manipulated to serve researchers in cetacean studies (Armstrong, 1996). GPS systems designed by Trimble technology for use in the Gulf War, could with modification be used to advance conservation research, as well as contribute to knowledge in respect to habitat use, dolphin home ranges and behaviour (Birss, 1997). I would suggest that such technology need not be solely focused on dolphin behaviour or conservation research, nor particularly only focus on marine mammals, but also be modified in order to serve terrestrial wildlife research, in an effort to add to overall ecological and conservation knowledge which spans both marine and terrestrial species.

With technology progressing quickly and allowing data to be collected that was not possible before, new opportunities arise for further research. With the added accuracy and efficiency available, studies of cetaceans which were once thought to be too time-consuming, difficult, and costly are becoming more accessible and possible.



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# **Chapter 3 - Behaviour Changes in *Cephalorhynchus hectori* as a Result of Tour Operator Presence**

## **3.1 Abstract**

Dolphin behaviours were observed aboard the Black Cat at Lyttelton and the Caroline Cat at Timaru. Behaviours were divided into three categories within which there were specific behavioural groupings which were comprised of individual transitional behaviours. Transitional behaviours represented a change from a specific behaviour to another specific behaviour. Behaviour data was collected using both count and time observations. Count data represented the number of times a particular behaviour or sequence of behaviours were observed and time data represented the duration of time over which a particular behaviour or sequence of behaviours occurred. The study showed that it is necessary to observe a range of behaviours to determine context with regard to stress. To report that dolphins exhibit stress a certain number of times or for a certain amount of the time is in itself inconclusive. It is necessary to define stress as either impacting in a negative or positive way, in order to determine any real cause for concern in relation to dolphin behaviour or reproduction. Boat type did not influence the numbers of dolphin observations at either Lyttelton or Timaru, but may have influenced Hector's dolphin responses to boat presence.

## **3.2 Introduction**

Tour operations commenced at Timaru at the end of 1999 with the introduction of the Caroline Cat which focused on taking mainly church and school groups to view Hector's dolphin prior to this study. No research had been conducted with regard to dolphin behaviour at Timaru either in the presence or absence of tour boats or any comparison made with regard to the chance of sighting dolphins at Timaru compared to other New Zealand sites. The Black Cat at Lyttelton commenced dolphin watching tours two years prior and as such serves as an important site for which to compare dolphin behaviour against, in view of the dolphins at Timaru being deemed a relatively naive population with respect to tour boats. The chance of observing a dolphin at Lyttelton and Timaru as well as behavioural differences in the presence of the respective tour vessels was investigated.

### **3.2.1 Stress as a Result of Interacting Factors**

Stress can be the result of many individual factors and are more likely to be the result of two or more interacting factors, as outlined in Chapter one. This makes it difficult to determine an exact cause of any physiological change, although physiological and neurological processes themselves are generally able to be identified by internal chemical reactions or results. Behavioural changes on the other hand are not so clear. Other than where an increase in a stress hormone can be measured, or mortality can be clearly identified and provide evidence of reduced overall fitness of a species, behavioural changes can be subjective and the result of choice of an individual animal and, are therefore more difficult to interpret and quantify. However, there appears to be a clear relationship between stress behaviour and other behaviour within dolphin literature which indicates behaviours such as swimming away from a vessel, especially at speed is stress or avoidance related and milling behaviour, for example, is indicative of relaxed or resting behaviour, but which may also be associated with uncertainty or apparent decision making in dolphins.

### 3.2.2 Definition of Stress

The term 'stress' in this study has been determined from the conclusions reached in existing research, and takes into account stress as relating to energy expenditure, for example, bow riding and avoidance behaviour which includes swimming away from the tour boat. It is also assumed that dolphins have a choice to either avoid boats or interact with them. The problem with some behaviours, such as bow riding, is that they can be viewed as stress, due to a possible change in behaviour from resting or foraging behaviour requiring significantly less energy expenditure, to bow riding, which requires dolphins to spend energy that they may have otherwise had held in reserve. However, expending energy does not necessarily mean dolphins are stressed, which is why it is important to determine context in regard to exhibited behaviours. Bow riding also requires that a dolphin needs to spend energy swimming towards the boat and subsequently bow ride. Because of this, bow riding is difficult to place within any one category of behaviour, as it represents an overall increase in stress yet can also represent, assuming choice is a factor, a positive interaction with a boat. As bow riding is also argued in previous literature to be an energetically beneficial behaviour in that it reduces aerobic expenditure compared to swimming without bow waves, then this behaviour could also be viewed as positive rather than negative stress behaviour. Due to the complexity of placing bow riding within a certain category it would be advisable to include it in two categories of behaviour, an overall stress category, which can also be separated into negative and positive stress, where negative stress includes avoidance behaviours but not bow riding, and positive behaviour includes bow riding and other boat-dolphin interaction behaviours, such as swimming to the boat. This would result in the need for two analyses. One conducted on the basis of overall stress, which includes bow riding and one which is conducted on avoidance behaviour (negative stress behaviours excluding bow riding) and positive stress (association behaviours). Rather than there being a clear definition of stress within this study, stress is defined according to behaviours which occur together. Later these behaviours are separated into avoidance and positive behaviours, giving a total of three behavioural categories to consider in analysis.

### **3.2.3 Behaviours Used to Determine Stress**

The following behaviours were used to identify stress:

1. an increase in swimming velocity away from the boat, which must be present at the same time as either
2. continued swimming away from a boat and/or,
  - breathing short breaths or puffs
  - a reduction in the distance between individual dolphins or grouping behaviour
  - jumping
  - bow riding
  - head or tail slaps.

Other behaviours recorded but not identified as indicating stress include swimming to the boat, swimming with the boat, bow riding, milling, logging, and porpoising.

### **3.3 Aims**

The aims are similar to those in Chapter 2, but where boat-based observations are the means of data collection, rather than cliff-based theodolite observations.

- To determine whether there is a greater chance of sighting Hector's dolphin at one site over the other per month, per season and overall.
- To identify any stress behaviour in Hector's dolphin in the presence of tour boats at Lyttelton and Timaru.

### **3.4 Objectives**

To determine whether dolphins exhibit stress behaviour in the presence of tour boats and determine whether these stress behaviours are wholly negative. The null hypothesis is that dolphins display no stress in the presence of tour boats.

### **3.5 Methods**

A pilot study was conducted during June, July and August 1999 and again in July and August 2000. During this time, data sheets were refined and behaviours noted in order to determine what methodology would best provide behaviour data. Observations included in this study began in September 2000. A total of 48 trips/season per site were undertaken. Trips ranged between two hours and two-and-a-half hours in duration. Observers were trained over several months in order to take accurate behavioural observations aboard the Black Cat at Lyttelton and the Caroline Cat at Timaru. Dates, weather conditions, such as cloud cover, rain, sunshine, and air temperature were recorded. Sea states using the Beaufort scale were also recorded in order to determine if there was a greater chance of observing a dolphin in any particular weather or seas state. The name of the skipper, the duration of the trip were also recorded.

There was a minimum of two observers per trip. One individual searched for a focal animal from an intersection between the bow and portside of the vessel of approximately 180° and the other from the opposite side between the stern and starboard for approximately 180°. The time that observations commenced was recorded as well as the time observations ceased. The estimated number of dolphins sighted at the beginning of each focal observation was recorded and a focal animal randomly chosen for which the duration of each exhibited behaviour was observed and recorded (Table 1).

To address issues of observer or data bias, observers intermittently changed positions so that the one observing from the portside bow intersection changed with the person

making observations on the starboard stern intersection (Figure 12). In addition, data collected by volunteers in the first season were compared to data collected by myself in order to determine any significant differences between directional and quadrant preference data, (directional data:  $P = 0.960$ , quadrant preference:  $P = 0.651$ ). There were no significant differences between the data collected by different observers. Volunteers were initially subject to a rigorous training schedule and continuous data accuracy checks prior to being permitted to take part in data collection used in analysis. Only those volunteers able to record accurate observations were used.

Observations began as soon as the observer sighted a dolphin. Once a focal animal had been chosen its behaviour was recorded until it could no longer be seen. At any one time each observer had one focal animal to observe and record behaviours for. A new focal animal was marked by saying 'new' on the voice recorder. Once the focal animal was no longer visible, observations ceased, either due to the dolphin swimming away to a distance too far to be able to adequately note its behaviour, out of a range of 20 m from the boat, or it dived to a depth out of visibility. The observer then sighted another focal animal and continued to take readings until there were no further dolphins present. After each trip concluded, records from each observation were collated in table form showing the number of dolphins present at the start of each focal observation, the start and end time of each focal animal observation period, and the duration of each behaviour recorded for each focal animal. A record was also made of the number of successful focal animal observations per trip. A successful focal animal observation was one where there were more than three different consecutive behaviours recorded, regardless of the duration of time they occurred over. The data was transferred immediately after every trip onto data sheets. This was done by rewinding the tape and writing down the behaviours as they were spoken along with the time recorded (Appendix C).

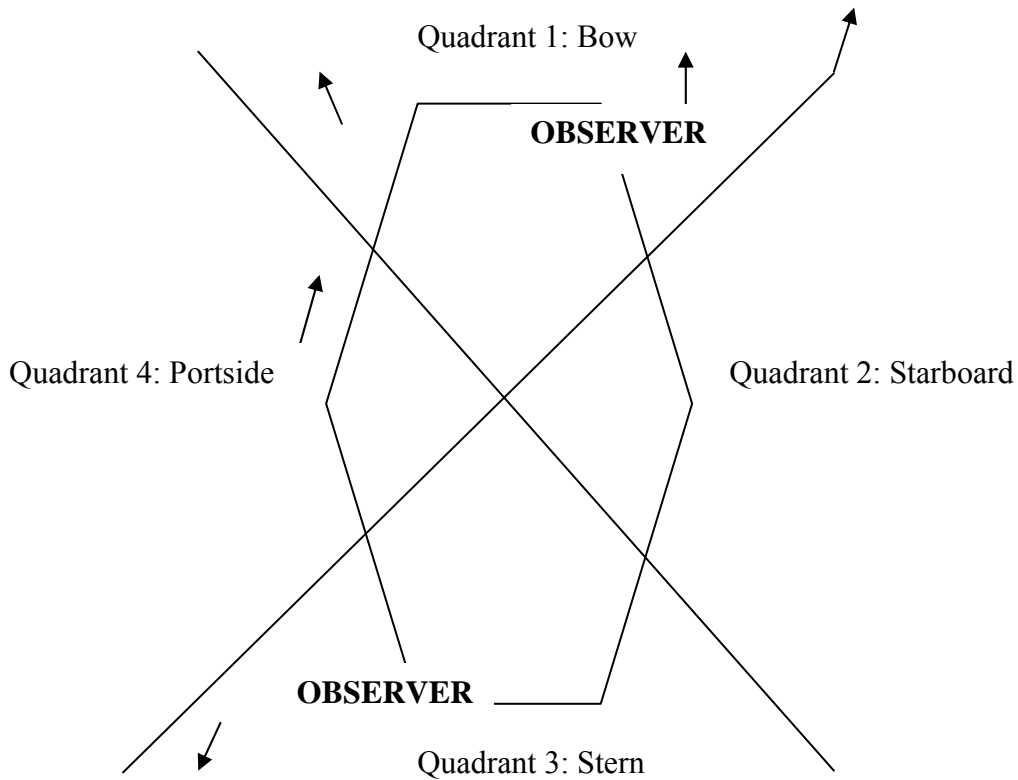


Figure 12: Schematic diagram showing the four quadrants used to mark dolphins approach and departure from the vessel. Quadrant 1: bow, Quadrant 2: starboard, Quadrant 3: stern, Quadrant 4: portside. Each quadrant was approximately 90°. Arrows represent the position and swimming direction of individual dolphins, where the arrowhead shows swimming direction and approximate position relative to the boat. In the above example there are four dolphins represented by arrows. The position of observers at the bow-starboard and stern-portside intersections are also shown. Observers rotated positions between the stern-portside intersection to the bow-starboard intersection or from stern-starboard intersection to the bow-portside intersection.

The number of observations related to a period of time when a dolphin was first sighted to when the last dolphin disappeared from view. Within this observation period there were a number of actual dolphins observed. For example, the first dolphin may be sighted at 1:00 pm. This would be the focal animal from the time it was sighted up until it disappeared from view. A new focal animal would then be chosen and observed until it also disappeared from view. This continued until no more dolphins were present. Therefore, within any one observation period, there were many



actual dolphin observations. The observation period ceased once no more dolphins could be viewed. A new observation period would then commence. An observation period was defined as a period of time where dolphins were continuously present. The time between observation periods ranged from five minutes to eight hours, where eight hours was represented by three successful trips on the same day.

The criteria employed in the previous chapter, including data analysis using Kruskal-Wallis and Friedmans tests, were used in order to determine if dolphins were swimming towards, away from, or with a boat. The Kruskal-Wallis test was used as the primary test to determine any significant differences. The Friedman test, although similar to the Kruskal-Wallis test, was also employed as it allowed further testing in order to determine significant differences that were not shown by the Kruskal-Wallis test. By using the Sum of Ranks values returned by the Friedman test Zars statistical test for  $Q$  could be applied and hence reveal differences which the Kruskal-Wallis test failed to indicate. An example of a behaviour data sheet designed and used to mark dolphin behaviour in tour boat presence is included (Appendix C).

The data from the worksheets were entered into a Microsoft Excel spreadsheet. As the resultant worksheets were significantly large, each season for each site was entered and saved separately. Headings were devised in order to reflect transitional behaviour: a change from one behaviour to another, for example, from porpoising to swimming. As there were 14 behaviours of interest, this resulted in 13 possible combinations per behaviour. For example, bow riding could move on to blow bubbles, breach/jump (Figure 13), long breath, short breath (Figure 15), grouping (Figure 14), logging, milling, porpoising, swimming (Figure 16), swimming away, swimming to, swimming speed increasing or tail/head slap. In addition swimming with, away from or to the boat could also have the precursor '>' to indicate an increase in swimming speed, giving an overall total of 16 possible variations per initial behaviour observed. In total the worksheet had 208 headings for transitional behaviours (excluding date, weather, skipper, site and sea state).



Figure 13: Hector's dolphin jumping, as taken from the Black Cat at Lyttelton Harbour (Black Cat Cruises, 2005).



Figure 14: Hector's dolphin grouping, as taken from the Black Cat at Lyttelton Harbour (Black Cat Cruises, 2005).



Figure 15: Hector's dolphin coming up to breathe as taken from the Black Cat at Lyttelton Harbour (Black Cat Cruises, 2005).



Figure 16: Hector's dolphin swimming as taken from the Black Cat at Lyttelton Harbour (Black Cat Cruises, 2005).

Due to the number of transitional behaviours, of which many had low occurrences, the total numbers of behavioural categories were reduced by combining them. Rather than simply showing one behaviour changing to another (x-x: where x represents one behaviour and the – sign represents a change to another behaviour which is represented by another x). A sequence of behaviours could be shown to move on to another sequence of behaviours (x+x-x+x where x represents a behaviour and + represents the following behaviour and – represents a movement to another sequence of behaviours). For example, the behaviour transition swimming to swimming away (s-sa) and porpoising to swimming away (p-sa) were combined to give swimming or porpoising to swimming away (s/p-sa). As the behaviour could also occur in the opposite direction, swimming away to porpoising (sa-p) and swimming away to swimming (sa-s), this group was combined to become swimming away to swimming or porpoising (sa-s/p). This resulted in sa-s/p and s/p-sa, which were further combined in order to give one overall group of transitional behaviours. Hence what were originally four transitional behaviours, (s-sa, p-sa, sa-s and sa-p) became two (s/p-sa and sa-s/p), and finally combined to form one overall transitional group of behaviours shown as sa-s/p, s/p-sa. Other behaviours were combined in this way, but may have resulted in a greater number of transitions. For example, swimming to the boat, or jumping or swimming with the boat or bow riding to swimming to the boat, swimming with the boat, or bow riding (st/j/sw/br-st/sw/br). The back slash '/' sign indicates 'or', the plus '+' sign indicates 'and', the dash '-' sign indicates 'movement to' and a comma ',' indicates that the behaviour observed also occurred in the opposite direction. In addition the greater than sign '>' indicated an increase in swimming velocity. All count and time data behaviour data were combined accordingly.

Condensing the data resulted in a significant reduction in the number of transitional behaviours, from 208 transitional behaviours to 39 transitional behaviours of which 19 were observed enough to be used in analysis. Due to some transition behaviours at Timaru having low values, the transitional groups were further combined resulting in 33 transitions, which incorporated values and transitions that would otherwise have been excluded. Each transitional behaviour group was assigned to one of three categories: stress, association or neutral behaviour.

The category 'stress' included the behaviour transitions:

- sa>-g, g-sa> swimming away at speed to grouping behaviour
- g-bs, bs-g grouping behaviour to short breaths
- sa>-sb, sb-sa> swimming away at speed to short breaths
- p/s->sa, >sa-p/s porpoising or swimming to an increase in swimming velocity away from the boat
- sa->sa swimming away to increasing swimming away
- s/p-sa, sa-s/p swimming or porpoising to swimming away
- sa-h/t, h/t-sa swimming away to head or tail slaps
- sa-j, j-sa swimming away to jumping
- l/m-sa/s, sa/s-l/m logging or milling to swimming away or swimming
- lb-sa, sa-lb long breaths to swimming away
- bs-bs short breaths to short breaths
- >sa-br increase in velocity swimming away from the boat to bow riding.

Short breaths to short breaths (sb-sb) may not be a true transitional behaviour, but were included in data analysis due to it having occurred enough to warrant inclusion as a behaviour which occurred frequently. Dolphins which increased speed away from the boat and then bow rode did so with another vessel that was near-by.

The category 'association' included any behaviour where dolphins appeared to choose to interact with the vessel, swimming to the vessel, bow riding, and swimming with the vessel. The group behavioural transitions included in the association category were:

- sw->s, >s-sw swimming with the boat to swimming
- bs-st/p, st/p-bs short breath to swimming toward the boat or porpoising
- st/j/sw/br-st/sw/br swimming towards the boat or jumping or swimming with the boat or bow riding to swimming toward the boat or swimming with the boat or bow riding
- st-j, j-st swimming towards the boat to jumping
- s/p->st/st, >st/st-s/p swimming or porpoising to swimming to the boat at at speed or swimming to the boat

- s/p/st+sa-sw swimming or porpoising or swimming towards the boat plus swimming away from the boat to swimming with the boat
- st-sa+st+>st, sa+st+>st-st swimming to the boat to swimming away from the boat plus swimming to the boat plus increasing swimming velocity to the boat
- m-sw, sw-m milling to swimming with boat
- st-lb, lb-st swimming to the boat to long breaths
- br-l/m, l/m-br bow riding to logging or milling
- st-l/m, l/m-st swimming to the boat to logging or milling
- br-lb, lb-br bow riding to long breaths.

The category ‘neutral behaviour’ was any behaviour that did not fall in to either the stress category or the association category. These transitional behaviours include:

- j-s/p, s/p-j jumping to swimming or porpoising
- l/m-lb/l, lb/l-l/m logging or milling to long breaths or logging
- p/s-p/s porpoising or swimming to porpoising or swimming
- p/s-l/lb, lb/l-p/s porpoising and swimming to logging or long breaths
- g-l/m/bl grouping to logging or milling or long breaths
- bs/l-bs short breath or logging to short breath
- sa-st-sw-sa swimming away to swimming toward the boat to swimming with to swimming away from the boat
- p/s-m, m-s/p porpoising or swimming to milling
- j-bl, bl-j jumping to long breath.

Neutral behaviours were exhibited away from the vessel at an estimated 10 m or greater. The behaviours sa-st-sa and sa-sw-st were placed in the neutral behaviour category as it was not clear if dolphins wished to interact with the vessel or leave the vicinity of the vessel. A dash (-) indicated a movement to another behaviour whereas a plus sign (+) indicated that the dolphin performed these behaviours in sequence and then moved on to another behaviour, again indicated by a dash (-) sign. An example would be st-sa+st+>st which indicated that a dolphin was observed swimming to the

vessel, and then performed the following behaviours in sequence: swimming away, swimming to the vessel and swimming to the vessel at increased speed. Another way to write this would have been st-sa-st->st, but this would then have been split into the categories st-sa, sa-st, st->st of which st-sa would have been classed as avoidance, and sa-st, st->st would have been classed as association. As the behaviours were sequential they are treated as a suite and therefore, included only in the association category rather than being split in to two categories, avoidance and association. Suites were determined by the data collected which showed the same suite of behaviour occurring, therefore allowing statistical analysis. Also, as grouping behaviour, short breaths, or more swimming away was not observed, there was no suggestion to indicate that avoidance was being exhibited. A comma indicated that the transitional behaviour observed was also observed in the opposite direction.

Two main data sets were analysed incorporating both count data and time data. For this reason an overview of data manipulation is given first, with a detailed explanation that follows. Count data is the record of the actual number of times a particular transitional behaviour or group of transitional behaviours occurred. Time data represents the duration of time spent exhibiting a particular transitional behaviour or group of transitional behaviours. For example, the number of times stress behaviour occurred was counted to be 370 times overall for the Black Cat, but the total time spent exhibiting stress is equal to 3437 minutes. The count data was analysed using a Log-linear Model and the time data analysed using a General Linear Model (GLM). Both analysis were conducted using Genstat (v. 8.2).

For statistical analysis, count and time data were transformed into means per month and time data log transformed in order to perform a General Linear Model (GLM) test. In addition, the data was further divided into negative and positive stress, association and neutral behaviours where the behaviour groups, association and neutral remained the same, but where the original stress group was separated into two groups, negative and positive stress. This was to show that combining all stress behaviour and placing them into one category, stress, has a major impact on any results obtained and subsequently the conclusions drawn, which in turn may have the potential to effect management decisions. By dividing all stress behaviours into one of two groups, negative or positive stress, rather than grouping all stress together gives a

clearer indication of whether dolphins are more often positively stressed, as indicated by bow riding and interaction with a boat, or whether they are significantly more negatively stressed as indicated by swimming away from a boat at speed.

Negative stress included the following behavioural transitions:

- sa>-g, g-sa> swimming away at speed to grouping
- g-bs, bs-g grouping to short breaths
- p/s-sa>/sa, sa/>sa-p/s porpoising or swimming to swimming away at speed
- sa->sa swimming away to an increase in swimming velocity away from the boat
- sa-h/t, h/t-sa swimming away to head or tail slap
- sa-j, j-sa swimming away to jumping.
- sa>+sb swimming away at speed and short breaths

The category positive stress included those behaviours, which had the transition swimming away present but the behaviour which followed did not indicate or reinforce avoidance behaviour. For example, swimming away followed by swimming away at speed (sa-sa>) was classed as negative stress or avoidance behaviour, whereas swimming away followed by bow riding was placed in the positive stress category. Therefore, the transitional behaviours included in the positive stress category include:

- l/m-sa/s, sa/s-l/m logging or milling to swimming away or swimming
- sa-lb, lb-sa swimming away to long breath
- sa-br, br-sa swimming away to bow riding.

Some of the data sets had numbers too low to enable robust statistical analysis the negative and positive categories were further refined to give the following transitional behaviour groups:

Negative Stress

- g-sa, sa-g grouping to swimming away
- sa>-sb, sb-sa> swimming away at speed to short breath
- sa-sa/>sa swimming away to swimming away or increase an



- sa-p/s increase in swimming velocity away from the boat swimming away to porpoising or swimming.

#### Positive Stress

- g+sa-sb+tb+wb grouping and swimming away to short breath and swimming toward the boat and swimming with the boat
- sa-lb, lb-sa swimming away to long breath
- g+sa-tb/br grouping and swimming away to swimming towards the boat and bow riding.

Further to this analysis, data were combined to reflect only avoidance behaviour, positive behaviour and neutral behaviour. The previous category, stress, association and neutral behaviour (SAN) included total stress within the stress group, whereas the category, negative stress, positive stress, association and neutral behaviour separated the stress behaviour group into two (NPAN). It is possible that an analysis of total stress versus association and neutral behaviours would provide a result indicating that dolphins are stressed a significant amount of time, whereas dividing the group into negative and positive stress may produce a different result, and may indicate that dolphins are stressed a significant amount of time, but that this is not greater for negative stress than positive stress, association or neutral behaviour. Data was further organised to give the category, avoidance, positive and neutral behaviour (APN). For this, positive stress and association behaviour were combined to give the category positive behaviour. The avoidance category is equivalent to the negative stress category above, positive behaviour is equivalent to the combination of positive stress and association behaviour and the neutral category remains the same. This was undertaken for both the count data and time data. Accordingly, both time and count data sets were analysed using SAN, NPAN and APN categories.

### 3.5.1 Categories of Behaviours

1. Stress, association and neutral behaviour (SAN), includes all stress-related behaviour such as swimming away from a tour boat, an increase in swimming speed

away from the tour boat, short breaths, bow riding, and grouping behaviour within the stress group. Jumping behaviour, head slaps, tail slaps and long breaths were also included in stress so long as they occurred along with avoidance behaviour, such as swimming away from the boat. Each behaviour taken individually is not believed to be indicative of stress but is required to be viewed in relation to the behaviour that follows or is before it in order to be considered stress. Long breaths followed by swimming away are therefore, considered stress, as too are jumps followed by swimming away. Association behaviour includes behaviours swimming towards or swimming with the boat. This included dolphins which swam around the vessel and under it. Neutral behaviour consisted mainly of milling, logging, or general swimming and porpoising behaviours that were not able to be placed in either the stress or association categories. Neutral behaviours also included grouping behaviour so long as logging or milling or long breaths occurred after the grouping behaviour, and swimming away from the boat was not observed either prior to or after any of these behaviours.

2. Negative stress, positive behaviour, association behaviour and neutral behaviour (NPAN) included avoidance behaviours within the negative behaviour group. This included combinations of grouping, swimming away, or swimming away at speed behaviours. Positive behaviour included sequences of behaviour which ceased with dolphins swimming with the boat regardless of whether the behaviour prior was swimming away and grouping behaviour. If the sequence of behaviour ceased with interaction in the form of bow riding or swimming with the boat, it is placed in the association group. The neutral behaviour group was consistent throughout the categories.

3. Avoidance, positive and neutral behaviour (APN) included the avoidance behaviours as per the negative stress behaviour group above, where the positive behaviour group is a combination of both the positive behaviour and association behaviours, and the neutral behaviour group remained the same. Furthermore, individual analysis on particular transitional behaviours within each of the groups which make up a category was conducted to determine any differences between transitional behaviours exhibited per seasons per site. This was done for both x-x transitional behaviours and also x+x-x+x grouped behaviours. The final categories

were i) stress, association and neutral behaviour (SAN), ii) negative stress, positive behaviour, association and neutral behaviour (NPAN) and, iii) avoidance, positive and neutral behaviour (APN). Accordingly, both time and count data sets were analysed using SAN, NPAN and APN categories. A breakdown of the specific analysis conducted on each data set now follows beginning with count data.

### **3.5.2 Count Data**

Non-parametric tests were used to determine if there was a greater chance of observing dolphins at Timaru or Lyttelton, the number of observations per site were compared per month, per site, and for each season, then the total number of observations per season per site was analysed to determine if there were any greater chance of sighting a dolphin in either Season 1 or Season 2 per site. The overall number of observations for combined seasons per site were analysed in order to determine if there were any overall difference in observation success per site. The number of observations for stress, association and neutral behaviours per site per month per season for the Black Cat and Caroline Cat were analysed to determine if there were any differences per month, per season for each site.

A Chi-Square test of independence was used on the data for combined seasons per site to determine any difference between stress, association or neutral behaviour. The same test was employed to determine any difference between seasons and the number of times a behaviour was observed for the Black Cat and the Caroline Cat. A Chi-Square test was used to determine if certain stress behaviours occurred more frequently in one season or another by using the number of observations versus the individual behavioural transitions within the category stress. This was also undertaken for association and neutral behaviours. These tests were performed again on each of the behavioural groups within the SAN category - stress, association and neutral behaviour where the transitional behaviours were further grouped for the purpose of statistical strength: some of the values between some transitions were so low as to be excluded from the initial analysis could now be included. Both results are included here in order to show that there was no compromise with the outcome of results.

The stress behavioural group was then broken down into two sub-groups, negative stress and positive stress, and the overall time spent exhibiting these behaviours calculated. The association and neutral behavioural groups remained the same. The total number of observations for combined seasons per site for negative and positive stress, association and neutral behaviours were tested, as were any difference between sites Black Cat (Lyttelton) and the Caroline Cat (Timaru).

Using a Chi-Square test of independence, the behaviours which made up each category were tested in order to show any changes over seasons in transitional behaviours. This was conducted for the behavioural group negative stress versus season for the Black Cat and Caroline Cat as per the original transitional behaviours within the stress group and then the re-grouped transitional behaviours which included those values which were initially too low to be analysed. A Chi-Square test for changes between seasons and sites for positive stress was also undertaken. The association and neutral behaviours remain unchanged. The behavioural groups positive stress and association behaviour were then combined in order to reflect three new behavioural groups giving the category APN: avoidance, positive behaviour and neutral behaviour. The overall totals for combined seasons per site were tested for differences, as were any differences between seasons for the Black Cat and Caroline Cat. A brief summary of results is presented. The data was then recalculated using duration of time (see below) for each behaviour rather than the number of times a behaviour was counted to occur.

### **3.5.3 Time Data**

Time data was also split into three main data sets. The first data set reflects all stress behaviour exhibited, association behaviour and neutral behaviour. Stress behaviour meets the criteria of having at least two of the following behaviours included in a transitional behavioural group:

- an increase in swimming velocity away from the boat, which must be present at the same time as either
- swimming away from a boat and or,
  - breathing short breaths or puffs

- a reduction in the distance between individual dolphins or grouping behaviour
- jumping
- head or tail slaps

Association behaviour included bow riding, swimming to the vessel, and swimming with the vessel. Neutral behaviour included logging, milling, long breaths and general behaviours which cannot be attributed to stress or avoidance.

The total amount of time in minutes was tabulated for each behaviour category for the combined seasons per site, along with the mean amount of time per month, per site, per season dolphins spent exhibiting behaviour which fell into each category. A General Linear Model test was undertaken to determine any significant difference between stress, association and neutral behaviour versus site, season or month at each site. The three factors in the model were site, season and month. The dependent variable was the mean number of minutes per observation per month. Using a Chi-Square test of independence the behaviours which made up each category were tested in order to show any changes over time in behaviour. This was conducted for stress versus season for the Black Cat and Caroline Cat, association and neutral behaviours.

The stress behavioural group was then broken down into two sub-groups, negative stress and positive stress, and the overall time spent exhibiting these behaviours calculated. The association and neutral behaviour groups remained the same. For the purpose of analysis, the mean duration of time in minutes per month, per site, per season spent exhibiting behaviour within the behaviour groups, negative, positive, association and neutral behaviours was tabulated. The same General Linear Model test was applied to test for changes between negative stress, positive stress, association behaviour and neutral behaviour. Using a Chi-Square test of independence, the behaviours which made up each category were tested in order to show any changes over time in transitional behaviours. This was conducted for the behaviour group negative stress versus season for the Black Cat and Caroline Cat, and positive stress per site per season. The association and neutral behaviour groups remain unchanged.

Negative stress was then renamed avoidance behaviour as this behaviour group included only transitional behaviours which led to dolphins swimming away from or avoiding either vessel. Positive stress was combined with association behaviour and included all the behaviour from the association category as previously, but also those behaviours which were originally in the stress group, and which moved to the positive stress category. These were any behaviour where dolphins were swimming with the vessel or bow rode regardless of whether the previous behaviour indicated avoidance. For example, a dolphin that swam away from the boat but then changed direction to the boat and began to bow ride were placed in the positive behaviour group. The neutral behaviour group remained unchanged.

The total number of minutes and the percentages to which this equated in relation to dolphins exhibiting avoidance, positive and neutral behaviour over the whole study were calculated and this was also broken down into time and percentage of time per season per site. Data were log-transformed and a General Linear Model (GLM) applied to determine if there were any differences in avoidance, positive and neutral behaviour between sites, months, seasons and whether there were any interacting factors. A brief summary of results is presented.

## **3.6 Results**

There were a total of 313 observation periods for both seasons at Lyttelton, where 1577 individual dolphin observations were recorded. There were a total of 126 observation periods for both seasons at Timaru, where 526 individual dolphin observations were recorded. This was equivalent to 422 hours of successful observations at Lyttelton and 32 hours of successful observations at Timaru.

### **3.6.1 Count Data: Number of dolphins**

A Friedman test on the number of observations per month based on seven blocks (months) of four treatments (seasons: 2 seasons per site) per site returned no

significant difference ( $P = 0.307$ ). Accordingly, there was no greater chance of sighting a dolphin at either site for any month in either season (Appendix D, Table 5).

A Kruskal-Wallis one-way analysis of variance on the number of observations per season per site also showed that there was no greater chance of sighting a dolphin at either site for either season ( $P = 0.244$ ) (Appendix D, Table 6). A Kruskal-Wallis one-way analysis of variance on the overall number of observations per site also returns no significant difference ( $P = 0.490$ ). There is no greater chance of sighting a dolphin at either site in either season (Appendix D, Table 7).

### 3.6.2 Count Data: Number of observations

The number of observations per site, per month per season for the group behaviours within the category SAN indicated that dolphins exhibited association behaviour most often for both sites for both seasons (Appendix D, Table 8).

A Chi-Square test of independence shows there was a significant difference between the overall numbers of observations versus total stress, association and neutral behaviours ( $\chi^2 = 15.622$ ,  $DF = 2$ ,  $P = 0.001$ ). In relation to the overall numbers of observations at Timaru aboard the Caroline Cat, there were more stress behaviours observed and less association behaviours observed than would be expected (Table 9).

Table 9: Total number of Hector's dolphin observations for combined seasons per site for stress, association and neutral behaviours (SAN). Bold figures indicate a significant difference in regard to behaviours exhibited in relation to behaviour which was expected.

Site	Stress	Association	Neutral
Black Cat	370	771	320
Caroline Cat	<b>129</b>	<b>166</b>	103

Table 10: Total number of Hector’s dolphin observations per season for the Black Cat in relation to stress, association and neutral behaviours (SAN). Bold figures indicate a significant difference in regard to behaviours exhibited in relation to behaviour which was expected.

Site	Stress	Association	Neutral
Black Cat S1	254	547	255
Black Cat S2	116	224	<b>65</b>

A Chi-Square test of independence using the number of observations versus stress, association and neutral behaviour shows that there was a season difference in neutral behaviour between Season 1 and Season 2 ( $\chi^2 = 11.882$ , DF = 2, P = 0.003). In relation to the overall number of observations there are less neutral behaviours observed in Season 2 at Lyttelton aboard the Black Cat than would be expected (Table 10).

Table 11: Total number of Hector’s dolphin observations per season for the Caroline Cat in relation to stress, association and neutral behaviours (SAN).

Site	Stress	Association	Neutral
Caroline Cat S1	84	100	62
Caroline Cat S2	45	66	41

A Chi-Square test of independence using the number of observations versus stress, association and neutral behaviours shows no significant change between behaviours exhibited between seasons aboard the Caroline Cat ( $\chi^2 = 0.884$ , DF = 2, P = 0.643) (Table 11).



Table 12: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviours which make up the stress, association and neutral behaviour category (SAN). Bold figures indicate a significant difference in regard to specific transitional behaviours which were exhibited per season per site in relation to transitional behaviours which were expected.

Stress behaviour								
Site/Season	Sa>-sb, sb-sa>	Sa-sb/g	>sa-p/s, p/s->sa	Sa->sa	s/p-sa	Lb-sa	Bs-bs	sa-br and br-sa
Black Cat Season 1	<b>19</b>	11	<b>22</b>	<b>72</b>	103	9	11	3
Black Cat Season 2	<b>0</b>	18	<b>65</b>	<b>13</b>	64	1	18	5
Caroline Cat Season 1	10	10	<b>2</b>	12	29		4	9
Caroline Cat Season 2	1	1	<b>9</b>	9	9		4	3

Association						
Site/Season	Bs-st, st-bs	Br/j/sw-br/j/sw	St-j, j-st	s/p-st, st-s/p	St/sa-sw, sw-sa/st	St-sa, sa-st
Black Cat Season 1	25	102	8	250	<b>64</b>	78
Black Cat Season 2	<b>25</b>	<b>73</b>	2	80	<b>5</b>	31
Caroline Cat Season 1		52	5	95	41	71
Caroline Cat Season 2		15	3	20	<b>1</b>	17

Neutral					
Site/Season	j-s/p, s/p-j	l/m-lb/l	p/s-p/s	p/s-l/lb	s/p-m
Black Cat S1	5	9	140	57	
Black Cat S2	<b>8</b>	0	46	8	
Caroline Cat S1	8	2	42	6	3
Caroline Cat S2	6	4	15	4	7

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category stress showed there was a difference between swimming away and short breaths (sa>-sb), swimming away and porpoising/swimming (sa-s/p), and swimming away and swimming away at speed (sa-sa>) for data collected on board the Black Cat ( $\chi^2 = 92.700$ , DF = 7, P < 0.001). In relation to the overall number of observations there were more swimming away-short breath (sa-sb), swimming away-porpoising/swimming (sa-p/s) and swimming away-swimming away (sa-sa) observations in Season 1 than would have been expected. There were lower than expected observations of swimming away-short breaths (sa-sb) and swimming away-swimming away (sa-sa) than were expected in Season 2 and lower swimming away-porpoising/swimming (sa-s/p) than would be expected for Season 1. The data set from on board the Caroline Cat exhibited a difference ( $\chi^2 = 21.607$ , DF = 6, P = 0.001) with less porpoising/swimming-swimming away (p/s-sa) in Season 1 and more porpoising/swimming-swimming away in Season 2 than would be expected (Table 12).

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category association shows there was a difference between seasons and some behavioural transitions for the Black Cat ( $\chi^2 = 44.278$ , DF = 5, P = 0.001). In relation to the overall number of observations there were more swimming to or swimming away-swimming with (st/sa-sw) observations in Season 1 than would have been expected. There were more than expected observations of short breaths-swimming to/porpoising (bs-st/p), and bow riding/jumping/swimming with- bow riding/jumping/swimming with (br/j/sw-br/j/sw) than were expected in Season 2 and lower swimming away-swimming with (sa-sw) than would be expected for season 2. The data collected on board the Caroline Cat showed a difference ( $\chi^2 = 10.177$ , DF = 4, P = 0.038) with less swimming away-swimming with (st/sa-sw) in Season 2 than would be expected (Table 12).

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category neutral showed there was a difference between seasons and some behavioural transitions for the Black Cat ( $\chi^2 = 32.140$ , DF = 4, P = 0.000). In relation to the overall number of observations, there were less jumping-swimming/porpoising (j-s/p) behaviour observed in Season 2 than

would have been expected. The Caroline Cat exhibits no ( $\chi^2 = 9.960$ , DF = 4, P = 0.041) significant change in behaviours between seasons than would be expected (Table 12).

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category stress shows there was a difference between grouping, swimming away, short breaths to short breaths and swimming to the vessel (g+sa+bs-sb+tb) and swimming away to swimming away at speed (sa->sa) for the Black Cat ( $\chi^2 = 31.745$ , Df = 6, P < 0.001). In relation to the overall number of observations there were more g+sa+bs-sb+tb and less sa->sa observations in Season 2 than would have been expected. The Caroline Cat showed no difference ( $\chi^2 = 5.041$ , DF = 6, P = 0.0539). However, before transitional behaviours were broken down into the above groups, both the Black Cat and Caroline Cat exhibited differences (Table 13).

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category association showed there was a difference between seasons and some behavioural transitions for the Black Cat ( $\chi^2 = 52.375$ , Df = 5, P = 0.001). In relation to the overall number of observations there were more short breaths to swimming to the boat and swimming with the boat (bs-st+sw), and more bow riding and jumping to jumping and bow riding (br-j, j-br) than expected for Season 2 for the Black Cat, and less swimming away to swimming to and swimming with the boat (sa-st+sw), and less swimming or porpoising to the boat (s/p-st) than expected in Season 2. In Season 1, there were less than expected changes from short breaths to swimming to, to swimming with the boat (bs-st+sw), and more swimming away to swimming to and with the boat (sa-st+sw) than expected. The Caroline Cat also exhibited a significant difference ( $\chi^2 = 37.349$ , DF = 5, P = 0.000) with less short breaths to swimming to and swimming with the boat in Season 1, but more than expected in Season 2 (bs-st+sw). There was also less than expected swimming or porpoising to swimming to the boat than expected in Season 2 (s/p-st, st-s/p) (Table 13).

Table 13: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviours which make up the ‘stress’ group within the stress, association and neutral behaviour category (SAN). Bold figures indicate a significant difference in regard to specific transitional behaviours which were exhibited per season per site in relation to transitional behaviours which were expected.

Stress behaviour							
Site/Season	g-sa, sa-g	Sa>-sb, sb-sa>	g+sa+bs-sb+tb	p/s->sa	sa->sa	g+sa-tb+br	lb-sa
Black Cat Season 1	43	11	11	98	72	7	9
Black Cat Season 2	13	8	<b>18</b>	63	<b>13</b>	3	1
Caroline Cat Season 1	3	11	10	31	12	7	10
Caroline Cat Season 2	1	4	<b>1</b>	18	<b>9</b>	5	7

Association						
Site/Season	bs-st+sw	br+j-j+br	st-j, j-st	s/p-st, st-p/s	sa-st+sw	sa-st
Black Cat Season 1	<b>50</b>	113	8	234	<b>64</b>	78
Black Cat Season 2	<b>50</b>	<b>70</b>	2	<b>66</b>	<b>5</b>	31
Caroline Cat Season 1	<b>0</b>	22	5	35	25	13
Caroline Cat Season 2	<b>17</b>	6	3	<b>9</b>	21	10

Neutral					
Site/Season	j-s+p, s+p-j	l/m-lb-lb-l/m	p/s-p/s	p/s-l/lb	s/p-m
Black Cat Season 1	12	9	150	67	17
Black Cat Season 2	15	0	42	8	0
Caroline Cat Season 1	8	2	42	6	4
Caroline Cat Season 2	6	4	15	6	<b>10</b>

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category neutral showed there was a difference between seasons and some behavioural transitions for the Black Cat ( $\chi^2 = 31.947$ , Df = 4, P = 0.000). In relation to the overall number of observations there were less jumping-swimming/porpoising (j-s/p) observed in Season 1 but more than expected in Season 2. The Caroline Cat showed a difference between seasons with Season 2 having more than expected swimming or porpoising to milling behaviour (s/p-m) ( $\chi^2 = 12.554$ , DF = 4, P = 0.014), showing a significant change in behaviours between seasons than would be expected (Table 13).

### 3.6.3 Count Data – Negative and Positive Stress, Association and Neutral Behaviour (NPAN)

The number of observations per site, per month per season for the group behaviours within the category NPAN indicated that dolphins exhibited association behaviour most often for both sites for both seasons (Appendix D, Table 14).

Table 15: Total number of Hector’s dolphin observations for combined seasons per site for negative and positive stress, association and neutral behaviours (NPAN). Bold figures indicate a significant difference in regard to behaviours exhibited in relation to behaviour which was expected.

Site	Negative stress	Positive stress	Association	Neutral
Black Cat	321	<b>49</b>	771	320
Caroline Cat	89	<b>40</b>	166	103

A Chi-Square test of independence using the number of observations versus negative stress, positive stress, association and neutral behaviour shows that there was a site difference for positive and negative stress ( $\chi^2 = 39.088$ , DF = 3, P = 0.001). In relation to the overall number of observations, there is less positive stress shown for the Black Cat but more positive stress observed at Timaru aboard the Caroline Cat than would be expected and less association behaviour exhibited at Timaru observed aboard the Caroline Cat than would be expected (Table 15).

Table 16: Total number of Hector’s dolphin observations per season for the Black Cat in relation to negative and positive stress, association and neutral behaviours (NPAN). Bold figures indicate a significant difference in regard to behaviours exhibited in relation to behaviour which was expected.

Site	Negative stress	Positive stress	Association	Neutral
Black Cat S1	224	27	547	255
Black Cat S2	97	<b>22 (+)</b>	224	<b>65 (-)</b>

A Chi-Square test of independence using the number of observations versus negative stress, positive stress, association and neutral behaviour shows that there was a season difference in neutral behaviour between Season 1 and Season 2 ( $\chi^2 = 17.553$ , DF = 3, P = 0.001). In relation to the overall number of observations there are less neutral behaviours observed in Season 2 at Lyttelton aboard the Black Cat and more positive stress occurrences observed in Season 2 than would be expected (Table 16).

A Chi-Square test of independence using the number of observations versus negative stress, positive stress, association and neutral behaviour showed no significant change between behaviours exhibited between seasons for the Caroline Cat ( $\chi^2 = 1.024$ , DF = 3, P = 0.795) (Appendix D, Table 17).

When using the initial behaviour transitions (Appendix D, Table 18) a Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the group negative stress showed there was a difference between seasons and some behavioural transitions for the Black Cat ( $\chi^2 = 49.035$ , Df = 7, P = 0.000). In relation to the overall number of observations there were more swimming away at speed – short breaths (sa>sb), more short breaths/swimming away-short breaths/grouping (bs/sa-bs/g), more swimming away-jumping (sa-j) and more long breaths-swimming away (lb-sa) than would have been expected in Season 2. Season 2 for the Black Cat also indicated that there were less porpoising/swimming-swimming away (p/s-sa), less swimming away-swimming away (sa-sa) and less short breath short-breath short (bs-bs) than would have been expected (Appendix D, Table 18). When grouping the behavioural transitions further the results were:

Table 19a: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviour which make up the ‘negative stress’ category (NPAN). Bold figures indicate a significant difference in regard to transitional behaviours exhibited in relation to transitional behaviour which was expected per site per season.

	Negative stress			
Site/season	g-sa,	sa>+sb,	sa-sa,	>sa/sa-p/s,
Black Cat S1	43	11	72	98
Black Cat S2	13	8	<b>13 (&lt;)</b>	<b>63 (&gt;)</b>
Caroline Cat S1	3	11	12	31
Caroline Cat S2	1	4	9	18

Table 19b: Total number of Hector’s dolphin observations per season per site for the individual transitional behaviour which make up the ‘positive stress’ category (NPAN). Bold figures indicate a significant difference in regard to transitional behaviours exhibited in relation to transitional behaviour which was expected per site per season.

Positive stress			
Site/Season	g+sa- sb+tb	sa-lb,	g+sa-tb+br
Black Cat S1	11	9	7
Black Cat S2	18	<b>1</b>	3
Caroline Cat S1	23	7	10
Caroline Cat S2	18	3	3

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category negative stress showed a difference between seasons and some behavioural transitions for the Black Cat ( $\chi^2 = 17.618$ , DF = 3, P = 0.001). In relation to the overall number of observations there were more swimming away to short breaths (sa-sb), and less swimming away to

swimming away (sa-sa) behaviour than would be expected for Season 2. The Caroline Cat showed no significant change ( $\chi^2 = 1.218$ , DF = 3, P = 0.749) (Table 19a).

Within the positive stress group less swimming away to long breaths (sa-lb) was observed for Season 2 for the Black Cat ( $\chi^2 = 9.276$ , DF = 2, P = 0.010). The Caroline Cat showed no significant changes in positive stress over the two seasons ( $\chi^2 = 2.111$ , DF = 2, P-Value = 0.348). However, the numbers of recorded positive stress occurrences are much higher at Timaru aboard the Caroline Cat than are indicated at Lyttelton aboard the Black Cat (Table 19b).

### **3.6.4 Count Data: Avoidance, Positive Behaviour and Neutral Behaviour (APN)**

A Chi-Square test showed no significant difference between the Black Cat and Caroline Cat in relation to avoidance behaviour, positive behaviour and neutral behaviour. ( $\chi^2 = 3.276$ , DF = 2, P-Value = 0.194), (Appendix D, Table 20)

A Chi-Square test showed a significant difference between Black Cat observations in Season 1 and those in Season 2 in relation to avoidance behaviour, positive behaviour and neutral behaviour ( $\chi^2 = 11.806$ , DF = 2, P-Value = 0.003) with less neutral behaviour observed in Season 2 than would normally be expected (Appendix D, Table 21). There was also no significant difference between Caroline Cat observations in Season 1 and Season 2 in relation to avoidance behaviour, positive behaviour and neutral behaviour, ( $\chi^2 = 0.3.04$ , DF = 2, P-Value = 0.859), (Appendix D, Table 22).



Table 23a: A brief summary of the behaviour transition results including the number of changes within each transitional group behaviour and whether that change was an increase ‘>’ or decrease ‘<’ in the overall number of transitional behaviours for a particular season (S1: Season 1, or S2: Season 2).

Stress, Association and Neutral Behaviour (SAN)							Negative Stress, Positive behaviour and Neutral behaviour (NPAN)								
	Lyttelton			Timaru				Lyttelton				Timaru			
Test	Stress	Association	Neutral	Stress	Association	Neutral	Negative stress	Positive Behaviour	Association	Neutral	Negative stress	Positive Behaviour	Association	Neutral	
Overall BC v CC	No change	No change	No change	>	<	No change	No change	<	No change	No change	No change	>	<	No change	
BC S1 v BC S2 CC S1 v CC S2	No change	No change	< S2	No change	No change	No change	No change	>S2	No change	<S2	No change	No change	No change	No change	
x-x stress	3>S1 1<S1 2<S2			1<S1 1>S2			4>S2 3<S2				No change				
x-x association		2>S2 1<S2			1<S2										
x-x neutral			1<S1			No change									
x+x-x+x stress	1>S2 1<S2			No change			1>S2 1<S2				No change				
x+x-x+x positive	n/a							1<S2				No change			
x+x-x+x association		2>S2 2<S2 1>S1 1<S1			1<S2 1>S2 1<S1				2>S2 2<S2 1>S1 1<S1				1<S2 1>S2 1<S1		
x+x-x+x neutral			1<S1 1>S2			1>S2				1<S1 1>S2				1>S2	

Table 23b: A brief summary of results for the APN category

Avoidance, Positive and Neutral behaviour						
	Lyttelton			Timaru		
Test	A	P	N	A	P	N
Overall BC v CC	No change	No change	No change	No change	No change	No change
BC S1 v BC S2 CC S1 v CC S2	No change	No change	<S2	No change	No change	No change

### **3.6.5 Time Data: Stress, Association and Neutral Behaviours (SAN)**

The total duration of time spent exhibiting stress, association and neutral behaviours over both seasons indicated that dolphins at Lyttelton and Timaru spent most time performing association behaviour (253 hours and 18 hours respectively). Dolphins at Lyttelton spent the least amount of time exhibiting stress behaviour (57 hours), whereas dolphins at Timaru spent least time exhibiting neutral behaviour (6 hours), (Appendix D, Table 24).

There was more time spent exhibiting association behaviour than either stress or neutral behaviour by dolphins at Lyttelton and Timaru, with the total amount of time spent exhibiting association behaviour being 253 hours at Lyttelton and 18 hours at Timaru. Dolphins spent the least time exhibiting stress at Lyttelton with a total of 57 hours and dolphins at Timaru spent least time exhibiting neutral behaviour with 6 hours (Appendix D, Table 25).

A General Linear Model (GLM) was used to test for significance between stress versus site, season and month as well as any interaction between factors site, month and season. Stress versus site, and stress versus site and season effects combined were not significant ( $P = 0.0586$  and  $P = 0.063$  respectively). However, these results are almost significant and may indicate an opportunity in regard to a future research opportunity, in that, there may be a site, season effect in relation to stress in future seasons. There was a significant season effect ( $P = 0.014$ ) with Season 1 showing more stress behaviour than Season 2. Month was also significant ( $P = 0.017$ ), (Appendix D, Table 26) with more stress in September and least in February. There is a difference between site and month ( $P = 0.043$ ), but the actual effect varies between sites (Figure 17).

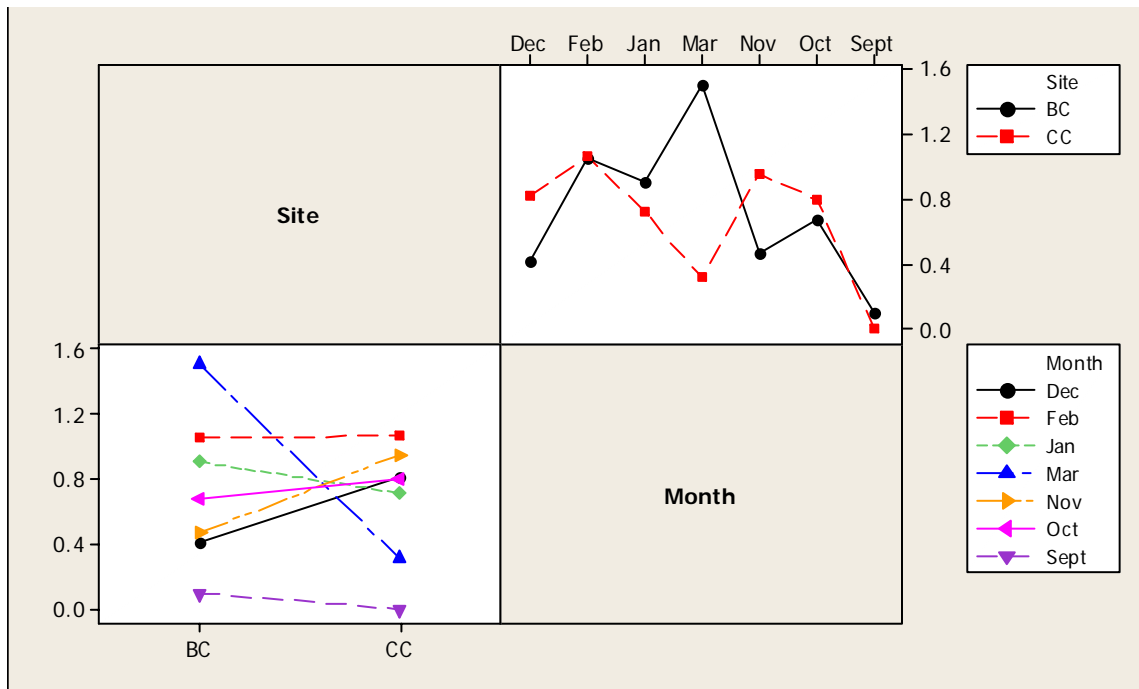


Figure 17: An interaction plot based on Log time (minutes) versus avoidance behaviour for Hector's dolphins observed in the presence of the Black Cat (BC) at Lyttelton and the Caroline Cat (CC) at Timaru (APN). The total number of minutes that the behaviour was observed was log-transformed. There is a significant difference between stress versus site and month but the difference varies between sites.

A GLM test was used to test for significance between association versus site, season and month as well as any interaction between factors site, month and season. Association versus site was significant with the dolphins at Lyttelton exhibiting more association behaviour than those at Timaru ( $P = 0.012$ ). Season 1 showed more association behaviour than Season 2 ( $P = 0.008$ ), and the factors site and season have an interaction ( $P = 0.024$ ) where there is a large decrease in association behaviour in Season 2 at Lyttelton when compared to Timaru (Figure 18). Association behaviour versus month was not significant ( $P = 0.265$ ), nor is the interaction between site and month ( $P = 0.197$ ) (Appendix D, Table 27).

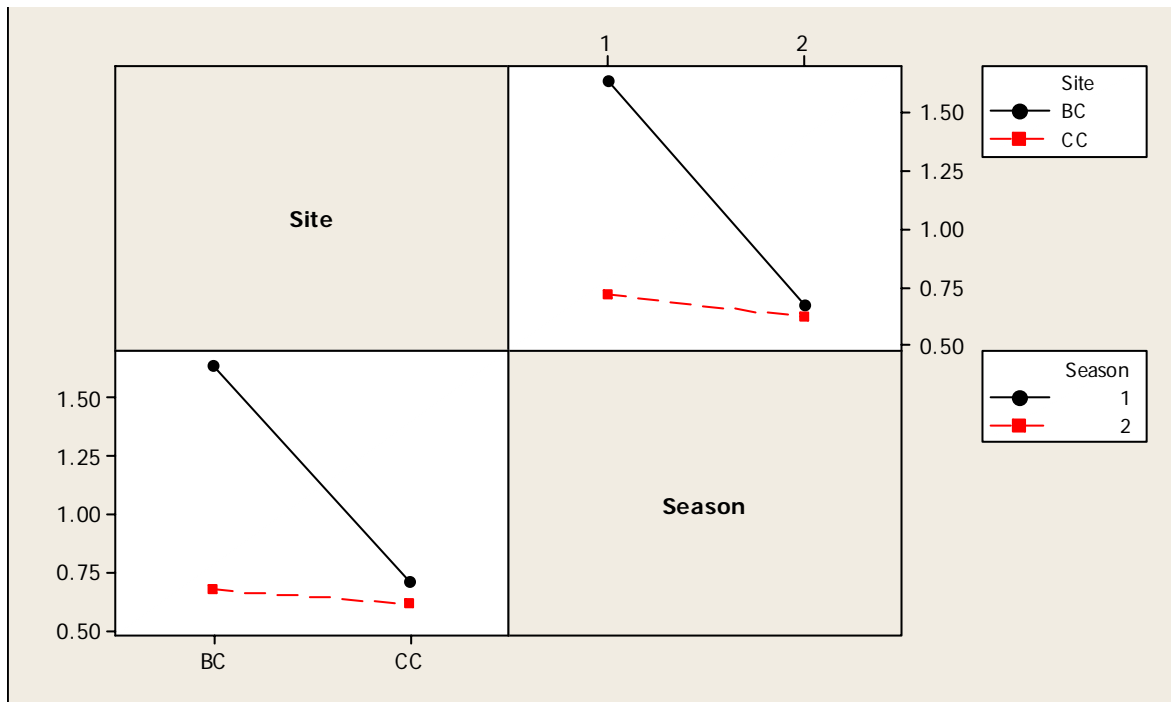


Figure 18: An interaction plot based on Log (time) versus association behaviour for Hector’s dolphins observed in the presence of the Black Cat (BC) at Lyttelton and the Caroline Cat (CC) at Timaru (APN). The total number of minutes that the behaviour was observed was log-transformed. The interaction plot shows a large decrease in association behaviour between Season 1 and Season 2 in the presence of the Black Cat (BC) at Lyttelton when compared to the Caroline Cat (CC) at Timaru. Site and season show a significant interaction.

There was a significant site effect ( $P = 0.025$ ) with Lyttelton having higher observations of neutral behaviour than Timaru (Figure 19). There was also a significant season effect ( $P = 0.031$ ) where Season 1 showed more neutral behaviour than Season 2 (Appendix D, Table 28). Neutral behaviour versus month was not significant ( $P = 0.534$ ) and site and month did not interact ( $P = 0.290$ ) but site and season did ( $P = 0.002$ ) where Lyttelton showed a large decrease in neutral behaviour when compared to Timaru (Figure 19).

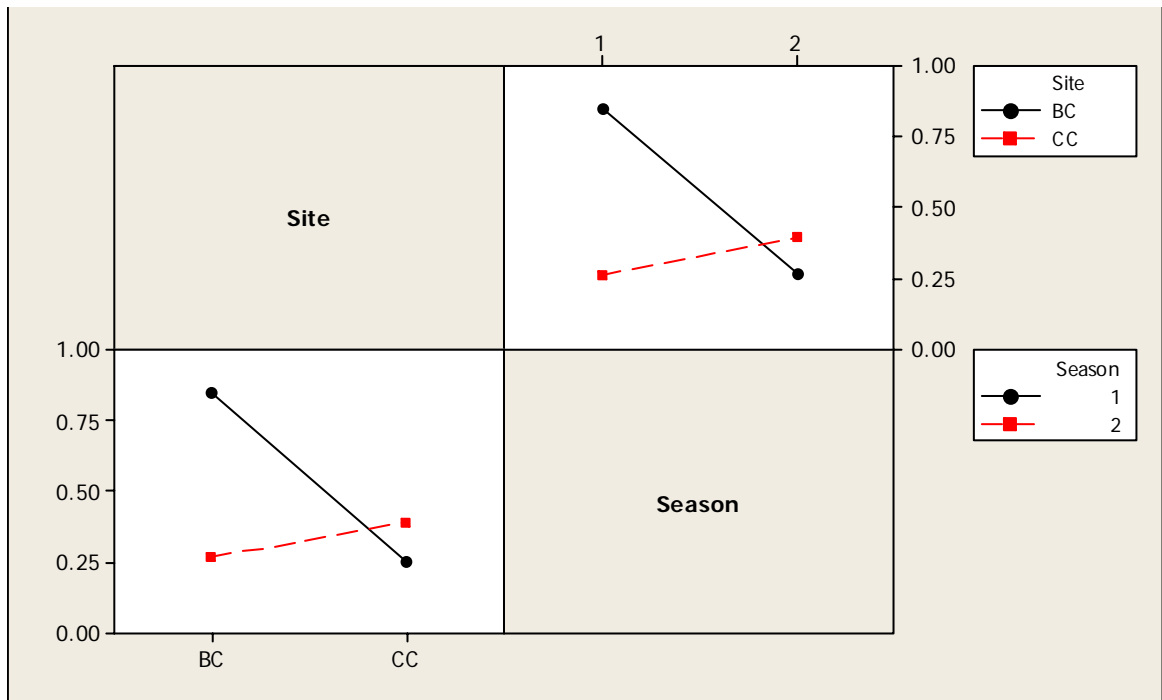


Figure 19: An interaction plot based on Log (time) versus neutral behaviour for Hector's dolphins observed in the presence of the Black Cat (BC) at Lyttelton and the Caroline Cat (CC) at Timaru (APN). The total number of minutes that the behaviour was observed was log-transformed. The interaction plot shows a large decrease in neutral behaviour in the presence of the Black Cat between Season 1 and Season 2 at Lyttelton when compared to Timaru. Site and season show a significant interaction.

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category stress showed there was a difference between behaviours over seasons for the dolphins at Lyttelton (Black Cat) ( $\chi^2 = 56.086$ , DF = 6, P = 0.000). In relation to the overall number of observations there were more sa->-sb, and more sa->sa with lower p/s->sa in Season 1 than would be expected, and more p/s->sa and less sa->-sb and less sa->sa in Season 2 than would have been expected. The dolphins at Timaru (Caroline Cat) showed no significant difference ( $\chi^2 = 8.799$ , DF = 5, P = 0.117) (Table 29).

Table 29: Total number of Hector's dolphin observations per season per site for the individual transitional behaviours which make up the stress, association and neutral behaviour groups (SAN). Bold figures indicate a significant difference in regard to transitional behaviours exhibited in relation to transitional behaviour which was expected per site per season.

Stress							
Site/Season	g-sa, sa-g	Sa>-sb, sb-sa>	g+sa+bs-sb+tb	p/s->sa	sa->sa	g+sa-tb+br	lb-sa
Black Cat S1	2	<b>19 (&gt;)</b>	11	<b>125 (&lt;)</b>	<b>72 (&gt;)</b>	6	9
Black Cat S2	2	<b>0 (&lt;)</b>	18	<b>129 (&gt;)</b>	<b>13 (&lt;)</b>	5	1
Caroline Cat S1	8	10	10	31	12	16	
Caroline Cat S2	8	1	1	18	9	8	

Association						
Site/Season	bs-st+sw	br+j-j+br	st-j, j-st	s/p-st, st-p/s	sa-st+sw	sa-st
Black Cat S1	127	102	8	250	<b>106 (&gt;)</b>	78
Black Cat S2	<b>98 (&lt;)</b>	<b>73 (&gt;)</b>	2	80	<b>5</b>	31
Caroline Cat S1	54	52	5	95	42	71
Caroline Cat S2	15	15	3	20	1	17

Neutral					
Site/Season	j-s+p, s+p-j	l/m-lb-lb-l/m	p/s-p/s	p/s-l/lb	s/p-m
Black Cat S1		9	140	57	
Black Cat S2		0	46	<b>8 (&lt;)</b>	
Caroline Cat S1	5	2	42	6	3
Caroline Cat S2	9	4	<b>15 (&lt;)</b>	4	7

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category association found there were differences between seasons and some behavioural transitions for the dolphins at Lyttelton (Black Cat) ( $\chi^2 = 71.147$ , Df = 5, P = 0.000). In relation to the overall number of observations there were less bs-st+sw and more sa-st+sw in Season 1 but more bs-st+sw and more br+j-j+br but less sa-st+sw) than expected in Season 2 for the Black Cat. The dolphins at Timaru (Caroline Cat) also showed no significant difference ( $\chi^2 = 10.772$ , DF = 5, P = 0.056) (Table 29).

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category neutral found there was a significant difference between seasons and some behavioural transitions for the dolphins at Lyttelton (Black Cat) ( $\chi^2 = 6.962$ , Df = 2, P = 0.031) and those at Timaru (Caroline Cat) ( $\chi^2 = 13.391$ , Df = 4, P = 0.010). In relation to the overall number of observations there were less p/s-p/s observed in Season 2 at both sites (Table 29).

### **3.6.6 Time Data: Negative and Positive Stress, Association and Neutral Behaviours (NPAN)**

Overall there was more association behaviour exhibited at Lyttelton than neutral positive stress or negative stress (253, 110, 48 and 9 hours respectively). The dolphins at Timaru exhibited more association behaviour than neutral, negative stress or positive stress (18, 6, 6 and 2 hours respectively), (Appendix D, Table 30). The mean duration of time dolphins spent exhibiting behaviour within the groups negative stress, positive stress, association and neutral behaviour indicated that dolphins exhibited association behaviour most often per month, per season, per site (Appendix D, Table 31). There were no dolphin sightings in September for either season at Timaru and, no dolphin sightings in October for Season 2 at Timaru (Appendix D, Table 31).

A GLM test was used to test for significance between negative stress versus site, season and month as well as any interaction between factors site, month and season. Negative stress versus site and negative stress versus season were significant (P =

0.005 and  $P = 0.025$  respectively). Month was not significant ( $P = 0.054$ ). There was no significant interaction between factors site versus season ( $P = 0.264$ ) nor site versus month ( $P = 0.053$ ). There was a difference between site and season with the negative stress being greatest during Season 1 than Season 2 for the Black Cat and negative stress being greater with the Black Cat than the Caroline Cat overall (Appendix D, Table 32).

A GLM test was used to test for significance between positive stress versus site, season and month as well as any interaction between factors site, month and season. Positive stress versus site, season and month were not significant ( $P = 0.970$ ,  $P = 0.149$  and  $P = 0.623$  respectively). There was no significant interaction between factors, site versus season ( $P = 0.321$ ) nor, site versus month ( $P = 0.506$ ) (Appendix D, Table 33).

A GLM was used to test for significance between association behaviour versus site, season and month as well as any interaction between factors site, month and season. Association versus site, season and month were not significant ( $P = 0.059$ ,  $P = 0.086$  and  $P = 0.498$  respectively). There was no significant interaction between factors site versus season ( $P = 0.410$ ) nor site versus month ( $P = 0.459$ ), (Appendix D, Table 34).

A GLM was used to test for significance between neutral behaviour versus site, season and month as well as any interaction between factors: site, month and season. Neutral behaviour versus site, season and month were not significant ( $P = 0.091$ ,  $P = 0.108$  and  $P = 0.499$  respectively). There was no significant interaction between factors site versus month ( $P = 0.682$ ). There was a significant interaction between site versus season ( $P = 0.016$ ). Neutral behaviour at the Black Cat is higher than for the Caroline Cat with a significant difference between Season 1 and no significant difference between Season 2 per site (Appendix D, Table 35). The Black Cat had a very big decline in neutral behaviour (Figure 19).



Table 36: Total number of observations per season per site for the individual transitional behaviours which make up the negative and positive stress, and association and neutral behaviour groups (NPAN). Bold figures indicate a significant difference in regard to transitional behaviours exhibited in relation to transitional behaviour which was expected per site per season.

	Negative stress			
Site/season	g-sa	sa>+sb	sa-sa	sa-p/s
Black Cat Season 1	2	<b>19 (&gt;)</b>	<b>72 (&gt;)</b>	<b>125 (&lt;)</b>
Black Cat Season 2	2	<b>0 (&lt;)</b>	<b>13 (&lt;)</b>	<b>129 (&gt;)</b>
Caroline Cat Season 1	8	10	12	31
Caroline Cat Season 2	8	1	9	18

Positive stress			
Site/Season	g+sa-sb+tb	sa-lb	g+sa-tb+br
Black Cat Season 1	11	9	6
Black Cat Season 2	18	<b>1 (&lt;)</b>	5
Caroline Cat Season 1	10		16
Caroline Cat Season 2	1		8

A Chi-Square test of independence using the number of observations versus the individual behavioural transitions within the category negative stress shows there was a difference between seasons and some behavioural transitions for the Black Cat ( $\chi^2 = 46.846$ , Df = 3, P = 0.001). In relation to the overall number of observations there were more sa>+sb, more sa-sa, and less sa-p/s than would be expected for Season 1 and more sa-p/s, less sa>-sb and less sa-sa than would be expected for Season 2. The dolphins at Timaru displayed no significant change ( $\chi^2 = 5.139$ , DF = 3, P = 0.162) (Table 36).

Within the positive stress group there was less swimming away to long breaths (sa-lb) was observed for Season 2 at Lyttelton ( $\chi^2 = 8.114$ , DF = 2, P = 0.017). The dolphins at Timaru showed no significant changes in positive stress over the two seasons ( $\chi^2 = 2.321$ , DF = 1, P = 0.128) (Table 36).

Association and neutral behaviour results are shown in the previous section, stress, association and neutral behaviour (see also Appendix D, Table 34 and 35 respectively).

### 3.6.7 Time Data: Avoidance, Positive and Neutral Behaviour (APN).

Table 37: The total duration of time, in hours and the percentage of time, per site, that dolphins spent exhibiting avoidance, positive and neutral behaviour (APN).

Overall total time in hours and percentage of time			
Site	Avoidance	Positive	Neutral
Black Cat at Lyttelton	19 (4.53%)	291 (69.13%)	111 (26.34%)
Caroline Cat at Timaru	6 (17.80%)	20 (62.55%)	6 (19.65%)

Time measurements for combined seasons indicate that dolphins at Lyttelton and Timaru exhibit more positive behaviour than neutral behaviour in the presence of the Black Cat and Caroline Cat respectively (Table 37). Dolphins at both sites exhibited avoidance behaviour the least amount of time (Table 37).

Table 38: The total duration of time, in minutes and the percentage of time, per site, per season, that dolphins spent exhibiting avoidance, positive and neutral behaviour (APN).

Overall time, in hours, per season per site for avoidance, positive and neutral behaviour			
Site	Avoidance	Positive	Neutral
Black Cat at Lyttelton – S1	16 (2.53%)	179 (62.34%)	92 (35.13%)
Black Cat at Lyttelton – S2	3 (2.38%)	112 (83.80%)	19 (13.82%)
Caroline Cat at Timaru – S1	<b>5</b> <b>(24.31%)</b>	11 (54.38%)	4 (21.31%)
Caroline Cat at Timaru – S2	<b>1</b> <b>(7.41%)</b>	9 (75.58%)	2 (17.01%)

Time measurements per season per site indicate that dolphins at Lyttelton and Timaru exhibit more positive behaviour than either avoidance or neutral behaviour in the presence of the Black Cat and Caroline Cat irrespective of season (Table 38). Dolphins at both sites exhibited avoidance behaviour the least amount of time with the exception of dolphins at Timaru during Season 1 (Table 38). Mean calculations per month per season per site indicate that positive behaviour was the most exhibited behaviour with the exception of the months September in Season 1 at Lyttelton, where neutral behaviour was exhibited most (Appendix D, Table 39).

A GLM was used to test for significance between avoidance behaviour versus site, season and month as well as any interaction between factors, site, month and season for the Black Cat. Avoidance versus site and season were significant ( $P = 0.005$ , and  $P = 0.032$  respectively), with the site effect being greater for Season 1 than Season 2 and with the difference between Season 1 and Season 2 being greater for the Black Cat than the Caroline Cat. Avoidance versus month was not significant ( $P = 0.052$ ), nor was there any significant interaction between factors, site versus month ( $P =$

0.682), or site versus season ( $P = 0.289$ ), or site versus month ( $P = 0.070$ ) (Appendix D, Table 40).

There were no significant differences at either site for positive behaviour versus site ( $P = 0.082$ ), season ( $P = 0.068$ ), month ( $P = 0.434$ ) or any interaction between factors, site and season ( $P = 0.313$ ) or site and month ( $P = 0.495$ ) (Appendix D, Table 41).

Neutral behaviour versus site, season, month and the interacting factors site and month were not significant at either site ( $P = 0.087$ ,  $0.113$ ,  $0.462$  and  $0.683$  respectively), but site and month were significant ( $P = 0.017$ ) (Appendix D, Table 42), where the biggest decline in neutral behaviour was shown at Lyttelton for the Black Cat from Season 1 to Season 2 (Figure 19).

Table 43a: A brief summary of results showing P-values for the categories of behaviour SAN, NPAN and APN. Bold figures indicate a significant difference.

	SAN				NPAN					APN		
Test	Stress	Association	Neutral		Negative stress	Positive stress	Association	Neutral		Avoidance	Positive	Neutral
Site	0.0586	<b>0.012</b>	<b>0.025</b>		<b>0.005</b>	0.970	0.059	0.091		<b>0.005</b>	0.082	0.087
Season	<b>0.014</b>	<b>0.008</b>	<b>0.031</b>		<b>0.025</b>	0.143	0.086	0.108		<b>0.032</b>	0.068	0.113
Month	<b>0.017</b>	0.197	0.534		0.054	0.623	0.498	0.499		0.052	0.434	0.462
Site-season	0.063	<b>0.024</b>	<b>0.002</b>		0.264	0.321	0.410	<b>0.016</b>		0.289	0.313	<b>0.017</b>
Site-month	<b>0.043</b>	0.265	0.290		0.053	0.506	0.459	0.682		0.070	0.495	0.683

Table 43b: Results showing how many transitional behaviours within each category changed and whether the change was an increase ‘>’ or decrease ‘<’ in the transitional behaviour observed, and the season which the change occurred: S1; Season 1, S2; Season 2

Stress, Association and Neutral Behaviour (SAN)							Negative Stress, Positive behaviour and Neutral behaviour (NPAN)								
	Lyttelton			Timaru				Lyttelton				Timaru			
Test	Stress	Association	Neutral	Stress	Association	Neutral		Negative stress	Positive Behaviour	Association	Neutral	Negative stress	Positive Behaviour	Association	Neutral
x+x-x+x stress	2>S1 1>S2 1<S1	1<S1 1>S1 2>S2	1<S2	No change	No change	1<S2		2>S1 1<S1 1>S2 1<S2	1<S2	1<S1 1>S1 2>S2	1<S2	No change	No change	No change	1<S2

## **3.7 Count Data: Summary and Discussion of Results for Each Category**

### **3.7.1 Count Data: Stress, Association and Neutral Behaviour (SAN)**

Overall, there were significantly more stress and less association behaviours observed at Timaru than at Lyttelton (Table 9:  $P = 0.001$ ). No significant changes in neutral behaviour were observed between seasons at Timaru (Table 11:  $P = 0.0643$ ), whereas there were significantly fewer than expected occurrences of neutral behaviour in Season 2 (Table 10:  $P = 0.003$ ) at Lyttelton. The higher occurrence of stress behaviours at Timaru may indicate that dolphins at Timaru are less willing to associate with the Caroline Cat than the Black Cat and that this did not change between seasons one and two. The result indicates that dolphin behaviour at Lyttelton varies more than at Timaru in relation to the display of neutral behaviour. However, there were no significant differences in stress or association behaviour in that these behaviours did not increase, indicating that the presence of the Black Cat over these two seasons did not result in an increase in stress, irrespective of the decline in neutral behaviour, suggesting that dolphins which may have exhibited avoidance behaviour in the presence of the Black Cat, did so prior to being able to observe them.

There were significant changes in certain transitional behaviours within the category stress for dolphins observed at Lyttelton (Table 12). There was more swimming away from the Black Cat exhibited during Season 1 and less than expected during Season 2, which may indicate habituation to the Black Cat over time. There were a greater number of transitional behaviours in the association category which changed at Lyttelton between seasons than there were at Timaru (Table 12). The dolphins at Lyttelton exhibited more sa-sw behaviour in Season 1 but a decrease in the same transitional behaviour in Season 2. This would mean a reduction in swimming with the Black Cat had occurred but as there were two other transitional behaviours which increased in Season 2, which included the behaviours bow riding, swimming with the boat and jumping, then this may indicate that, overall, dolphins continued to be associated with the Black Cat. Dolphins at Timaru also exhibited a decrease in sa-sw

in Season 2 but no other change, indicating that dolphins at Timaru swam less often with the Caroline Cat in Season 2 than Season 1. The decrease in sa-sw was common to both sites in the same season.

For the category neutral behaviour, the dolphins at Lyttelton exhibited a change in behaviour from Season 1 to Season 2 (Table 12) exhibiting less than expected jumping to swimming or porpoising in Season 2 ( $P = 0.001$ ). The dolphins at Timaru exhibited no significant change in behaviour between seasons for any neutral transitional behaviour although there was a significant change overall ( $P = 0.041$ ).

The transitional behaviours which were initially used on the basis of one behaviour moving on to a second behaviour (x-x) were combined in order to include those behaviours at Timaru that would otherwise have had too low a value to be included in analysis. This resulted in the transitional behaviours within the stress, association and neutral behaviour categories representing a sequence of behaviours which moved on to another sequence of behaviours (x+x-x+x). The results from the x-x analysis were generally found to also be reflected by the new groupings. For example, in the new groupings an analysis on the transitional behaviours within the stress category for dolphins in the presence of the Black Cat showed more than expected grouping, swimming away, and short breath occurrences in Season 1 (Table 13) but less than expected swimming away occurrences in Season 2 ( $P = 0.001$ ), whereas dolphins in the presence of the Caroline Cat showed no significant changes ( $P = 0.0539$ ). This would indicate that dolphins during Season 1 at Lyttelton were avoiding the Black Cat and were stressed by its presence as reflected in more occurrences of grouping behaviour, short breaths and swimming away from the vessel. However, in Season 2 there are less occurrences of avoidance indicating that habituation may have taken place. The dolphins at Timaru did not show any change in transitional behaviours and, therefore, stress levels can be argued to be unaffected by the presence of the Caroline Cat.

The association category showed that the dolphins at Lyttelton exhibited more association behaviours in Season 2 ( $P = 0.001$ ) including the behaviours jumping, bow riding, short breaths, swimming to and with the Black Cat (Table 13). Short breaths are also in the stress category, but are also placed in the association category if

the context of the behaviour warrants, for example, exerting energy and bow riding will change breathing patterns to short breaths, hence short breaths, in context, can be association behaviour. Likewise, short breaths whilst swimming away from a boat at speed indicates stress or avoidance behaviour and would be placed in the stress or avoidance behaviour group. Therefore, some individual behaviours overlap behaviour groups, but in context are correctly placed.

The Timaru dolphins exhibited less than expected short breaths, swimming to and with the Caroline Cat in Season 1 but more than expected in Season 2 ( $P = 0.001$ ). Both the dolphins at Lyttelton and Timaru exhibited more association behaviours in Season 2 than Season 1 with an increase at both sites in swimming to and swimming with the vessels.

This result is similar to the x-x results where Timaru resulted in less sa-sw during Season 2 (Table 12), but showed less s/p-st in the x+x-x+x results. Both represent a possible decrease in association behaviour in Season 2. However, the latter analysis also revealed more than expected swimming with the boat in Season 2, hence there is no real change in overall dolphin association behaviour with the Caroline Cat.

The neutral category showed that dolphins at Lyttelton exhibited less than expected jumping to swimming and porpoising in Season 1 (Table 13), but more than expected in Season 2 ( $P = 0.001$ ) which is the opposite of the results found in the x-x analysis (Table 13). There are more than expected occurrences of s/p-m behaviour at Timaru in Season 2 ( $P = 0.014$ ). For both sites there is an increase in observed occurrences of neutral behaviour, and this could indicate tolerance to both the Black Cat and the Caroline Cat.

The results for the Black Cat were generally consistent regardless of using an analysis based on x-x (Table 12) or x+x-x+x (Table 13) behaviour groupings, whereas the results for the Caroline Cat were generally quite different. When using the x-x transitional behaviour within the stress group a change was noted in swimming away from the Caroline Cat with an apparent decrease in swimming away in Season 2. When using the x+x-x+x transitional behaviours there were no significant changes.



In trying to encompass as much transitional behaviour as possible it appears two things occurred:

1. That the transitional behaviours  $x-x$  were valuable in providing information about individual populations in isolation, and gave a clearer understanding of what is happening at a specific site and can assist in determining any changes within a specific population.
2. That combining more behaviours to give a sequence of behaviours to another sequence of behaviours (in order to have comparable data for analysis) resulted in gaining a clearer understanding about the overall changes between different sites.

For example, in Timaru there were differences in behavioural transitions when looking at specific  $x-x$  behaviours, but no significant differences when looking at group transitions  $x+x-x+x$ . It may be possible that using transitional behaviour data from one site may not adequately reflect changes in behaviour when used at another site, especially where results for determining stress are sought in order to provide management or conservation advice. It appears that tests on each individual site independent of any other are required using the  $x-x$  transitional behaviour which will determine any changes within a specific population. The transitional behaviours which are common to both sites and, therefore, can be combined into a  $x+x-x+x$  type analysis appear to reveal overall changes between populations but not subtle changes, which may be individual to the specific site or population. This suggests that both sites need to be studied independently of the other as well as in comparison with each other. This will then provide an overall picture of any changes whether simple, for example changes in behaviour from  $x-x$ , or to more complex  $x+x-x+x$ .

The group transitions appear to provide information regarding the overall changes between sites which are only possible with comparable data, that is, comparison of behaviours which are common to both sites. The group transitions were therefore employed in the rest of the study. In view of this, it may therefore be beneficial to undertake individual isolated observations at each site of interest, providing site specific information for wildlife populations as well as conduct an overall comparison between populations using those behaviours which are common to both.

### **3.7.2 Count Data: Negative and Positive Stress, Association and Neutral behaviour (NPAN)**

The overall stress category was split to represent negative stress and positive stress. Negative stress was defined as behaviour which is clearly avoidance: grouping behaviour, swimming away from the boat, short breaths, or a combination of these. Positive stress included swimming away from the boat, short breaths or grouping behaviour but which end with bow riding or swimming to the boat. Long breaths were also included in positive stress if it were observed at the same time or sequentially with swimming away from the vessel. As long breaths were not considered to indicate stress, as, for example, short breaths would be, they are included in positive behaviour rather than avoidance behaviour.

Over both seasons there was less positive stress observed at Lyttelton than at Timaru (Table 15) and less association behaviour at Timaru than Lyttelton. Overall it appears that dolphins at Timaru exhibited more positive stress behaviour but less association behaviour than at Lyttelton. Lyttelton showed more positive stress but less neutral behaviour in Season 2 (Table 16) which, rather than simply indicating an increase in positive behaviour, may actually reflect or indicate a change or transfer in behaviour from neutral behaviour to positive stress behaviour. Timaru showed no significant changes between seasons for any of the behaviour categories ( $P = 0.795$ ), which indicated that the presence of the Caroline Cat did not have an overall effect on dolphin behaviour.

When using the x-x behaviour transitions for analysis with regard to the negative stress category, the results showed that dolphins at Lyttelton exhibited more avoidance behaviour in the form of swimming away at speed to short breaths (sa>-sb), short breaths or swimming away to short breaths or grouping (bs/sa-bs/g), swimming away to jumping (sa-j), and long breaths to swimming away (lb-sa) in Season 2, but at the same time exhibited a reduction in porpoising or swimming to swimming away (p/s-sa), swimming away to swimming away (sa-sa) and short breaths to short breaths (bs-bs) in the same season, which makes the results inconclusive with regard to determining overall effects (Table 18).

Dolphins at Lyttelton exhibited more sa-sb (swimming away from the boat-short breaths) but less sa-sa (swimming away-swimming away) in Season 2 (Table 19a). Some transitional behaviour have either increased or decreased, but overall no real changes in negative stress can be inferred. For positive stress, the dolphins at Lyttelton exhibited less sa-lb (swimming away-long breaths) in Season 2 (Table 19b) with no other significant behaviour difference. Dolphin behaviour in the presence of the Caroline Cat showed no significant difference ( $P = 0.348$ ), but the actual recorded numbers of positive stress at Timaru were higher in Season 1 than for Lyttelton - 23 and 11 respectively (Table 19b), indicating that there may be a difference between responses to tour boats dependant duration of time they have been operating.

Grouping behaviour followed by swimming away to short breaths to swimming to the boat (g+sa-sb-tb) could indicate aggression with dolphins forming groups and swimming toward the object of threat. This transitional group behaviour is included in the positive behaviour category with the following justification. Grouping and swimming away would indicate avoidance behaviour. Grouping, swimming away and short breaths in sequence would indicate avoidance and stress, while grouping behaviour, swimming away, short breaths and swimming to the boat would indicate positive stress. Should the dolphins have continued to exhibit swimming away behaviour, then the behaviour would have been placed in the avoidance category, but it is assumed that as the dolphins swim to the boat they wish to interact with it. Dolphins may have swum with the boat, or bow rode, and could possibly have swum away from the boat after observations ceased but as it is assumed that dolphins would not be in the vicinity of the boat unless they choose to be this behavioural transition is categorised as positive stress due to the final behaviour 'swimming to the boat (tb)' indicating an intention to interact with the vessel.

### **3.7.3 Count Data: Avoidance, Positive and Neutral behaviour (APN)**

An overall Chi-Square test between site and avoidance, positive and neutral behaviours analysed as counts returned no significant difference between dolphin behaviour at Lyttelton or Timaru ( $P = 0.194$ ). An individual analysis of site versus season showed that at Lyttelton there were less neutral behaviour in Season 2 than

would be expected ( $P = 0.003$ ). There were no significant difference for the dolphin behaviour at Timaru between observations for each season ( $P = 0.859$ ).

#### **3.7.4 Time Data: Stress, Association and Neutral Behaviour (SAN)**

A General Linear Model test on each behaviour category analysed as time showed a significant difference between seasons where stress behaviour was greater in Season 1 than Season 2 which varied between months. For the dolphins at Lyttelton the highest month of stress was March and the lowest September (Figure 17). For dolphins at Timaru the highest month of stress was February and the lowest also September (Figure 17). The months of highest stress may coincide with calving or mating periods. The lowest month of stress with reduced tourist numbers during the Autumn period.

The results for association showed that dolphins exhibit more association behaviour at Lyttelton than Timaru, where Season 1 had more occurrences of association than Season 2 and the factors site and season interact. Association was not dependent on month, but there was a large decrease in association at Lyttelton from Season 1 to Season 2 when compared to Timaru (Figure 18). Seasons at Lyttelton were major factors in the reduction in association behaviour which indicated that the presence of the Black Cat affected association behaviour resulting in dolphins significantly reducing interaction with the vessel over time.

The results for neutral behaviour showed a significant site effect ( $P = 0.025$ ) where Lyttelton showed greater occurrences of neutral behaviour than Timaru (Figure 19). Again there was season and site interaction ( $P = 0.002$ ) where Season 1 showed more occurrences of neutral behaviour than Season 2 and where Lyttelton showed a higher occurrence of neutral behaviour than Timaru ( $P = 0.025$ ). However, Lyttelton showed a significant decrease in neutral behaviour between seasons when compared to Timaru (Figure 19).

Both association and neutral behaviours reduced in Season 2 for Lyttelton. This may indicate concern to anyone preparing a management or conservation plan as the

results indicate that dolphin behaviour is significantly changed by the presence of the Black Cat. An anomaly exists in that there were more stress behaviours observed in S1 than S2. It may well be that dolphins chose to avoid the vessel in Season 2 once aware of its presence, thus reducing observations of stress, as the individuals had already left the vicinity of the boat and therefore could not be observed. The results for both association and neutral behaviours would indicate that this may be the case for Lyttelton.

The transitional data for stress behaviour shows that overall there were more stress behaviours in Season 1 than would be expected but less than would be expected in Season 2 at Lyttelton (Table 33:  $P = 0.001$ ). Dolphins at Timaru showed no significant difference. This result seems to reflect the previous findings that stress was higher in Season 1 at Lyttelton than Season 2 and that the Caroline Cat has no effect on dolphin stress at Timaru.

The association category returned significant differences for dolphin behaviour at Lyttelton where there was an increase and decrease in specific association behaviours in Season 1, but where in Season 2 there were more changes with regard to an increase in association behaviour than a decrease (Table 29). The Caroline Cat had no effect on the association behaviour of dolphins at Timaru. Neutral behaviour changed at both sites (Table 29) with less p/s-p/s observed at Lyttelton and Timaru.

Overall it appears that the Black Cat had an effect on dolphin behaviour at Lyttelton with a reduction in both association and neutral behaviours and a decrease in stress.

### **3.7.5 Time Data: Negative and Positive Stress, Association and Neutral Behaviour (NPAN)**

Again, negative stress was greater in Season 1 than Season 2 for dolphins at Lyttelton, and negative stress being greater at Lyttelton than Timaru overall. There were no significant differences for positive stress or association behaviour at either site for any factor or interacting factors. For neutral behaviour, no significant differences were found other than an interaction between site and season and dolphins at Lyttelton

showing a large decline in neutral behaviour from Season 1 to Season 2 when compared to the dolphin behaviour at Timaru. Neutral behaviour was also greater in Season 1 at Lyttelton when compared to Timaru (Appendix D, Table 35), whereas there was no significant difference between the sites in Season 2 for neutral behaviour.

The transitional behaviour data showed that overall there was more negative stress in Season 1 than in Season 2 at Lyttelton, with a change in three of the four negative behaviour groups from Season 1 to Season 2 (Table 36). There was no significant difference in the behaviour of dolphins at Timaru regarding negative stress. The positive stress category shows a decline in the behaviour sa-bl at Lyttelton in Season 2, but no significant change in the positive behaviour of the dolphins at Timaru. Association and neutral behaviours remained the same. The Caroline Cat had no effect on the association behaviour of dolphins at Timaru. Neutral behaviour changed at both sites (Table 29) with less p/s-p/s observed at both Lyttelton and Timaru.

### **3.7.6 Time Data: Avoidance, Positive and Neutral Behaviour (APN)**

Avoidance and site and avoidance and season were significant at Lyttelton with the site effect being greater at Lyttelton than Timaru and the difference between Season 1 and Season 2 being greater for dolphins at Lyttelton than at Timaru, indicating that the Black Cat has a greater effect on dolphins at Lyttelton than the Caroline Cat at Timaru. There were no significant differences at either site for positive behaviour. Neutral behaviour decreases markedly from Season 1 to Season 2 at Lyttelton which is also a consistent result (Figure 19). Site and month were significant for neutral behaviour but no other factors were significant.

## **3.8 Count Data: Comparison Between SAN-NPAN-APN Results**

### **3.8.1 Overall Comparison of Results - Black Cat versus Caroline Cat**

Comparison of the results from the three data sets reveal some important differences with stress being of highest importance. The SAN category showed that overall for stress behaviour; between sites the Black Cat appears to have no effect on dolphin behaviour, whereas the dolphins at Timaru exhibit more stress and less association behaviour in season 2. This would indicate that dolphins at Timaru are more affected by the presence of the Caroline Cat whereas dolphins at Lyttelton are unaffected by the presence of the Black Cat. The increase in stress and decline in association behaviour at Timaru appears to indicate that dolphins are detrimentally impacted by the presence of the Caroline Cat which is reflected by more occurrences of stress behaviour in the form of grouping behaviour and swimming away from the vessel. This result seems to be substantiated by the decline in association behaviour, or swimming with or to the Caroline Cat.

When stress is divided into negative stress and positive behaviour (NPAN), where negative stress is determined by exhibiting avoidance behaviour, and where positive behaviour is determined by any behaviour which results in bow riding with the vessel, dolphins at both sites show no change in negative stress (NPAN). The dolphins at Lyttelton show a decrease in positive behaviour or a reduction in the occurrence of bow riding, but as there is no change in negative stress or association behaviour the result cannot be said to be detrimental, only that fewer dolphins were observed to be bow riding with the Black Cat. The dolphins at Timaru show an increase in positive behaviour along with a decrease in association behaviour, but rather than the decrease in association behaviour indicating that fewer dolphins swim with the Caroline Cat, the result may simply reflect a change in exhibited behaviour from association to positive behaviour. Dolphins may be bow riding when they would have otherwise have been swimming to or with the boat, so rather than reflecting a decline in

interaction with the Caroline Cat the indication is that there is a change in behaviour associated with the presence of the Caroline Cat.

When combining positive stress with association behaviour giving the group negative stress, the overall APN category results then show that there are no significant differences in behaviour for dolphins at Lyttelton or Timaru. Looking at the data in different ways and making defined categories then changes the results from indicating stress at Timaru and no effect at Lyttelton (SAN), to indicating no stress at Lyttelton but a decrease in positive behaviour and a transfer of behaviours between association to positive behaviour at Timaru (NPAN) to neither site having any significant difference in avoidance, association or neutral behaviour (APN). In view of this, the category APN would be the recommended category for analysis, where behaviour is clearly distinguished between dolphins which may exhibit avoidance behaviour, such as short breaths, swimming away and grouping together and positive stress behaviour which may include bow riding and short breaths. Combining all stress together as in the SAN is not useful for the purpose of defining behaviour within its true context.

### **3.8.2 Black Cat Season 1 versus Black Cat Season 2 and Caroline Cat Season 1 versus Caroline Cat Season 2**

The SAN results indicate that between seasons for the Black Cat there is a decrease in Season 2 for neutral behaviour, but no difference in stress or association behaviour. Timaru shows no difference in behaviour. This remains the same for Timaru when using NPAN, but at Lyttelton rather than there being only an increase in neutral behaviour, there is also an increase in positive behaviour in Season 2, indicating that dolphins are not necessarily performing less behaviours overall, but may have transferred behaviour from neutral (milling and logging), to positive behaviour (bow riding), which also indicated that the presence of the Black Cat changes dolphin behaviour with its presence. When using APN the results are the same as for SAN, where the dolphins at Lyttelton exhibit less neutral behaviour in Season 2 but there are no changes in dolphin behaviour at Timaru - again indicating that the Caroline Cat has no significant effect on dolphin behaviour. In this instance the results obtained by combining all stress behaviour into one behavioural group, stress, in SAN, and



comparing this to avoidance behaviour in APN, both results clearly showed that dolphins at Lyttelton are affected by the presence of the Black Cat but dolphins at Timaru are not by the presence of the Caroline Cat. Although, in this instance, both categories SAN and APN returned the same result, I would hesitate in using the category SAN in regard to interpreting these results for the purpose of making management suggestions. Generally, the analysis of the SAN category has shown that dolphins are stressed for the majority of the time, which may in fact be the case, especially when recording bow riding and erratic swimming behaviour in the presence of tour boats. However, a major flaw exists with the category SAN, in that it does not separate positive from negative stress, which generally provides a much more realistic picture. Using SAN could lead to conclusions outlining major concerns where in fact these may not be present. In view of this APN, would be the preferred approach in regard to data collection. In combining all stress into one behavioural group regardless of its context can lead to incorrect interpretation of data, and indicates that dolphins are stressed for the majority of the time. Determining what is positive and negative stress, or in the case of the APN category, what is avoidance behaviour and positive behaviour leads to a more realistic view of dolphin behaviour. The similarities between the categories SAN, NPAN and APN are discussed further below, but for latter chapters the emphasis will be on using APN for the purpose of behavioural analysis.

SAN and APN return the same results with NPAN reflecting the results found in both these categories, but in addition also return an increase in positive behaviour in Season 2 for Lyttelton. This increase may explain the reduction in neutral behaviour. As all three sets of data, SAN, NPAN and APN, appear to agree, the suggestion is that the Caroline Cat has no significant effect on dolphin behaviour. There is also a consensus between data sets on the reduction of neutral behaviour at Lyttelton, which may be explained by the simultaneous increase in positive behaviour, in-so-much as dolphins may be changing their behaviour from neutral to positive behaviour rather than exhibiting less behaviour overall. This would suggest that dolphins at Lyttelton are choosing to interact with the Black Cat rather than not, as suggested by the decrease in neutral behaviour and an increase in positive behaviour when the Black Cat is present.

### **3.8.3 Black Cat versus Caroline Cat Using x-x Behavioural Transitions**

Of the eight x-x transitional behaviours within the stress group of the SAN category there were six significant changes. These include an increase in three of the transitional behaviours and fewer occurrences for one of the transitional behaviours during Season 1 as well as a reduction in two transitional behaviours in Season 2. From eight possible x-x transitions, five changed, of which three increased and two decreased. Four in the first season and one in the second season indicated that dolphins overall reacted to the Black Cat with more stress behaviours in Season 1 than in Season 2, which may indicate habituation or sensitisation to the Black Cat over time. The Caroline Cat showed an increase in only one transitional behaviour during Season 2 from a possible eight x-x transitions. As such the inference of stress cannot be made, only that dolphins exhibited more of one behaviour than another in any particular season. The same can be argued for the one transitional behaviour that occurred on fewer occasions in season 1. Timaru showed no change in behaviour thus indicating again that the Caroline Cat did not significantly affect dolphin behaviour with its presence.

The NPAN category reveals a similar pattern for the dolphins at Lyttelton when looking at the occurrences of negative stress. There was an increase of four of eight possible x-x transition behaviours in Season 2, but in the same season three other transitional behaviour groups declined. In total seven of the eight transitional behaviours changed, indicating that overall the Black Cat has an affect on dolphin behaviour at Lyttelton. However, as four of the transitions increased and three decreased, it is difficult to determine whether negative stress is in fact significantly greater or whether overall dolphins are just exhibiting more of one type of stress behaviour than another, hence the increase in some transitional behaviours and a decrease in others within the negative stress group.

The dolphins at Timaru showed no significant difference in negative stress (NPAN), which would suggest that the result in the SAN category that indicated a change in both seasons with a reduction in one transitional behaviour in Season 1 and an

increase in one transitional behaviour in Season 2 reflects only that dolphins performed one particular transitional behaviour either less or more frequently in a particular season as can be implied with the results in NPAN. As no significant difference was found between seasons for the Black Cat and negative stress, it is apparent that the behaviours, which were noted to have changed do not indicate more or less negative stress overall but that a decrease in one transitional behaviour may be reflected in the increase in another, and that overall there is no significant change within the behavioural group.

The SAN association x-x behavioural transitions results reflect those found in the overall comparison between sites, where the dolphins at Timaru exhibited less association behaviour in Season 2. Where the SAN, NPAN or APN data sets all returned no change in association behaviour at Lyttelton, the individual x-x transitional behaviour data analysis shows that there is an increase in two transitional behaviours and a reduction of one in Season 2. Although particular transitions may have changed significantly within the transitional group, the overall occurrence of association behaviour did not. There would need to be a significant change in a significant number of the transitional behaviours within a group in order for that group to be significantly different overall. For example, the x-x behavioural transitions in the neutral category showed a decrease in one of the three neutral behaviour transitions. This change is sufficient enough to give a significant result for the overall group as indicated by both SAN and NPAN, which show a significant decrease in neutral behaviour in season 2. Dolphins have, therefore, not simply replaced one behaviour with another across the remaining transitions within the neutral behaviour group, nor have they replaced the behaviour with any from the other two groups - association or stress. It is possible that dolphins that would have been observed exhibiting neutral behaviour left the vicinity of the boat prior to being observed, but those dolphins interacting with the boat or exhibiting association behaviour and stress behaviour remain constant, hence reflecting no change in the two latter groups but a change in the neutral group.

### 3.8.4 Black Cat versus Caroline Cat Using Behavioural Transitions

x+x-x+x

When comparing transitional behaviours x+x-x+x within the stress group of SAN dolphins exhibited an increase in one transitional behaviour but a decrease in another during Season 2 at Lyttelton. This is equivalent to the result for the negative stress group within NPAN, where no overall significant difference is recorded for the group overall. The results are also equivalent for SAN and NPAN where both stress and negative stress respectively show two transitional behaviours increasing in occurrence and two others decreasing in Season 2 at Lyttelton. Season 1 shows an increase in one and reduction in one other transitional behaviour. Neither SAN or NPAN show a significant difference overall in dolphin behaviour at Lyttelton indicating that the Black Cat may affect individual behavioural transitions but not to the extent that the overall behavioural groups are significantly different from one season to another. Therefore, the Black Cat appears not to effect dolphin behaviour in a significantly detrimental way.

Positive behaviour decreases in Season 2 at Lyttelton is equivalent to the overall analysis if the Black Cat between seasons, but this cannot be interpreted as detrimental as the other groups within the category NPAN do not significantly change. It may mean that dolphins bow rode less frequently in Season 2 but as negative stress is not significantly different, it is difficult to determine if the decrease reflects avoidance by those dolphins who may have otherwise bow rode.

The association group in the categories SAN and NPAN show the same number of increases and decreases in each season at both Lyttelton and Timaru. Two transitional behaviours within the group association occur more frequently and two less frequently at Lyttelton in Season 2 and one transitional behaviour more and one less frequently in Season 1. Timaru shows the same result regardless whether SAN or NPAN, with one transitional behaviour increasing and one decreasing in Season 2 and only one decreasing in Season 1. Overall the results per site showed no significant difference per association behaviour group for either Lyttelton or Timaru. They show only that some transitional behaviours were more frequent in one of the seasons and others less

frequent in particular seasons. At Timaru, the overall analysis showed the same result for both SAN and NPAN in that there was an overall reduction in association behaviour when compared to Lyttelton, but when site specific there is no difference between Season 1 and Season 2 with regard to association behaviour. This suggests that the Caroline Cat does not influence association behaviour in dolphins at Timaru and that this result does not change whether using x-x or x+x-x+x.

The results for neutral behaviours are also equivalent between SAN and NPAN with Lyttelton exhibiting less neutral behaviour in Season 1 than Season 2. There was no change in the number of transitional behaviours which had either a decrease or increase in occurrence for either the Black Cat or Caroline Cat whether using SAN or NPAN categories. This indicates that when using count data, combining more behaviour together in order to increase transitional behaviours included in the analysis, do not give different results. The results are the same regardless of using the group stress in SAN or the group negative stress and positive behaviour as in NPAN.

### **3.9 Time Data: Comparison Between SAN-NPAN-APN Results**

#### **3.9.1 Overall Black Cat versus Caroline Cat**

When using SAN time data, there were more significant differences than using NPAN or APN. However, there were more significant changes within the individual transitional behaviours when using NPAN than using SAN or APN. Using SAN there was more time spent exhibiting stress behaviours in Season 1 than Season 2 at Lyttelton, with March having the greatest difference between Lyttelton, and Timaru. November represents the month of greatest difference between Timaru and Lyttelton where Timaru had the highest stress value compared to Lyttelton, but, overall, dolphins at Lyttelton exhibited the most stress. The amount of stress varied between months, which could be a result of mating, calving, or breeding periods. Where stress versus site were not significant in SAN, negative stress was significant in NPAN ( $P = 0.005$ ). Where stress versus season was significant ( $P = 0.014$ ), negative stress versus

season was also significant ( $P = 0.025$ ), but where SAN gave a significant result for stress versus month and stress versus the interaction between site and month NPAN gave no significant difference, nor was negative stress versus month or stress versus interaction between site and month. Stress is dependent on season in both categories SAN and NPAN, but the overall results show that if taking stress overall there is a significant difference between sites until dividing stress into negative stress and positive behaviour groups. Site versus the interaction site and month appear not to be a major factor in negative stress (NPAN) but in regard to overall time of stress (SAN). SAN shows that there is a greater occurrence of stress in Season 1 than Season 2, but NPAN further clarifies this by indicating that negative stress is greatest for the dolphins at Lyttelton in Season 1 than Season 2 and that overall negative stress is greatest at Lyttelton than Timaru.

For avoidance in APN, both site and season are significant, which concurs with the results for NPAN but not those for SAN. Avoidance was greatest in Season 1 than Season 2 for the Black Cat and avoidance overall greatest at Lyttelton than Timaru. The stress group within SAN determined that stress was greatest in Season 1 than Season 2. Negative stress in NPAN determined that Lyttelton had greater stress than Timaru and avoidance in APN determined that dolphins at Lyttelton exhibited greater avoidance behaviour than those at Timaru. Therefore it can be argued that the Black Cat had an affect on dolphin behaviour at Lyttelton, but this effect appears to reduce with regards stress, negative stress and association behaviour over time. All three data sets concur that there is a season effect, but only two agree that there is also a site effect – NPAN and APN.

SAN returns a significant difference for association for site, season and the two interacting factors site and season. NPAN returns no significant difference for association and neither NPAN nor APN show any significant difference for positive behaviour. Neutral behaviour in SAN is significant for site, season and the interaction between site and season whereas NPAN and APN show a significant difference only for the interaction between site and season. As all three categories or data sets, SAN, NPAN and APN, return a significant difference in neutral behaviour it can be argued that both the Black Cat and Caroline Cat have an effect on dolphin behaviour at Lyttelton and Timaru respectively, with a reduction in neutral behaviour observed for

both sites in Season 2 in SAN, but where NPAN shows that neutral behaviour is greater at Lyttelton than Timaru but also that Lyttelton experienced a large decline in neutral behaviour between Season 1 and Season 2 and the difference between neutral behaviour at Lyttelton and Timaru being significant in Season 1, but not Season 2.

It could be argued that the decline in amount of time spent exhibiting neutral behaviour was due to the presence of the Black Cat, but what is more interesting is that the decline in neutral behaviour at Lyttelton where the difference between sites was significant in Season 1, results in no significant difference between sites in Season 2. Possibly the reduction in time spent exhibiting neutral behaviour was due to the fact that the Caroline Cat commenced tours in November 1999 but only became properly established in 2000, where the Black Cat had been operating tours for two years prior to this. The decline in neutral behaviour resulted in both sites having a comparable level of neutral behaviour during Season 2, which may indicate that in the second or subsequent years of tour operation neutral behaviour decreases to a comparable level between sites. In SAN neutral behaviour versus site and season are also significant indicating that overall neutral behaviour is influenced by the presence of the Black Cat and Caroline Cat in both seasons over time.

### **3.9.2 Black Cat versus Caroline Cat Using Behavioural Transitions**

**x+x-x+x**

There were four behavioural transitions within the group stress that changed at Lyttelton, of which two increased and one decreased in Season 1 and one increased in Season 2. This is the same for negative stress in NPAN but this group also showed a decrease in one transitional group in Season 2. There were no significant changes at Timaru in stress or negative stress for any category. Regardless of testing association in SAN or NPAN the association behaviour transitions return the same result for Lyttelton where there is one transitional behaviour which increases and one which decreases in Season 1, and two which increase in Season 2. Timaru exhibits no change in transitional behaviours regardless of category.

Neutral behaviour also reflects the same result between the categories SAN and NPAN where there is a decrease in season 2 for both sites in p/s, s/p. Where the results can be seen as equivalent for each individual site the results between sites are very different with Lyttelton exhibiting more changes than Timaru in all groups other than the neutral group, indicating that the Black Cat has a much greater impact on the behaviour of dolphins at Lyttelton and that the Caroline Cat had little overall effect on the behaviour of dolphins at Timaru. This appears to be upheld by the results from the APN category. Avoidance behaviour was greatest at Lyttelton where a large decline in neutral behaviour was also seen from Season 1 to Season 2.

It is difficult to ascertain whether a decrease in neutral behaviour reveals anything about dolphin behaviour with regard to the effect that a tour boat may have on behaviour. A decrease in neutral behaviour but no increase in any other observed behaviour indicates that dolphins that would normally be observed performing neutral behaviour either left the vicinity as the boat approached, or performed other behaviours in place of the neutral behaviour, but not significantly more of one behaviour than another. The decrease in stress behaviour exhibited by the dolphins in Season 2 at Lyttelton could be attributed to habituation, adaptation or sensitisation to the Black Cat resulting in less stress behaviour.

### **3.10 Adaptation**

Adaptation, in biology, refers to the way an animal adjusts to its environment. However, some adapted animal behaviour may show no obvious advantage (Ridley, 1986), for example, dolphins that swim to or with tour boats. To determine why an animal performs a particular behaviour it is first necessary to determine how that behaviour enables an animal to produce off-spring. It is also necessary to look at why a behaviour is performed and what triggers or mechanisms produces that particular behaviour, how it developed and what its evolutionary history is (Ridley, 1986).

Behaviour may differ due to the animal's adaptation to a particular environment, which in theory would result in relatively more reproduction than a less well-



developed behaviour (Ridley, 1986). This would be interesting to study with regard to Hector's dolphin behaviour and tour boat presence. The same animal may also not respond to the same stimulus in the same way on different occasions and may change its behaviour even if environmental factors appear to be constant. If an animal is hungry, its behaviour would be different than if it was not, when in the presence of food. This is a change due to internal conditions (Ridley, 1986). Dolphins may be more inclined to be present around a tour vessel if a vessel such as the Minerva, which is a fishing boat, were present at the same time and in close proximity. There are also external conditions to note. The animal may cease feeding because a predator is close by (Ridley, 1986), or if a tour boat were to disturb the feeding area. So, for any behaviour pattern in any species there will be some motivational tendency and external stimuli which describe the condition under which that behaviour is performed. Animals are not only controlled by external stimuli, but also an internally-determined preferences and motivation (Ridley, 1986).

### **3.10.1 Associative and Non-associative Learning**

In addition animals can change their behaviour due to experience and learning. There are two descriptions of learning: associative and non-associative.

A dolphin learns that different properties of the environment or different stimuli are associated. The behaviour of the dolphin is then modified in response to one of the stimuli. For example, a chimpanzee may learn an association between poking a stick into a termite mound and pulling out a stick covered with a meal of termites (Ridley, 1986), and a dolphin may learn an association between a non-moving fishing vessel and a meal of fish. As the chimpanzee learns to poke a stick into a termite mound when it is hungry, so a dolphin learns to approach a non-moving fishing vessel when it is hungry, but never a trawler, which does not represent a meal. Bottlenose dolphins have been shown to be highly trainable and to pick up plastic rings on command, and when blindfolded dolphins adapt by using 27% more echolocation per unit time to compensate for loss of vision, when compared to being permitted to visualise the rings (Akamatus *et al.*, 1995). This can also be divided into two categories: habituation and sensitisation (Ridley, 1986).

### **3.10.2 Habituation**

If a stimulus is repeated and determined to be harmless to the animal, the animal ceases to have a behavioural response to it. For example, when repeatedly prodded, the sea hare *Aplysia* comes to ignore the stimulus and its siphon and gills stay out instead of re-coiling (Ridley, 1986). Habituation can be seen in ourselves when we ignore the noise of a fan but immediately notice when it stops or changes (Slater, 1999). Habituation is a learned behaviour in that an animal does not continue to respond to a repeated but seemingly harmless stimulus (Ridley, 1986). In view of this definition, it could be argued that dolphins who continuously approach boats year after year consider that the vessels are harmless. Habituation means to become less sensitive to a stimulus. On the other hand we may not have observed dolphins in the vicinity of a boat until after they had become accustomed to the presence of the vessel, resulting in loss of avoidance behaviour observations, as could be argued to have been observed at Lyttelton.

Habituation has been recorded in marine mammals but may not necessarily be indicative of long-term effects. In order to determine this one would need to undertake prolonged studies on the same group of animals over an extended time (National Research Council, 1994), and preferably include a naïve population from which an ethogram can be attained, Timaru would represent an opportunity for this to occur.

To determine if habituation has occurred, longitudinal, sequential measurements of individual responses are suggested in response to controlled stimuli. Otherwise studies will be measuring tolerance to vessels rather than true habituation (Bejder *et al.*, 2006b). Or, it may be that habituation did not take place, but those dolphins most vulnerable to the presence of the Black Cat left the study site prior to commencement of observation as suggested in other studies (Bejder *et al.*, 2006b).

### **3.10.3 Sensitisation**

This is the opposite of habituation. An electric shock to the *Aplysia* causes it to become responsive to prods it would otherwise be less responsive to (Ridley, 1986).

Dolphins may become less responsive to tour boat presence the longer tour boats operate in the area, thus causing a change in behaviour or response to the vessel over time. As was the case with regard to the study on dolphins that were subjected to intermittent noise and continuous noise, whereby dolphins exhibited no stress to the continuous noise disturbance yet showed stress behaviour toward the intermittently disturbing noise, sensitisation may occur where boat traffic is constant or to a set timetable than boat traffic which is intermittent and hence dolphins are unable to anticipate the time and duration of disturbance.

Once such a response is learned it can be passed on by imitating one another. Behaviours can therefore be inherited by imitation rather than Mendelian genetics (Ridley, 1986). Inherited behaviour imitation is found in many species which form social groups and is known as 'cultural behaviour' (Ridley, 1986). For example, Imo the Japanese macaque is a favoured example by behaviourists, of cultural behaviour from a social animal where after washing potatoes and grain in the ocean eventually lead to 80% of the macaques in Imo's social group exhibiting the same behaviour five years later (Ridley, 1986). Dolphins are also social animals and may learn cultural behaviour such as bow riding and avoidance behaviour.

What makes the study of dolphins and other social animals challenging is that behaviours cannot be distinguished purely as inherited behaviour or learned behaviour, but are influenced by both factors which also have contributions from many other factors such as anatomical, physiological, environmental, and genetic.

### **3.11 Relation to Other Studies**

A study by Bejder *et al.* (2006b), showed that when comparing an area where no tour operators exist to a site with one tour operator, the number of dolphins did not change. When tour operators are increased to two there was a decline of one in every seven dolphin individuals within the site but as dolphin abundance rose in the adjacent site this was thought to show the displacement of more sensitive dolphins from one site to the other resulting in a subset of the population being absent from the study (Bejder,

*et al.*, 2006b). In view of this, it is possible that the more sensitive dolphins within the population at Lyttelton moved to an adjacent site within the harbour, or simply left the specific vicinity when the Black Cat was present. A further explanation may be that dolphins performed other behaviours across the other behavioural groups.

Bejder *et al.* (2006b), and Lemon *et al.* (2006), question whether short-term changes in behaviour with regards vessel presence are sufficient in determining disturbance or impacts on wildlife, and, therefore, any observed short term behavioural responses to a disturbance may not be adequate to determine any significant biological impact. Lars Bejder *et al.*, (2006b), states that short term impacts on behaviour due to disturbance can seldom be transformed to reflect long term changes in relation to reproduction, survival or population size. This is made more difficult in that the group that appears most stressed as indicated by a particular response may not remain so should another indicator of stress be employed (Barton, 2002). That is the case in this study where using an overall category of stress and then dividing this into negative and positive stress provides different results and subsequently different implications. Hence, it is important to ensure that behaviours are viewed in context and analysed appropriately as in the APN category, rather than generally as with the SAN category which combines all stress behaviours regardless of whether negative or positive.

Research undertaken on bottlenose dolphins in Jervis Bay, Australia, indicates that dolphins oriented themselves away from powerboats and that, at a distance of 100 m away from a boat, a change in surface behaviour took place as well as a change in swimming direction (Lemon *et al.*, 2006). If Hector's dolphin were to change direction of swimming as to be oriented away from the Black Cat or Caroline Cat at a distance of 100 m the behaviour would not be seen by an observer and hence not be recorded. Hector's dolphin have been recorded to react to vessel approach from a distance up to 3 km (Bejder *et al.*, 1999). If the reduction in neutral behaviours were due to avoidance behaviour, or swimming away, the observations of avoidance at a distance of 3 km would be overlooked and may explain why there were no significant differences in negative stress or association group behaviours as the dolphins left the vicinity before a chance to observe avoidance behaviour occurred. This could be argued to be a highly probable argument due to the fact that the decline in neutral behaviour from Season 1 to Season 2 for the Black Cat is so great.

A study on bottlenose dolphins (*Tursiops sp*) in Shark Bay, Australia, found no difference in dolphin abundance over time where no or only one tour operator existed (Bejder *et al.*, 2006a). This may also be true of Timaru, as no significant change was determined in either SAN or NPAN groups indicating that overall dolphin behaviour was unchanged throughout the study. It could be argued that dolphin numbers remained constant as well as the exhibited behaviours. If a significant number of dolphins had left the population and hence exhibited avoidance behaviour which had not been recorded, there would have been a change from one season to the next in the results for association or neutral behaviours, as is presented for the Black Cat. As there was no significant change in dolphin behaviour at Timaru it appears that the presence of one tour operator has no overall effect on dolphin behaviour. This could be due to the fact that tour operators at Timaru had only recently commenced, but an influencing factor could have been boat type.

There are studies which suggest that dolphin behaviours are less intense towards smaller vessels (Bilgmann *et al.*, 2007). The Caroline Cat was significantly smaller than the Black Cat and this may have been a contributing factor towards dolphin responses towards the vessels. During the collection of transitional data for dolphins targeted for DNA collection using a biopsy pole system on bow riding dolphins in New South Wales (NSW), Australia, a clear pattern emerged with regards behaviour and boat size (Bilgmann *et al.*, 2007). This leads to the suggestion that dolphins at Lyttelton and Timaru may respond differently to the Black Cat than the dolphins at Timaru respond to the Caroline Cat. However, the results obtained using theodolite observations, indicate that dolphins at both sites reacted more positively, in that they associated with smaller watercraft rather than larger boats or ships, and that dolphins at both sites showed a preference to the tour operators boat with no greater chance of observing a dolphin at Lyttelton or Timaru in the presence of their respective tour boat operators. The size of the Black Cat and the Caroline Cat appears not to be a major factor in regard to dolphin behaviour at these sites, especially in regard to swimming direction and quadrant preference. Responses to sampling from larger boats resulted in weaker responses, all of which resulted in either no noticeable reaction and the dolphins continued to bow ride or the dolphin flinched and continued to bow ride. (Bilgmann *et al.*, 2007). It may be inferred from this study that boat type

did not influence the numbers of observations at either Lyttelton or Timaru, but may have influenced Hector's dolphin responses to boat presence.

### **3.12 Conclusion**

There is no greater chance of sighting a dolphin with the Black Cat than with the Caroline Cat or at one sight over another. The Caroline Cat negatively affected dolphin behaviour at Timaru during season 1, as indicated by dolphins exhibiting avoidance behaviour for the majority of the time observed, 24.31% (Table 38), whereas dolphins at Lyttelton exhibited much less avoidance behaviour, and did not show any change in avoidance behaviour between seasons (2.53% and 2.38% respectively). Dolphins at Timaru appear not to be negatively impacted by the presence of the Caroline Cat over time, shown by the significant reduction in the time spent exhibiting avoidance from season 1 to season 2 (24.31% – 7.41% respectively). However, neutral behaviour was shown to be consistently lower in season 2 than season 1 for dolphins at Lyttelton, but where positive behaviour increased, indicating that dolphins at Lyttelton choose to interact with the Black Cat when it is conducting wildlife or dolphin watching tours, rather than rest. Count data revealed no consistent changes between sites or between observed behaviour when comparing behaviour categories SAN, NPAN and APN, whereas time data showed that dolphins at Lyttelton are more stressed than those at Timaru.

Time series data appears to be the most reliable method of data collection showing that the Black Cat at Lyttelton has a greater impact on dolphin behaviour than the Caroline Cat had on dolphin behaviour at Timaru. Avoidance behaviour was greatest at Lyttelton although this declined between seasons along with a decline in neutral behaviour. Overall it appears that the Black Cat had a significant affect on Hector's dolphin behaviour at Lyttelton, but whether this can be deemed detrimental on overall biological fitness remains uncertain.

In order to determine if dolphins are negatively impacted it is necessary not only to record the number of observations that stress behaviours were exhibited, but also

include time as a factor to show the duration of stress compared to other behaviours. It is also necessary to make a distinction between negative and positive stress in order to gain an overall picture. Stress behaviour for the Black Cat was observed on 370 occasions and neutral behaviour observed on 320 occasions but the 320 observations of neutral behaviour were equivalent to a total of 1696 minutes compared to the 370 observations of stress behaviour of which negative stress behaviour had a total of 910 minutes, even though total stress behaviours amounted to 3564 minutes. It is, therefore, clear that recording only stress versus all other behaviours is not adequate in defining dolphin behaviour, or in determining an overall accurate depiction of a situation.

It is necessary to observe a range of behaviours to enable context with regard to stress. It is not simply a case of determining what stress is, or whether dolphins exhibit stress, but rather what type of stress it is and in what context it was exhibited. To report that dolphins exhibit stress a certain number of times or for a certain percentage of the time is in itself inconclusive. The matter should be more focused on defining stress as either good or bad, negative or positive, and only then is it possible to determine any real cause for concern in relation to dolphin behaviour or reproduction.

It is also not conclusive to record solely how often stress behaviour occurs or how many times avoidance behaviour is recorded. Other than providing basic factual information, recording in this way does not give a clear indication of whether stress is significant in occurrence. Stress behaviour may occur on more occasions than a neutral behaviour but this does not necessarily indicate that dolphins are negatively impacted.

### **3.13 Further Research**

Specific research investigating habituation, sensitisation and tolerance of Hector's dolphins is required in order to determine if the decrease in avoidance and neutral behaviour is the result of becoming accustomed or adapting to the presence of the Black Cat. Studies should be conducted over a long-term period, rather than

seasonally and intermittently, in order to present genuine affects of long-term tour boat presence on any behavioural changes. Substantial focal animal sampling would be useful in determining individual responses over time of specific individuals, and possibly also indirectly render information about spatial distribution and group dynamics.



# **Chapter 4 - Approach Quadrant Preference Exhibited by Hector's Dolphin Towards Tour Boats at Lyttelton and Timaru**

## **4.1 Abstract**

Any preference in swimming direction in the presence of tour boats, and whether Hector's dolphin exhibit preference when approaching either the Black Cat at Lyttelton or the Caroline Cat at Timaru was investigated. Any preference and avoidance of specific boat quadrants was investigated in relation to the stern, portside, bow and starboard side of the tour boats. Swimming direction was recorded as either swimming towards, swimming away from or swimming with the boat and quadrants included the stern, bow, starboard and portsides. Dolphins consistently showed a preference to the direction of approach and departure from tour vessels with a strong tendency toward the bow of the boat, and least with the stern. The results were similar irrespective of site, season or vessel.

## **4.2 Introduction**

Killer whales show no preference in swimming direction when left undisturbed, but when disturbed they favour a course which allows them to escape the narrow Johnstone Strait and enter the open waters of the Queen Charlotte Strait (Kruse, 1991). One of the most abundant dolphins around New England is the Atlantic white-sided dolphin (*Lagenorhynchus acutus*). Research examining their behaviour in the

presence of boats showed that Atlantic white-sided dolphin spent most time bow riding and wake riding at the stern of boats and that these behaviours represented the most common observed behaviour in the presence of boats (Weinrich *et al.*, 2001). Whether dolphins prefer the bow or stern or have any preference between the portside and starboard sides of vessels may assist in identifying the quadrant most preferred with regards approach and departure and hence assist research vessels in locating dolphins for observations within a particular quadrant. If dolphins exhibit preference to the stern of the vessel this would assist in suggestions for propeller use whilst dolphins are in the vicinity of a boat.

Investigations into the affect of tours to view dolphins at Pipa Beach, Rio Grande do Norte in Brazil, showed that the way tour boats approach dolphins can have a major influence on the behaviour of dolphins, especially where groups with calves were present (Santos *et al.*, 2006). The study also showed that short term affects were discrete, and that long term studies were needed in order to determine any long-term impacts on dolphin behaviour (Santos *et al.*, 2006). When tour boats interacted with bottlenose dolphins (*Tursiops sp.*) in Doubtful Sound, New Zealand they avoided the vessel by either swimming away or diving away, and swimming behaviour became more erratic during all boat-dolphin interactions, but more so if boats were more intrusive (Lusseau, 2006a). A study around Aberdeen Harbour, Scotland showed that behavioural responses by bottlenose dolphins to boats varied significantly according to boat size, activity and speed, but that dolphins also showed habituation to boat traffic (Sini *et al.*, 2005). A study on bottlenose dolphins in Milford Sound, New Zealand between December 1999 and February 2002 showed that dolphins spent less time in Milford Sound during periods of heavy boat traffic and that they avoided tour boats by remaining at the entrance of the fjord rather than entering the Sound itself (Lusseau, 2005).

A study of the northern resident killer whale (*Orcinus orca*) in Johnstone Strait, British Columbia, Canada, over seven years from 1995 to 2002 showed that disturbance from boat traffic changed killer whale activity in that whales exhibited different activities in the presence and absence of boats with a decrease in feeding

time which resulted in a reduced energy intake when boats were present (Williams *et al.*, 2006). Male and female bottlenose dolphins in Doubtful Sound have been shown to respond differently to interactions with boats where male dolphins began to avoid boats as they became present, but females exhibited vertical avoidance (Lusseau, 2003). The difference in behavioural response was suggested to be related to the different physiology of males and females in that metabolic rates differ, where males have a larger energy store than females and hence are able to meet the energetic demands easier (Lusseau, 2003). Behavioural responses by the grey dolphin, (*Sotalia guianensis*) to the presence of tour boats in the Bay of Curral, Pipa-RN, Brazil, showed that dolphins dived for longer periods and formed a tighter cohesive group as the boats came closer than 100 m. However, the study was unable to conclude what particular aspect of the boats caused the avoidance behaviour, but suggested that the noise of the engines were probably responsible (do Valle and Melo, 2006).

Dolphins have also been observed to be associated with smaller watercraft (Simmons *et al.*, 2006), and are reported to become habituated to the presence of small power boats in areas where local recreational boating activity exists (Sayigh *et al.*, 1993). The association and habituation to smaller boats could possibly be linked to the difference in noise from various engines and propellers. Underwater noise has been shown to have an effect on the behaviour of a range of cetacean species, with dolphins being more sensitive to certain types of noise than humans (DeLong *et al.*, 1998) and being able to hear underwater noise up to eight kilometres away (Goold and Fish, 1998).

Boat traffic has been shown to have an affect on the acoustic behaviour of Pacific humpback dolphins (*Sousa chinensis*), in Moreton Bay, Australia, although communication clicks did not alter, whistling significantly increased after a boat moved at a distance of 1.5 km from the group (Van Parijs *et al.*, 2001). This has also been observed in Bottlenose dolphins resident in Sarasota, Florida (Buckstaff, 2004). Group cohesion became closer and mother and calf increased vocal communication (Van Parijs *et al.*, 2001). Noise levels in the St. Lawrence River Estuary have been

shown to have a detrimental affect between individuals of beluga whales (Scheifele *et al.*, 2005).

Anthropogenic underwater noise has been shown to affect fish abundance (Mitson and Knudson, 2003), and boat engine noise has been shown to significantly elevate the fathead minnow fish (*Pimephales promelas*) auditory threshold at 1 kHz (7.8 dB), 1.5 kHz (13.5 dB), and 2.0 kHz (10.5 dB) (Scholik and Yan, 2002). Over short durations this leads to a significant change in hearing capability, implying that noise generated from boat engines can have significant environmental impacts on fishes (Scholik and Yan, 2002). Whether the noise is intermittent or continuous also seems to be a major factor. The common carp (*Cyprinus carpio*), the gudgeon (*Gobio gobio*) and the European perch (*Perca fluviatilis*) were exposed to intermittent ship noise at 153 dB and continuous noise at 156 dB re 1  $\mu$ Pa, 30 min. All fish species responded with increased cortisol secretion when exposed to intermittent boat noise but showed no elevation when exposed to continuous noise, indicating that intermittent ship traffic constitutes a potential stressor in contrast to continuous noise (Wysocki *et al.*, 2006).

The Indo-Pacific humpbacked dolphins (*Sousa chinensis*) and finless porpoises (*Neophocaena phocaenoides*) reside in Sha Chau, an area heavy in boat traffic, in Western Hong Kong (Wursig and Green, 2002). Tankers were recorded emitting noise at levels of 110 dB re 1  $\mu$ Pa<sup>2</sup>/Hz at distances up to 200 m, and as it is thought that humpbacked dolphins and finless porpoises are not very sensitive to sounds below 300 Hz, the Airport Authority Hong Kong (AA) restricted underwater sounds to spectrum levels to no greater than 110 dB re 1  $\mu$ Pa<sup>2</sup>/Hz at frequencies above 300 Hz for distances greater than 300 m (Wursig and Green, 2002). At the time of the study it was unknown as to whether the noise levels inhibited acoustically based feeding or communication, or whether dolphins became stressed or suffered any permanent hearing damage (Wursig and Green, 2002). However, communication ranges are not the same for all cetacean species, nor are all cetacean species equally sensitive to the same noise. The range of whistle communication of the white-beaked dolphin (*Lagenorhynchus albirostris*) Faxafloi Bay (Iceland) ranged from 140 m to 10.5km at

levels of 118 dB and 167 dB respectively (Rasmussen *et al.*, 2006). A study on killer whales (*Orcinus orca*) in British Columbia showed that killer whale calls are at levels of 105-124 dB re 1  $\mu$ Pa (Erbe, 2002).

Hector's dolphins have been reported to be able to hear noise from up to three kilometres away (Bejder *et al.*, 1999). Tour boats at both Lyttelton and Timaru run dolphin watching tour activities. The Black Cat is the tour boat operating out of Lyttelton Harbour, and the Caroline Cat out of Timaru Harbour. The Black Cat at Lyttelton represents the vessel with the largest engine and therefore produces the greatest underwater noise. A higher avoidance rate may therefore be due to boat noise and size.

However, there remains a lack of knowledge about many of the normal behaviours of marine mammals due to the amount of time they are below the surface of the water (National Research Council, 1994). There is also lack of distribution and population numbers for many marine mammals, including the three species of *Cephalorhynchus* other than the one studied here (IUCN, 2006). We, therefore, most likely still know much less than we consider we do. To date there have been no specific studies using quadrant methods as outlined in this study in order to determine preference in approach or departure from tour boats.

### **4.3 Aims**

- To show any preference of approach direction towards tourist boats and any preference in swimming behaviour during boat presence.

## **4.4 Objectives**

To determine whether dolphins exhibit any preference in approach or departure from the bow, stern, portside or starboard sides of our boats, the Black Cat at Lyttelton or the Caroline Cat at Timaru. Dolphins may approach a boat from the stern, sides or bow. The null hypothesis is that dolphins show no preference to any swimming direction relative to the boat, nor is there a preference when approaching or departing from the boats.

## **4.5 Methods**

Where possible, volunteers (Appendix E), who had previously been trained during the pilot study in 1999, were employed again when boat-based observations commenced during September 2000. They were already able to take accurate and detailed observations aboard the Black Cat at Lyttelton and the Caroline Cat at Timaru and their data compared to ensure there were no significant biases or difference between observations recorded between observers. A total of 48 successful trips, in regard to dolphin presence, were undertaken at each site per season, of which trip duration varied between two and two-and-a-half hours each. Observations were conducted over two seasons of six months' duration each. Season 1, commenced in September 2000 and ceased at the end of March 2001. Season 2, commenced September 2001 and ceased at the end of March 2002.

Data sheets were designed so that dolphin presence could be marked according to individual dolphin approach relative to quadrant. There were four quadrants each of approximately 90° (Figure 12). The direction of the dolphin(s) were marked using an arrow. The arrowhead represents the dolphin's head as well as the swimming direction of each dolphin. Observations commenced as the first dolphin was sighted and ceased after the last dolphin disappeared from view. Dolphins generally dived beyond the depth they were visible or swam away from the vessel. At a distance of 50

m dolphins could still be seen but were too far away in order to accurately record behaviour.

There were a minimum of two volunteers per trip, or alternatively the author and a volunteer. One individual observed from the bow 180° and the other from the opposite side at the stern 180°. In order to address any unforeseen possible bias, observers intermittently changed positions so that the one observing from the portside-bow intersection changed with the person making observations on the starboard-stern intersection (Figure 12). As dolphins were spotted they were marked on specifically designed data sheets (Figure 20). Observations were not made over a set time period or at the same time for each observer. The duration of time for each observation was recorded.

Once observations ceased, either due to the dolphin swimming away or the boat returning to Harbour, the observer returned to deck and tabulated the observations according to quadrant, direction and the number of successful observations. At the end of the day this data was summarised (Table 44).

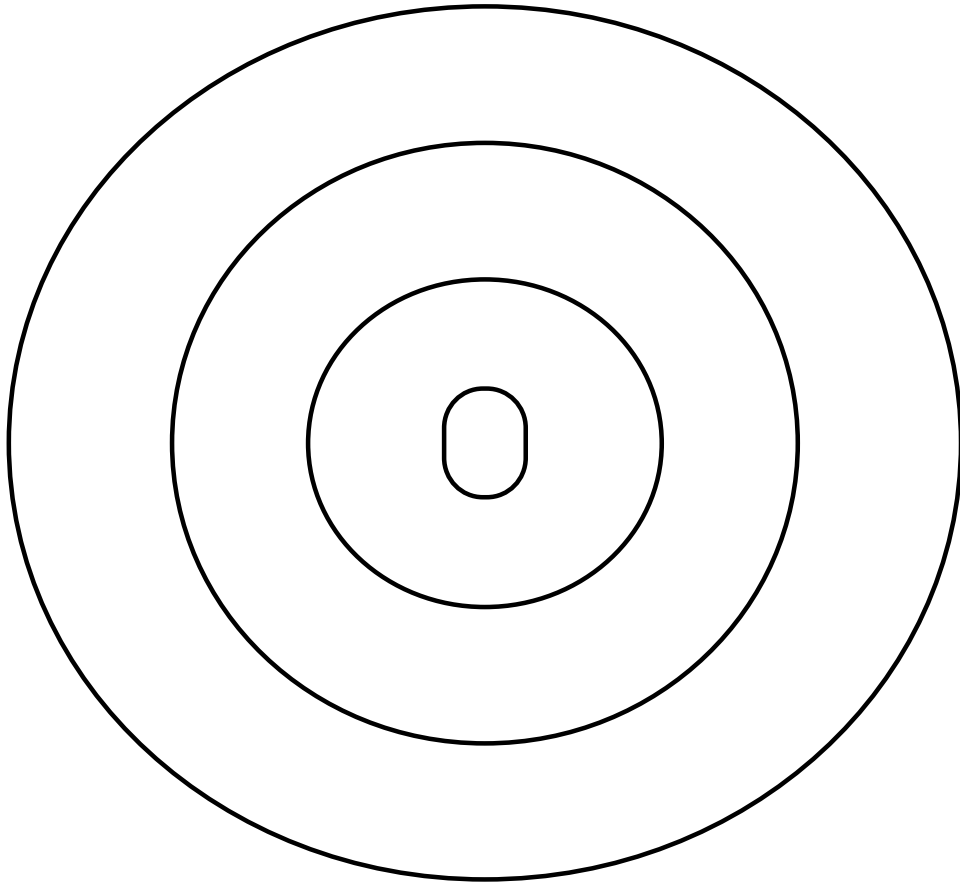


Figure 20: An example of a circular data sheet designed and used to mark dolphin direction and position relative to the tour boat. Each ring around the vessel represents one boat length in order to give a reference from which to work and mark observations. Beyond three boat lengths behaviour generally became obscured by waves and reflection of the water.

Table 44: An example of how data was tabulated after completion of each day’s trips. The table shows the date of observations, the quadrant the dolphins were associated with, swimming direction, the total number of observations and total observation time.

<b>Date</b>	<b>Total # trips</b>	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>	<b>Total # obs</b>	<b>To</b>	<b>Away</b>	<b>With</b>	<b>Total obs time</b>
2 Sept 00	4	2	3	5	3	13	8	2	3	54 mins 40sec
2 Oct 00	3	26	12	0	2	40	27	10	3	1 hr 27 min 32 sec
1 Nov 00	6	2	3	24	28	57	38	15	4	28 mins 10 sec



On each trip there were at least two observers. Each observer was assigned two quadrants. Q1, the bow and Q2, starboard for the 1<sup>st</sup> observer and Q3, the stern and Q4, portside for the 2<sup>nd</sup> observer. All observations were focused on gaining a ‘snap-shot’ of dolphin movement within a particular quadrant over time and marking these ‘snap-shots’ on a data sheet. This included the number of dolphins present in one quadrant, their orientation to the boat and estimated distance from the vessel. Each observer scanned each of their assigned quadrants as each observation period ended. An observation period ended when the dolphin or dolphins that had been sighted were no longer visible. A new observation would then commence. The observers would intermittently change from the Q1, bow-Q2, and starboard intersection to Q2, starboard-Q3, and stern intersection and from Q3, stern to Q4, portside intersection to Q4, portside and Q1, the bow intersection (Figure 10).

If a focal dolphin was observed in Q1, the bow, when that particular observation ceased, Q2, starboard side was scanned for a new focal dolphin. The observer situated at the opposite and reverse side of the vessel also conducted research in the same manner. If initial recording of observations commenced in Q3, the stern, then once that observation had been completed, Q4, the portside, was scanned for dolphin presence. As much as possible, observers interchanged between quadrants in order to reduce bias in observations. If the alternate quadrant did not have dolphins present then observations continued in the same quadrant if dolphins continued to be visible in it. Dolphins were not observed for a standard period of time, but for the time each individual dolphin were present, which generally ranged from between 3 – 40 seconds. Individual dolphins were not identified and therefore, it is probable that in some instances the same individual were recorded. However, this was addressed as far as possible by changing intersections and scanning alternate quadrants. A scan for a new focal animal ranged from a few seconds to hours.

After each trip had concluded, the observations were collated in table form showing the number of dolphins present in each quadrant and orientation to the boat, which was used to determine the swimming direction: either swimming towards, swimming away from or swimming with the vessel. Swimming to the vessel meant that the dolphin’s head was at least pointing toward the boat. Swimming away from the boat meant that the dolphin’s head was pointing away from the boat. Swimming with the

boat meant a dolphin was bow riding or swimming next to the boat or around the boat regardless of which orientation the head was directed in. Swimming with the boat also meant a dolphin was within five meters approximately of the vessel. Any dolphin that did not fit these criteria were not included in the table. For example, a dolphin at some distance away which was seemingly parallel to the vessel or orientated at such an angle as not to be pointing directly to or away from the boat and was not close enough to the boat to be considered swimming with the vessel was not included. This was not a common occurrence. The majority of trips did not have ambiguities with regard to swimming direction. Dolphins that initially swam to the boat would generally, eventually swim away from the boat, but there were dolphins sighted which immediately swam away from the boat as it approached them.

Both seasons' data were combined in order to determine the proportion of trips which resulted in dolphin observations at each site and also to determine the percentage of dolphin observations per quadrant per site.

Observation months were grouped together according to the dolphin calving period, which is considered to be late spring/early summer (Jefferson *et al.*, 1993). Data were combined for both seasons relative to site. September and October were combined to reflect the courting or mating period (Figure 21a; Figure 21b). November, December and January were combined to reflect the calving period and February and March combined to reflect the weaning period. Non-parametric tests were applied in order to determine any difference between dolphin observations and each period of time: courting, mating or weaning. These values were used to determine any difference in dolphin observations per site and also per quadrant per site. The periods mating, calving and weaning were somewhat arbitrary but much less so than using individual months. These arbitrary periods do not assume that all dolphins are mating, calving or weaning at these times, only that a proportion of the population are expected to be engaged in these activities during these periods.

Using combined data for both seasons per site, the median number of dolphin observations per quadrant Q1, Q2, Q3 and Q4 were calculated. These values were used for non-parametric analysis in order to show any significant difference between the number of dolphin observations and quadrant, or to determine any preference to or

avoidance of a particular quadrant, (see section below for full explanation of statistical techniques).

Using combined data for both seasons per site, the average number of dolphin observations for each of the recorded swimming directions: to, away from and with the vessel were calculated. These values were used for non-parametric analysis in order to show any significant difference in swimming direction in the presence of a particular boat, or to determine any preference in approach to, parting from or swimming with a particular vessel.

#### **4.5.1 Statistical Tests Applied to Each Set of Data**

In this study the difference between the numbers of dolphins in response to type of boat was tested. Overall, Kruskal-Wallis tests for equality of population means or medians where there are inequalities for some of the  $x$ . The problem with this test is that it assumes that the response, that is, the number of dolphins, is unaffected by some other factor (Lehmann and D'Abbrera, 1975). For example, it is assumed that weather need not be distinguished between treatments. In support of the Kruskal-Wallis Test is its optimal power when applied to samples containing not more than 15 observations each (Dijkstra, 1988). In this study observations were averaged, resulting in a maximum of 15 observations per sample, therefore, allowing the Kruskal-Wallis Test to be applied with appropriate confidence (Appendix F). Because of such assumptions it was necessary to undertake further statistical tests to determine whether other factors, such as weather, affected the response, which is the number of dolphins, thus allowing the Kruskal-Wallis Test to be applied with more confidence. To this end, a Friedman's Test was also employed to see whether blocking the monthly variation would improve the data analysis. Accordingly, I have presented the results of both the Kruskal-Wallis and Friedman's test for the remainder of the chapter.

A Kruskal-Wallis Test was conducted to determine any difference in quadrant preference for each site per season, for each mating, calving and weaning period and also to determine any difference in dolphin swimming direction per site whilst the tour boats were present. A Friedman Test, blocked by month, was also conducted in

order to determine any specific significance between quadrants, or swimming direction, or periods of mating, calving and weaning at each site. The percentages overall of observations at Q1, Q2, Q3 and Q4 were calculated for the Black Cat and Caroline Cat (Figure 22).

The swimming direction of dolphins was also recorded and the percentage calculated for both sites for observations of dolphins swimming to, swimming away from and swimming at the two sites (Figure 23). Again a Kruskal-Wallis and Friedman Test were conducted to determine any significant difference.

## **4.6 Results**

### **4.6.1 Trips and Observations over Both Seasons**

Of the 96 trips undertaken aboard the Black Cat, 60 trips (76%) were successful in sighting dolphins. The total number of individual dolphin observations at Lyttelton for both seasons was 1121. Of the 96 trips conducted at Timaru, 19 trips (24%) were successful over both seasons with the total number of dolphin observations for both seasons totalling 390.

During the mating, calving and weaning periods, the Black Cat had consistently higher observations associated with Q1, the bow for all periods (Figure 21a). The Caroline Cat showed a higher percentage of dolphin observations at Q2, starboard, during calving and weaning periods but where there was an equal chance of observing a dolphin at Q1, the bow, and Q2, starboard during the mating period (Figure 21b).

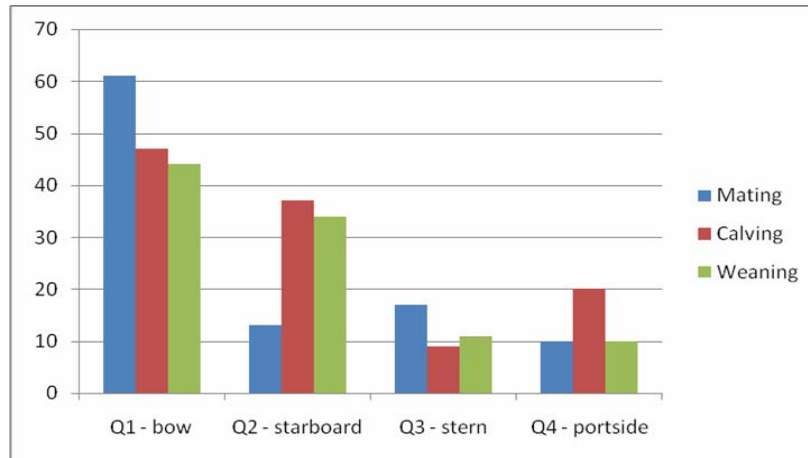
A Kruskal-Wallis Test and Friedman Test on the median number of dolphin observations per quadrant for each period, mating, calving and weaning, for the Black Cat return a significant difference ( $P = 0.025$  and  $P = 0.042$  respectively), but Zars statistical test for  $Q$  returns no significant differences between all mating period and quadrant comparisons (Table 45).

A Kruskal-Wallis Test and Friedman Test on the median number of dolphin observations per quadrant for each of the periods for the Caroline Cat also return a significant difference ( $P = 0.023$  and  $P = 0.049$  respectively), and Zars statistical test for  $Q$  also returns a significant difference between Q1, the bow and Q3, the stern ( $P = < 0.05$ ) and Q2, starboard and Q3, the stern ( $P = < 0.05$ ).

The percentages overall of observations at Q1, Q2, Q3 and Q4 were also calculated for the Black Cat and Caroline Cat (Figure 22). Dolphins were observed most often at Q1, the bow, of the Black Cat (46.57%) and at Q2, starboard, for Caroline Cat (33.59%). There were least dolphins observed at Q3, the stern, for both the Black Cat and Caroline Cat (11.86%; 16.92%), (Figure 22).

## 4.6.2 Mating, Calving and Weaning Periods

Percentage of dolphin observations per quadrant for the Black Cat for each period: Mating, calving and weaning.

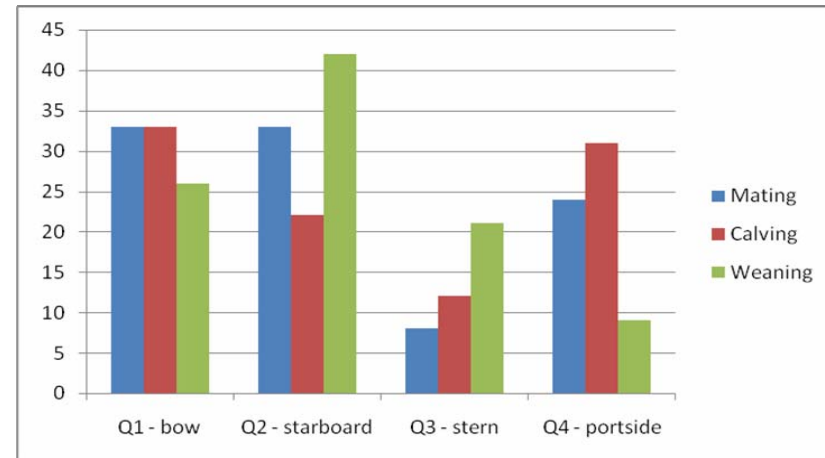


Quadrant Q1, the bow, Q2, starboard, Q3, the stern and Q4, portside.

Figure 21a: Percentage of dolphin observations per quadrant for each period mating, weaning and calving for the Black Cat and Caroline Cat as observed over two seasons. The Black Cat had consistently higher observations associated with Q1, the bow of the boat than any other quadrant for all periods.

Figure 21a/b: Q4, portside had the least dolphins observations during the mating and weaning period for the Black Cat and during the weaning period for the Caroline Cat.

Percentage of dolphin observations per quadrant for the Caroline Cat for each period: Mating, calving and weaning.



Quadrant Q1, the bow, Q2, starboard, Q3, the stern and Q4, portside.

Figure 21b: The Caroline Cat had the highest percentage of dolphin observations at Q2, starboard during the calving period but equal to dolphin observations at Q1, the bow and Q2, starboard during the mating season and the highest percentage of observations at Q2, starboard during the weaning period.

Table 45: Kruskal-Wallis and Friedman Test for significance when testing the mean number of dolphin observations per quadrant per period: mating, calving and weaning, and calculating Zars Statistical test for  $Q$  for the Black Cat and Caroline Cat.

**BLACK CAT - Mating, Calving and Weaning**

**CAROLINE CAT - Mating, Calving and Weaning**

Kruskal-Wallis Test on dolphin observations v Quadrant for each period: Mating, Calving and Weaning

Quadrant	N	Median	Ave Rank	Z
Q1	3	46.3	11.0	2.5
Q2	3	23.56	8.0	0.83
Q3	3	11.36	3.7	-1.57
Q4	3	11.26	3.3	-1.76
Overall 12			6.5	

H = 9.36 DF = 3 P = 0.025

\* NOTE \* One or more small samples

Quadrant	N	Median	Ave Rank	z
Q1	3	27.98	36	2
Q2	3	23.61	30.6	0.55
Q3	3	14.37	17.6	-2.89
Q4	3	23.44	29.8	0.34
Overall 12			28.5	

H = 9.55 DF = 3 P = 0.023

\* NOTE \* One or more small samples

Friedman Test on dolphin observations v Quadrant for each period: Mating, Calving and Weaning (blocked by month)

S = 8.20 DF = 3 P = 0.042

Quadrant	N	Est Median	Sum of Ranks
Q1	3	45.94	12.0
Q2	3	24.09	9.0
Q3	3	11.04	4.0
Q4	3	11.62	5.0

Grand median = 23.17

Zars statistical test for  $Q$  for the Black Cat

Q1-Q2 / 4.8308 = 0.621	no significant difference
Q1-Q3 / 4.8308 = 1.511	no significant difference
Q1-Q4 / 4.8308 = 1.594	no significant difference
Q2-Q3 / 4.8308 = 0.89	no significant difference
Q2-Q4 / 4.8308 = 0.973	no significant difference
Q3-Q4 / 4.8308 = -0.58	no significant difference

S = 1.00 DF = 3 P = 0.801

Quadrant	N	Est Median	Sum of Ranks
Q1	3	28.544	40.5
Q2	3	27.064	38.0
Q3	3	16.852	24.5
Q4	3	24.537	37.0

Grand median = 24.249

Zars statistical test for  $Q$  for the Caroline Cat

Q1-Q2 / 4.8308 = 1.12	no significant difference
Q1-Q3 / 4.8308 = 3.809	<b>significantly different at &lt;0.001</b>
Q1-Q4 / 4.8308 = 1.283	no significant difference
Q2-Q3 / 4.8308 = 2.691	<b>significantly different at &lt; 0.05</b>
Q2-Q4 / 4.8308 = 0.166	no significant difference
Q3-Q4 / 4.8308 = 2.525	no significant difference

### 4.6.3 Preference to Quadrant

Dolphin observations per quadrant over two seasons for the Black Cat (BC) and the Caroline Cat (CC)

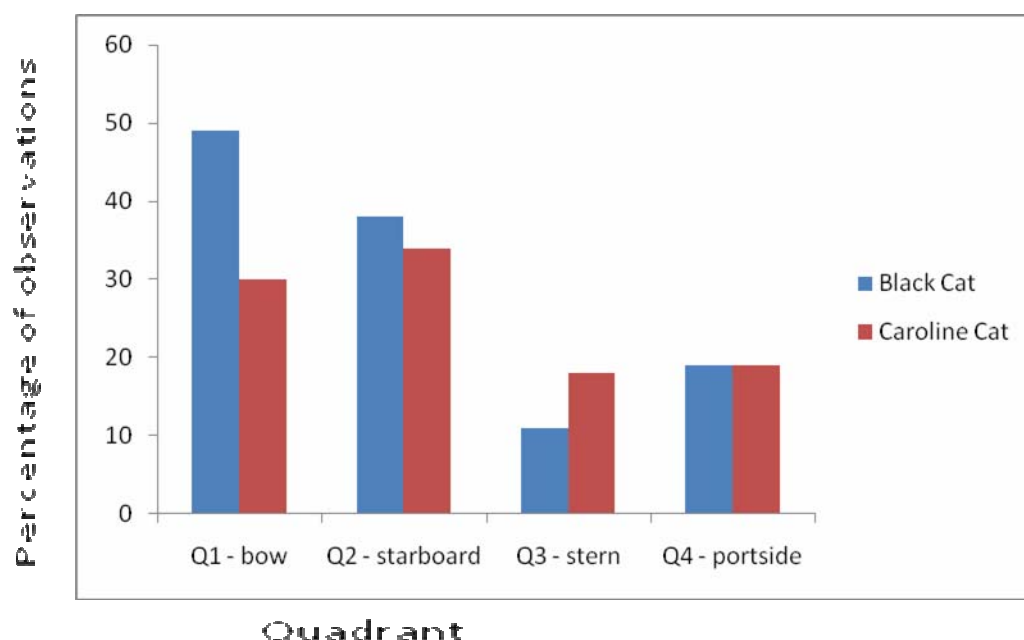


Figure 22: Percentage of dolphin observations per quadrant over two seasons for the Black Cat (BC) at Lyttelton and Caroline Cat (CC) at Timaru. The greatest percentage of dolphin observations for the Black Cat were at Q1, the bow (46.57%) and the least at Q3, the stern (11.86%). The greatest percentage of dolphin observations for the Caroline Cat were Q2, starboard (33.59%) and the least at Q3, the stern (16.92%).

A Kruskal-Wallis Test for quadrant versus number of dolphin observations for the Black Cat returned a significant difference ( $P = 0.000$ ). A Friedman Test for dolphin observations versus quadrant blocked by month for the Black Cat also showed a significant difference ( $P = 0.000$ ) with the Sum of Ranks ranging from 21.5 for Q3, the stern to 50.5 for Q1, the bow (Table 46). Zars statistical values of  $Q$  for non-parametric multiple testing return significant differences between dolphin observations versus quadrant for the Black Cat between Q1, the bow and Q2, starboard ( $P < 0.05$ ), Q1, the bow and Q3, the stern ( $P < 0.001$ ), Q1, the bow and Q4, portside ( $P < 0.001$ ), Q2, starboard and Q3, the stern ( $P < 0.001$ ), Q2, starboard and Q4, portside ( $P < 0.05$ ). There was no significant difference between



the number of dolphin observations between Q3, the stern and Q4, portside (Table 46).

A Kruskal-Wallis Test for quadrant versus dolphin observations for the Caroline Cat returns no significant difference ( $P = 0.128$ ), but the Friedman Test for dolphin observations versus quadrant blocked by month for the Caroline Cat does show a significant difference ( $P = 0.087$ ) with the Sum of Ranks ranging from 24.5 for Q3, the stern to 40.5 for Q1, the bow (Table 46). Zars critical values of  $Q$  for non-parametric multiple testing return significant differences between Q1, the bow and Q3, the stern ( $P = < 0.01$ ), Q2, starboard and Q3, the stern ( $P = < 0.05$ ) and Q3, the stern and Q4, portside ( $P = < 0.1$ ). There were no significant differences between Q1, the bow and Q2, starboard, Q1, the bow and Q4, portside nor Q2, starboard and Q4, portside (Table 46). Dolphins did not prefer one quadrant over another with respect to the bow, portside and starboard sides of the boat, nor were there preferences between the portside and starboard side.

Table 46: Kruskal-Wallis and Friedman Test for significance when testing the mean number of dolphin observations per quadrant based on two seasons observations, and calculating Zars Statistical test for  $Q$  for the Black Cat and Caroline Cat.

**BLACK CAT-QUADRANT**

Kruskal-Wallis Test on Average Number of Dolphin observations v quadrant for the Black Cat and the Caroline Cat

Quadrant	N	Median	Average Rank	Z
Q1	14	10.165	40.4	3.16
Q2	14	6.261	32.7	1.12
Q3	14	1.75	17.9	-2.81
Q4	14	3.335	23	-1.47
Overall	56		28.5	

H = 15.96 DF = 3 P = 0.001

H = 15.98 DF = 3 P = 0.001 (adjusted for ties)

Friedman Test on Average Number of Dolphin observations v quadrant for the Black Cat and the Caroline Cat blocked by month

Quadrant	N	Est Median	Sum of Ranks
Q1	14	10.733	50.5
Q2	14	7.057	40.5
Q3	14	3.65	21.5
Q4	14	3.287	27.5

Grand median = 6.182

S = 21.81 DF = 3 P = 0.000

S = 23.86 DF = 3 P = 0.000 (adjusted for ties)

Zars statistical test for  $Q$  for the Black Cat

Q1-Q2 / 4.8308 = 2.7018	<b>Significantly different at &lt;0.05</b>
Q1-Q3 / 4.8308 = 6.004	<b>Significantly different at &lt;0.001</b>
Q1-Q4 / 4.8308 = 4.761	<b>Significantly different at &lt;0.001</b>
Q2-Q3 / 4.8308 = 3.933	<b>Significantly different at &lt;0.001</b>
Q2-Q4 / 4.8308 = 2.691	<b>Significantly different at &lt; 0.05</b>
Q3-Q4 / 4.8308 = 1.242	no significant difference

**CAROLINE CAT -QUADRANT**

Quadrant	N	Median	Average Rank	Z
Q1	14	5.5	35.1	1.74
Q2	14	3.5	30.7	0.58
Q3	14	1.585	20.8	-2.03
Q4	14	3.25	27.4	-0.28
Overall	56		28.5	

H = 5.69 DF = 3 P = 0.128

H = 5.76 DF = 3 P = 0.124 (adjusted for ties)

Friedman Test on Average Number of Dolphin observations v quadrant for the Black Cat and the Caroline Cat blocked by month

Quadrant	N	Est Median	Sum of Ranks
Q1	14	4.578	40.5
Q2	14	4.391	38
Q3	14	1.953	24.5
Q4	14	3.641	37

Grand median = 3.641

S = 6.58 DF = 3 P = 0.087

S = 7.87 DF = 3 P = 0.049 (adjusted for ties)

Zars statistical test for  $Q$  for the Caroline Cat

Q1-Q2 / 4.8308 = 0.517	no significant difference
Q1-Q3 / 4.8308 = 3.312	<b>Significantly different at &lt;0.01</b>
Q1-Q4 / 4.8308 = 0.725	no significant difference
Q2-Q3 / 4.8308 = 2.795	<b>Significantly different at &lt; 0.05</b>
Q2-Q4 / 4.8308 = 0.207	no significant difference
Q3-Q4 / 4.8308 = 2.588	<b>Significantly different at &lt; 0.1</b>

#### 4.6.4 Preference in Swimming Direction in the Presence of Tour Operator Vessels

Whether dolphins at either site exhibited preference with regard to swimming direction was investigated.

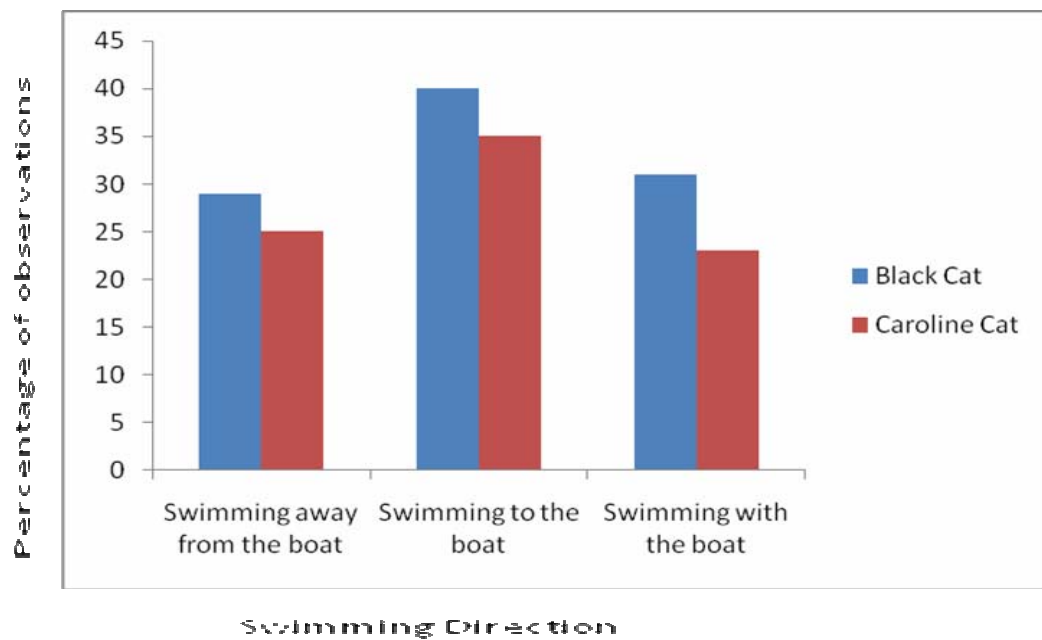


Figure 23: Percentage of dolphin observations per swimming direction over two seasons for the Black Cat and Caroline Cat. There were more dolphins observed swimming towards the Black Cat (39.25%) than were observed swimming away from (29.26%) or with (31.49%) the Black Cat. The Caroline Cat had the same overall result with more dolphins being observed swimming towards (33.59%) than were observed swimming away (25.64%) or with (22.31%) the vessel.

A Kruskal-Wallis Test for swimming direction versus quadrant for the Black Cat and the Caroline Cat show no significant difference in swimming direction and quadrant ( $P = 0.491$  and  $P = 0.573$  respectively) (Table 47). A Friedman Test blocked by month confirms this initial finding returning no significant difference between swimming direction and quadrant for the Black Cat ( $P = 0.484$ ) and the Caroline Cat ( $P = 0.297$ ) (Table 47).

Table 47: Kruskal-Wallis and Friedman Test for significance when testing the percentage of dolphin observations per direction of swimming: swimming towards, away and with the vessel based on two seasons' observations, and calculating Zars Statistical test for  $Q$  for the Black Cat and Caroline Cat.

**BLACK CAT-DIRECTION**

Kruskal-Wallis Test on % of Dolphin observations v swimming direction

Quadrant	N	Median	Average Rank	Z
Swim away	14	30.45	20.2	-0.49
Swim to	14	36.35	24.7	1.19
Swim with	14	30.99	19.6	-0.69
Overall	42		21.5	

H = 1.42 DF = 2 P = 0.491

H = 1.43 DF = 2 P = 0.490 (adjusted for ties)

Friedman Test on the % of Dolphin observations v swimming direction

Direction	N	Est Median	Sum of ranks
Swim away	14	31.077	26.5
Swim to	14	37.223	31.5
Swim with	14	29.8	26

Grand median = 32.700

S = 1.32 DF = 2 P = 0.516

S = 1.45 DF = 2 P = 0.484 (adjusted for ties)

Zars statistical test for  $Q$  for the Black Cat

tb - aw / 3.742 = 1.336 No significant difference  
 aw - wb / 3.742 = 0.134 No significant difference  
 tb - wb / 3.742 = 1.470 No significant difference

**CAROLINE CAT -DIRECTION**

Quadrant	N	Median	Average Rank	Z
Swim away	14	32.05	22.2	0.25
Swim to	14	19.26	18.8	-1.01
Swim with	14	35.25	23.5	0.76
Overall	42		21.5	

H = 1.11 DF = 2 P = 0.573

H = 1.12 DF = 2 P = 0.572 (adjusted for ties)

Direction	N	Est Median	Sum of ranks
Swim away	14	31.686	28.5
Swim to	14	22.968	24
Swim with	14	31.054	31.5

Grand median = 28.569

S = 2.04 DF = 2 P = 0.361

S = 2.43 DF = 2 P = 0.297 (adjusted for ties)

Zars statistical test for  $Q$  for the Caroline Cat

tb - aw / 3.742 = 1.203 = No significant difference  
 aw - wb / 3.742 = -0.802 = No significant difference  
 tb - wb / 3.742 = -2.004 = No significant difference

## 4.7 Discussion

The Black Cat at Lyttelton was most successful for the purpose of dolphin observations than the Caroline Cat at Timaru (76% and 24% respectively). At both sites dolphins showed a preference for the bow of the boat and least for the stern, with no preference between portside and starboard. At both sites there were significantly more dolphins observed swimming to the tour-boats than away or with the boats. Splitting dolphins in to arbitrary periods, mating, calving and weaning was found to have no significant result.

### 4.7.1 Mating, Calving and Weaning Periods

There were no significant difference in dolphins associated with the four quadrants when testing each individual period, mating, courting and weaning periods, although there was a significant difference between dolphin observations and these periods when compared to each other at for the Black Cat at Lyttelton (Kruskal-Wallis:  $P = 0.025$  and  $P = < 0.042$  respectively). There were no significant differences within each site, for each period mating/quadrant, calving/quadrant and weaning/quadrant, but differences between mating/calving/weaning/quadrant. The Caroline Cat also returned a significant difference between mating, courting and weaning periods ( $P = < 0.023$  and  $P = < 0.049$  respectively) and a significant difference when testing the Sum of Ranks as per Zars Statistical test of  $Q$ . This test showed that the number of observations were significantly different between Q1, the bow and Q3, the stern ( $P = < 0.05$ ) and also between Q2, starboard and Q4, portside ( $P = < 0.05$ ). This suggests that there is a difference in dolphin behaviour around a tour vessel which has been operating for a number of years such as the Black Cat, and a tour vessel which has just begun operating and is not yet established, as was the situation with the Caroline Cat. The Black Cat had been conducting tours at Lyttelton for two years prior to commencement of this research whereas the Caroline Cat had just begun tour operations. Differences in behaviour may also be related to the differences in boat size, where the Black Cat was larger than the Caroline Cat. During trips the Black Cat followed a specific route whereas the Caroline Cat had no pre-determined course. In addition, there are other important differences between the sites. The harbour at Lyttelton is more enclosed than at Timaru and is subject to more boat traffic, including cruise

liners, and large commercial vessels associated with a large working dock. These factors may also influence dolphin behaviour at each site.

A non-significant result between dolphin observations and quadrant for the Black Cat at Lyttelton may reflect a degree of habituation of the dolphins to the presence of the vessel and hence a decrease in stress or concern around the stern. It could be argued that this was because the Caroline Cat was operating around a naive population, a population which had not yet become accustomed to tour operations. The resultant significant difference seen between dolphin observations at Q1, bow and Q3, the stern at Timaru could be argued to be a direct result of the reaction of a virgin population towards the Caroline Cat. The results in relation to the numbers of dolphins observed at Q1, the bow and Q3, the stern are what would be expected in relation to propeller and engine noise.

The Caroline Cat showed the greatest numbers of dolphin observations being observed at Q1, the bow and Q2, starboard sides and the least at Q3, the stern, whereas there were no significant differences in dolphin observations between any of the quadrants for the Black Cat during mating, calving and weaning periods at Lyttelton. This suggests that dolphins at Timaru exhibit avoidance behaviour or ‘concern’ relative to the stern of the Caroline Cat, whereas dolphins at Lyttelton have become accustomed to the presence of the Black Cat and, therefore, exhibited no significant avoidance behaviour to the stern and were therefore more randomly dispersed around the vessel.

#### **4.7.2 Preference to Quadrant**

There was a difference between sites for quadrant preference with dolphins at Lyttelton showing a preference to Q1, the bow and dolphins at Timaru exhibiting a preference to Q2, the starboard side. Both sites showed least numbers of dolphins at Q3, the stern, which may indicate avoidance behaviour towards the propellers which was situated at the rear of both vessels.

The dolphins at Lyttelton associated with the Black Cat returned more significant differences between quadrant comparisons than did the Caroline Cat at Timaru with four of the six pairwise comparisons returning significant differences for the Black Cat compared to only three of the six paired comparisons for the Caroline Cat thereby

indicating a definite association within certain quadrants at both sites although more preferences were exhibited at Lyttelton than Timaru. Dolphins at Lyttelton exhibit a significant difference greater than at Timaru in each of the two paired quadrant comparisons where a significant difference was indicated: Q1, the bow versus Q3, the stern ( $P = 0.001$  and  $P = 0.01$  respectively) and Q2, starboard versus Q3, the stern ( $P = 0.001$  and  $P = 0.05$  respectively). Whether or not this is due to the duration of tour operations at each site is unclear and further research would be required in order to determine if the persistence of tour operations over time has an effect on quadrant preference.

The level of significance between quadrants and dolphin observations suggests that dolphins at Lyttelton exhibit a clear difference in preference to quadrant where tours have been operating for several years than are exhibited where tours have recently commenced. The results suggested a more random distribution of observations around the Caroline Cat than the Black Cat. It could be argued that the greater significant difference between dolphin observation and quadrant may be seen where dolphins have become accustomed to a particular vessel, and thus exhibit a preference to the bow and avoidance of the stern as seen in the results at Lyttelton. However, quadrant preference could also be the result of one site having a greater amount of traffic than the other. Lyttelton is an operating Harbour with cruise ships, cargo ships and other commercial ships using the channel as well as recreational and tour operator vessels, whereas Timaru has much less traffic. This would account for the difference in significant levels between the dolphin observations and quadrant between the Lyttelton and Timaru where dolphins at Lyttelton showed a significance difference between Q1, the bow and Q3, the stern ( $P = 0.001$ ), and Q2, starboard and Q3, the stern ( $P = 0.001$ ) and the same quadrants for the Caroline Cat being significant at lower levels ( $P = < 0.01$  and  $P = < 0.05$  respectively).

The Black Cat tends to have a set, regulated route around the harbour, which would result in dolphin observations showing bias should dolphins exhibit tenacity in location within the harbour. In the theodolite section, clusters of dolphins were marked within certain areas of each of the harbours at Lyttelton and Timaru. As the Black Cat followed an assigned course around the harbour this would result in dolphins being observed in particular areas of the harbour and thus within a particular quadrant of the Black Cat.

The Caroline Cat at Timaru did not follow a set, assigned, regulated route and often directed its course on an opportunistic course as advised by local fishermen who had sighted dolphins earlier in the day and thus reported to the skipper of the Caroline Cat the best location to sight dolphins. As the Caroline Cat had no set course it would be reasonable to expect that dolphin observations would be more random with regard to quadrant even if clusters had been recorded within the harbour. However, the clusters of dolphin observations as recorded by theodolite observations at Timaru showed a more random and more numerous set of dolphin clusters which were also spread over a larger area at Timaru than were observed and recorded at Lyttelton. This suggests that the lower significance in preference to quadrant observed at Timaru may be due to the reaction of a naive population towards the presence of the Caroline Cat, and the significant preference to quadrant at Lyttelton be a reaction to a population of dolphins who may be accustomed to the Black Cat and this exhibit a clear preference.

#### **4.7.3 Preference in Swimming Direction in the Presence of Tour Operator Vessels**

Although the percentage of dolphin observations indicated that more dolphins swimming towards the Black Cat than to the Caroline Cat, the statistical analysis shows that there was no significant difference in swimming direction around either the Black Cat or Caroline Cat. This would strongly suggest that only those dolphins which “choose” to be present with either vessel remained in the vicinity of the boat and, any dolphins that did not ‘choose’ to interact with either vessel departed the vicinity either prior to being observed or, represented those observations of dolphins, which departed from the vicinity, but that those which departed were not significantly more than those that remained and interacted with the vessel.

#### **4.7.4 Efficiency of and Justification for Using Non-parametric Tests**

It has long been thought that non-parametric methods have less power than parametric methods (Noether, 1967; Sprent, 1993). Examples of the value and efficiency of both the Kruskal-Wallis Test and the Mann-Whitney tests are supported and outlined in detail in several publications and specialised texts (Randles and Wolfe, 1979; Noether, 1967; Sprent, 1993). The Kruskal-Wallis Test can be compared to the two sample *t*-test, but



whereas the two sample *t*-test is not distribution free the Kruskal-Wallis Test has more flexibility (Noether, 1967). It has been determined that the efficiency of the *W*-test relative to that of the *t*-test is never less than 0.86. In other words, for every 100 observations expanded on the *W*-test there has to be at least 86 observations on a *t*-test to achieve the same power (Noether, 1967). Often there are more observations required by the *t*-test than required for the *W*-test. Hodges and Lehman (1956), investigated the problem of large deviations in samples and determined that that the *W*-test is less likely to reject the (true) null hypothesis than is the *t*-test if large deviations are present within samples as at result of errors. They showed that any rank test is insensitive to the size of large deviations, thus resulting in efficiency equal to if not more than a comparative parametric test where samples are equal (Noether, 1967).

## **4.8 Conclusion in relation to Trips and Observations over Both Seasons**

### **4.8.1 Mating, Calving and Weaning Periods**

The results for the mating, calving and weaning periods show that a naive dolphin population exhibits a clear preference towards different quadrants when unaccustomed to the presence of a tour vessel. They further show that a dolphin population exhibits no difference between quadrant preference and any of the periods mating, calving or weaning.

### **4.8.2 Preference to Quadrant**

There was a significant difference at each site between quadrant preference and quadrant avoidance. The results showed that Q3, the stern, was avoided by dolphins at both sites and Q1, the bow, was the preferred quadrant. The results showed that the population with the least contact with a tour vessel resulted in a more random distribution of dolphins and the longer the contact with a tour vessel the greater the significance in preference to boat quadrant. More preferences were exhibited in relation to quadrants at Lyttelton in relation to the Black Cat than were exhibited at Timaru in relation to the Caroline Cat, suggesting that a naive population is less likely to exhibit avoidance behaviour and is more randomly

distributed around a tour vessel than a population such as seen at Lyttelton, which is in regular contact with the Black Cat and has very clear quadrant preferences.

### **4.8.3 Preference in Direction in the Presence of Tour Operator Vessels**

Regardless of whether a tour vessel had operated for two years as per the Caroline Cat at the end of data collection, or for four years as per the Black Cat at the end of this data collection, there was no significant difference in swimming direction at either site for either tour vessel. Accordingly, there was an equal chance of sighting a dolphin swimming to, away from or with the Black Cat and Caroline Cat at each site, irrespective of the length of time the vessel may have been operating in the area.

## **4.9 Difficulties and Challenges**

### **4.9.1 Quadrants**

When making observations it was sometimes difficult to determine which quadrant a dolphin was approaching or leaving from. Observations over the ocean, particularly in rough or windy conditions, made any observations at distances greater than 20 metres difficult to gauge. For this reason any observations, which were not clearly in one quadrant or another were dismissed for the purpose of analysis. In reality at least 10 degrees either side of each quadrant were not recordable at a distance of more than 10 metres away as the actual position relative to the vessel became distorted. However, on clear, calm days it was possible to observe dolphins some hundreds of metres away.

Weather and ocean states played a vital role in data collection. When the boat was under sail and generally heading in one direction in a straight line, one could mark from which direction the dolphins appeared and approached the vessel. Once associated with the vessel it was obvious which quadrant the dolphins were associated with. However, the engines were not always running and often stopped to allow passengers to view dolphins. The boat can then move from one direction to another on the waves, so a dolphin that was initially sighted on the portside of the bow then ends up on the starboard side of the bow.

No alteration was made to take this into account due to a dolphin's ability to swim and manoeuvre to any position around the boat. For example, if the boat was moved by ocean currents or wind and the dolphins stayed in the position observed, it would be expected that the dolphins would become randomly distributed in all quadrants. As the boat moved, the position of dolphins changed accordingly. However, if dolphins were not equally or randomly distributed in all quadrants, then there was an assumption that there was some preference to a particular quadrant to which they swam.

### **4.9.2 Observations**

Observations were not at regular time intervals or over standard time periods as would normally be preferred. Due to the nature of the animal under observation, standardising observation times or observation time durations were not possible. There are no guarantees of dolphin presence for durations of 10 minutes, for example, from 2 pm to 2.10 pm, or that observations be successful on every trip. It may be argued that data must be collected in this precise systematic way to minimise biases but when working with wild population this is not always possible, especially where animals have freedom to move out of observational view. If we were to restrict observations to a particular time for a particular duration observations would be minimal. There were occasions where trips of 2-3 times a day would result in no observations for up to two weeks. Other occasions resulted in successful observations throughout the day and observations ceased only because the tour operator had to work to a schedule. For this reason, the numbers of observations per month were treated as a sampling replicate in order to give an overall picture of dolphin observations, and any quadrant preferences.

### **4.9.3 Volunteers**

Unfortunately, many volunteers resulted in disappointment because, after being trained, they took advantage of the trust placed in them and proceeded to take friends onto the tour boats under the guise of research, but did not actually collect data. Some volunteers collected data but it was not of sufficient quality to be rendered usable. This was determined by comparing data collected by volunteers and data collected by me as already outlined in Chapter 3. The problems were always addressed immediately and discarded data amounted to less than 5% of the total data collected in Season 1, and less

than 1% in Season 2. These problems became apparent very early on in the research and as a result a volunteer manual was produced along with an application form. In order to ensure the motive of new volunteers training was conducted at Timaru, thus requiring them to rise at 5 am and be ready to depart Christchurch by 6am. Strict guidelines were also imposed regarding behaviour, dress and timekeeping while aboard either of the tour boats (Appendix E). As a rule, most volunteers were excellent candidates and dedicated volunteers whose input, time and energy were invaluable (see Acknowledgements).

## **Acknowledgements**

To retired skipper, Graham Copp, for sharing his 50 years of skipper experience, advice on ocean states, weather, and for ensuring that everyone adhered to boat safety and water regulations, and the volunteers who rose at 5am ready to commence observations. Often the trips resulted in nights away from families and for this sacrifice I am very appreciative.

# **Chapter 5 – Behavioural Response of Hector’s dolphin Towards Tour-Boats and a Recreational Yacht Over One Breeding Season**

## **5.1 Abstract**

Hector’s dolphins were observed at Lyttelton and Timaru from tour boats, and in addition a private yacht at Timaru over a six month period between September-February 1999-2000. Due to intense vessel traffic, working docks, a busy port, and regularly conducted dolphin watching tours at Lyttelton in comparison to Timaru, which is relatively quiet and where tour boats run intermittently and infrequently, it was expected that dolphins would show differences in behaviour between sites and between boats. Quadrant and swimming direction were investigated in relation to tour boats present at both sites, and a private yacht at Timaru. Both count and time data were collected, where count data represented the number of times a behaviour occurred and time data included the duration over which the behaviour occurred. Positive and neutral behaviour were found to be significantly higher at Lyttelton and positive and neutral behaviour significantly lower for both the tour boat and private yacht at Timaru.

## **5.2 Introduction**

In addition to investigating dolphin behaviour solely between tour boats at Lyttelton and Timaru, an additional study was conducted which investigated dolphin behaviour in the presence of a private yacht, which was then compared to dolphin behaviour in the presence of both tour boats. The Henrietta, is a privately owned yacht operated at

Timaru. The tour boat at Timaru (Caroline Cat), and the private yacht, the Henrietta, had smaller engines than that of the Black Cat with the engine of the Caroline Cat being smaller than that of the Black Cat and the Henrietta having the smallest. As dolphins have been reported to react differently to different levels and frequencies of noise, this chapter investigates any difference in dolphin behaviour between boats of varying size, specifically two commercial tour-boats and a private yacht. The Black Cat and Caroline Cat are large catamarans whereas the Henrietta is a small yacht with a significantly smaller engine.

To some degree this study was hindered by the lack of a control, but as with any wild animal research this is not a practical expectation. However, in this instance it can be argued that the population at Timaru was the nearest representative of a control factor that could be found in New Zealand, insomuch as the population of Hector's dolphins at Timaru were a relatively naive population which encountered tour operators for the first time in the year this study commenced, and where the Black Cat had commenced tours a year earlier.

### **5.3 Aims**

- To show any preference or change of approach direction towards the Henrietta, a private yacht, and any preference in swimming behaviour during boat presence over a six-month period.
- To show if there is a significant difference in Hector's dolphin behaviour with regard to avoidance, positive or neutral behaviour in the presence of tour boats, the Black Cat at Lyttelton and the Caroline Cat at Timaru and the Henrietta, a private yacht at Timaru as observed over a six-month period.
- To identify any stress behaviour in Hector's dolphin in the presence of a private yacht at Timaru.

## 5.4 Objective

Dolphins may approach a boat from the stern, sides or bow. The null hypothesis is that dolphins show no preference to any swimming direction relative to the boat, nor is there a preference when approaching or departing from a private yacht.

- To determine whether dolphins exhibit stress behaviour in the presence of a private yacht and determine whether these stress behaviours are wholly negative. The null hypothesis is that dolphins display no stress in the presence of a private yacht.

## 5.5 Methods

In addition to the Black Cat, a private recreational yacht was used to collect quadrant, swimming direction and behavioural data as per the methods outlined in Chapters 3 and 4. Methods varied in the position of observers aboard the yacht who were unable to rotate between the stern-portside intersection to the bow-starboard intersection or from stern-starboard intersection to the bow-portside intersection, and hence, remained static at the bow and stern, facing each other which gave a complete 360 degree view. Data were tabulated after completion of each day's trips (Table 5). The date observations were made, the quadrant dolphins were associated with, swimming direction around the yacht, the total number of observations and total observation time were recorded. Dolphin approach and departure from the yacht were also marked using reference to Q1, the bow, Q2, starboard, Q3, the stern and Q4, portside (Figure 10). A Kruskal-Wallis and Friedman Test were used to determine any significant difference to quadrant and swimming direction. Focal animal sampling was undertaken and behaviour recorded as per the methods in Chapter 4. The behavioural groups within the category APN (avoidance, positive and neutral behaviour) were used to determine any difference in exhibited behaviours.

Arrows were marked on the data sheets which represent the position and swimming direction of individual dolphins, where the arrow head shows swimming direction and

approximate position relative to the boat. Both Kruskal-Wallis and Friedman Tests were blocked by month to remove any major weather variations were used to determine any significant difference to quadrant and swimming direction from September-February 1999-2000. Focal animal sampling was undertaken and behaviour recorded as per the methods in Chapter 4, and the behaviour category APN (avoidance, positive and neutral behaviour) used to determine any difference in exhibited behaviours. A General Linear Model (GLM) was employed to test time data and a Log-linear model employed to test count data.

## **5.6 Results**

### **5.6.1 Quadrant and Swimming Direction**

A Kruskal-Wallis Test showed that dolphins exhibited no significant difference with regard to quadrant preference ( $P = 0.220$ ) or swimming direction ( $P = 0.843$ ) in the presence of a private yacht, the Henrietta (Table 48). A Friedman Test also showed no significant difference with regard to quadrant preference ( $P = 0.109$ ) and swimming direction ( $P = 0.607$ ) for the Henrietta (Table 48). Zars critical value of  $Q$  showed no significant difference between quadrant 1, the bow versus quadrant 2, starboard; quadrant 1, the bow versus quadrant 4, portside; and quadrant 3, the stern versus quadrant 4, portside (Table 48). There were significant differences between dolphins numbers observed with quadrant 1, the bow versus quadrant 3, the stern; quadrant 1, the bow versus quadrant 4, portside and, quadrant 2, portside versus quadrant 3, the stern (Table 48).

Both Kruskal-Wallis and Friedman Tests return no significant differences with regard to dolphins exhibiting preference to one quadrant over another. However, Zars statistical test for  $Q$  showed that there were significant differences between the stern and bow, the stern and starboard side, and the bow and portside of the Henrietta with the Sum of Ranks values indicate that dolphins preferred quadrant 1, the bow and least preferred quadrant 3, the stern, and portside and starboard being most similar (Sum of Ranks; 21.00, 15.50, 10.50, 13.00 for quadrant 1, the bow; quadrant 2, starboard; quadrant 3, the stern and, quadrant 4, starboard side respectively) (Table 48).



Both Kruskal-Wallis and Friedman Tests returned no significant difference with regard to dolphins exhibiting preference in swimming direction in the presence of the Henrietta (Table 48).

The observational count data indicated that in the presence of the Henrietta dolphins at Timaru consistently exhibited more positive behaviour in the months between September and February (Table 49), whereas time data indicated that avoidance behaviour was the most commonly occurring behaviour in four of the five months when dolphins were visible. The exception was September in which positive behaviour was the most exhibited behaviour in the presence of the Henrietta (Table 49). The count data indicated that the behaviour most exhibited at Lyttelton in the presence of the Black Cat for all months September to February was positive, whereas time data indicated that in five out of the six months observed positive behaviour was the most exhibited behaviour. The exception was September in which dolphins exhibited neutral behaviour more often than avoidance or positive behaviour (Table 49). The count data for the Caroline Cat indicated that positive behaviour was the most exhibited behaviour in four of the five months where dolphins were observed. The exception was November where there were equal sightings of dolphins exhibiting avoidance and neutral behaviour (Table 49). Time data also indicated that positive behaviour was the most exhibited behaviour in four of the five months where dolphins were observed. The exception was October where dolphins exhibited neutral most often. There were no sightings in October for either count or time data (Table 49).

Table 48 (following page): Kruskal-Wallis and Friedman Test for significance when testing the mean number of dolphin observations per month versus quadrant and swimming direction in the presence of the Henrietta, and a test on the Sum of Ranks using Zars Statistical Test for  $Q$  for both quadrant and swimming direction.

Kruskal-Wallis Test					Friedman test			
Quadrant	N	Median	Ave Rank	Z	Quadrant	N	Median	Sum of Ranks
Q1	6	9.5	16.4	1.57	Q1	6	9.438	21.00
Q2	6	6.5	13.5	0.4	Q2	6	6.438	15.50
Q3	6	2	8	-1.8	Q3	6	0.687	10.50
Q4	6	5	12.1	-0.17	Q4	6	5.687	13.00
Overall 24		12.5			Grand median	5.562		
H = 4.41 DF = 3 P = 0.220					S = 6.05 DF = 3 P = 0.109			
H = 4.49 DF = 3 P = 0.213 (adjusted for ties)					S = 7.41 DF = 3 P = 0.060 (adjusted for ties)			
Zars statistical test for $Q$ for the Henrietta on quadrant preference					Q1-Q2/2.8868 = 1.905 no significant difference <b>Q1-Q3/2.8868 = 3.637 significant at &lt; 0.002</b> <b>Q1-Q4/2.8868 = 2.771 significant at &lt; 0.05</b> <b>Q2-Q3/2.8868 = 1.732 significant at &lt; 0.05</b> Q1-Q4/2.8868 = 0.866 no significant difference Q3-Q4/2.8868 = -0.866 no significant difference			
$SE = \sqrt{\frac{ba(a+1)}{12}} \quad SE = \sqrt{\frac{5x4(4+1)}{12}} = 2.8868$								
Kruskal-Wallis Test					Friedman test			
Swimming Direction	N	Median	Ave Rank	Z	Direction	N	Median	Sum of Ranks
Sa	6	7.50	9.30	-0.140	sa	6	6.417	11.00
St	6	11.00	10.50	0.560	st	6	10.250	14.00
Sw	6	4.00	8.80	-0.420	sw	6	5.583	11.00
Overall 18		9.5			Grand median	7.417		
H = 0.34 DF = 2 P = 0.843					S = 1.00 DF = 2 P = 0.607			
H = 0.35 DF = 2 P = 0.841 (adjusted for ties)					S = 1.20 DF = 2 P = 0.549 (adjusted for ties)			
Zars statistical test for $Q$ for the Henrietta on swimming direction					sa - st / 2.2361 = -1.341 no significant difference sa - sw / 2.2361 = 0 no significant difference st - sw / 2.2361 = 1.342 no significant difference			
$SE = \sqrt{\frac{ba(a+1)}{12}} \quad SE = \sqrt{\frac{5x3(3+1)}{12}} = 2.2361$								

### **5.6.2 Count and Time Data per month (APN)**

Count data showed that positive behaviour was the most common occurring behaviour exhibited by dolphins in the presence of the Black Cat, Caroline Cat and Henrietta, whereas time data indicated that positive behaviour was the most often occurring behaviour in the presence of both tour boats, the Black Cat and Caroline Cat, but that avoidance behaviour was exhibited most in the presence of the Henrietta (Table 49).

### **5.6.3 Count Data: Avoidance, Positive and Neutral Behaviour (APN)**

A Log-linear analysis of the count data per month, versus avoidance, positive and neutral behaviour showed that there was a significant difference in overall dolphin behaviour between the sites ( $P = 0.001$ ), with a significant difference between the Black Cat and Caroline Cat ( $P = 0.001$ ) and the Black Cat and Henrietta ( $P = 0.001$ ) with significantly lower number of dolphins being observed in September and October compared to other months ( $t = 0.001, 0.001, 0.117, 0.321$  and  $0.025$  for September, October, November, December and February respectively). With regard to positive behaviour there were significant differences between watercraft ( $P = 0.001$ ) and month ( $P = 0.001$ ) where dolphins in the presence of the Black Cat showed significantly more positive behaviour than those dolphins in the presence of either the Caroline Cat or Henrietta ( $t = -16.16, -9.59$  and  $-0.83$  for the Black Cat, Caroline Cat and Henrietta respectively). The months September and November showed significantly less positive behaviour ( $P = 0.001$ ) than all other months ( $t = -5.13, -2.36, 3.61, 0.90$  and  $-0.83$  for September, October, November, December and February respectively). With regard to neutral behaviour there was a significant difference between watercraft ( $P = 0.001$ ) and month ( $P = 0.001$ ) where dolphins in the presence of the Black Cat showed significantly more neutral behaviour than those dolphins in the presence of either the Caroline Cat or Henrietta ( $t = 24.89, -10.16$  and  $-8.95$  for the Black Cat, Caroline Cat and Henrietta respectively). The month November showed significantly greater neutral behaviour ( $P = 0.001$ ) than all other months ( $t = -2.37, -1.24, 5.77, 1.10$  and  $-0.38$  for September, October, November, December and February respectively).

Table 49: The number of occurrences and mean duration of time that avoidance, positive and neutral behaviour were observed (APN). Bold figures indicate the behaviour which occurred the greatest number of times and for the greatest duration of time for each month within Season 1, September 1999-February 2000 for the Black Cat, Caroline Cat and Henrietta.

COUNT DATA: Avoidance, Positive and Neutral Behaviour (APN)				
Site and Season	Month	Negative	Positive	Neutral
Black Cat	Sept	2	<b>42</b>	23
	Oct	18	<b>114</b>	40
	Nov	51	<b>130</b>	84
	Dec	48	<b>122</b>	28
	Jan	66	<b>97</b>	42
	Feb	23	<b>76</b>	32
Caroline Cat	Sept	0	0	0
	Oct	5	<b>16</b>	1
	Nov	<b>28</b>	26	<b>28</b>
	Dec	4	<b>7</b>	0
	Jan	4	<b>28</b>	5
	Feb	9	<b>27</b>	21
Henrietta	Sept	17	<b>45</b>	8
	Oct	0	0	0
	Nov	21	<b>89</b>	23
	Dec	15	<b>59</b>	37
	Jan	9	<b>46</b>	6
	Feb	21	<b>53</b>	4

TIME DATA: Avoidance, Positive and Neutral Behaviour (APN)				
Site and Season	Month	Negative	Positive	Neutral
Black Cat	Sept	0.87	7.74	<b>15.22</b>
	Oct	5.26	<b>24.20</b>	5.46
	Nov	1.54	<b>9.30</b>	3.07
	Dec	4.88	<b>31.46</b>	15.96
	Jan	4.98	<b>6.65</b>	2.67
	Feb	9.62	<b>35.54</b>	18.04
Caroline Cat	Sept	0.00	0.00	0.00
	Oct	0.00	0.00	<b>0.25</b>
	Nov	2.76	<b>14.10</b>	5.31
	Dec	5.00	<b>11.00</b>	0.00
	Jan	1.25	<b>8.58</b>	1.08
	Feb	1.51	<b>11.54</b>	1.32
Henrietta	Sept	<b>8.95</b>	2.25	0.4
	Oct	0	0	0
	Nov	<b>5.3</b>	4.45	1.05
	Dec	<b>5.1</b>	3.05	1.55
	Jan	<b>6.9</b>	2.3	0.3
	Feb	1.65	<b>2.65</b>	0.2

#### **5.6.4 Time Data: Avoidance, Positive and Neutral Behaviour (APN)**

A GLM indicated that there were no significant difference between all three water craft; both tour boats, the Black Cat at Lyttelton and the Caroline Cat at Timaru or the private yacht (Henrietta) at Timaru with regard to avoidance behaviour ( $P = 0.483$ ). There were no significant differences between watercraft and month for positive behaviour ( $P = 0.180$ ), although watercraft was significant ( $P = 0.013$ ) where dolphins showed significantly less occurrence of positive behaviour in the presence of the Henrietta than dolphins showed in the presence of the Black Cat at Lyttelton or the Caroline Cat at Timaru. Month was not significant with regard to neutral behaviour ( $P = 0.723$ ), but watercraft were ( $P = 0.002$ ) where dolphins in the presence of either the Caroline Cat or Henrietta at Timaru showed significantly less neutral behaviour than was exhibited in the presence of the Black Cat at Lyttelton.

### **5.7 Discussion**

Although no comparisons were made between behaviours which occurred at varying distances from the Black Cat at Lyttelton or the Caroline Cat or Henrietta at Timaru, the results in this study indicate that Hector's dolphin do not show an overall preference towards swimming direction in the presence of the Henrietta and, it would also appear that Hector's dolphin do not have a preference for approaching a boat. A study on dugongs in Australia showed that the percentage of time the animals spent feeding and swimming was not affected by boat presence, nor was swimming direction, surface behaviour or distance from the boat (Hodgson and Marsh, 2007). However, this changed when boats passed within fifty metres at which time the dugong's energy intake was reduced (Hodgson and Marsh, 2007). The behavioural repertoires of bottlenose dolphins (*Tursiops sp.*) in Doubtful Sound, New Zealand have been documented in which jumping behaviour was omitted from any category of behaviour due to being unable to be placed in any one category as a result having more than one interpretation (Lusseau, 2006b). Problems interpreting the meaning of behaviours within this study were outlined in Chapter 1, and as a result behavioural groups were made more complex. In view of this jumping behaviour were included in several categories of behaviour, including stress, positive and association behaviour groups.

In view of the behavioural results obtained regarding the behaviour of Hector's dolphin in relation to tour boats the Black Cat at Lyttelton and Caroline Cat, at Timaru compared to the private yacht, the Henrietta, also at Timaru, it appears that dolphin behaviour at both sites in the presence of either tour boat or the private yacht are of little immediate concern. No significant increase in avoidance behaviour was observed over this six month period at either site in relation to either tour boat or the private yacht. The count data indicated that dolphins at Lyttelton exhibited significantly more positive and neutral behaviour in the presence of the Black Cat than either vessel at Timaru, even though it is the largest and noisest vessel. The significant decline in September and November of positive behaviour at Lyttelton may be due to mating or calving, rather than be attributed to avoidance behaviour. A significant change in avoidance behaviour was not observed, nor was there a significant change in neutral behaviour, which would be reasonable to expect if dolphins were exhibiting avoidance behaviour towards the Black Cat. The significant increase in neutral behaviour during November would seem to support this suggestion, and indicate that a reduction in positive behaviour and no change in avoidance behaviour are likely to be due to dolphins calving.

The time data also showed significant differences in positive behaviour and neutral behaviour, but as with the count data did not show any significant change in observed avoidance behaviour over these six months of observations. Both positive and neutral behaviour did not significantly change for any month at either site for either tour boat or the yacht. However, positive behaviour around the Henrietta was significantly lower than for both tour boats. Neutral behaviour was also significantly lower overall at Timaru where dolphins exhibited significantly less neutral behaviour in the presence of the tour boat, (the Caroline Cat), and the private yacht, (the Henrietta). Whether this can be attributed to avoidance of both vessels at Timaru is difficult. The Hector's dolphin population was relatively naïve at Timaru but one would expect an increase in avoidance behaviour if dolphins were actively avoiding both vessels. However, it could be that dolphins exhibited avoidance behaviour prior to being observed and hence these observations were missed. Another explanation may be due to the naivety of the population, the irregularity of tour operations at Timaru, which ran as required and not to any specific timetable as the Black Cat at Lyttelton, dolphins had not yet formed an association with either the Caroline Cat or Henrietta. As neutral behaviour was also

significantly low for the Henrietta it may indicate that dolphins at Timaru were mating or calving. As exact months for mating and calving are unknown for dolphins at Lyttelton and Timaru it may be that dolphins at Lyttelton calved during the months where significantly lower positive and neutral behaviour were observed, and at Timaru where there were less boats and commercial operations and therefore less disturbance, dolphins possibly mate and calve over a longer period of time, thus explaining the overall difference in neutral behaviour for both boats.

Lyttelton Harbour has a large capacity for dealing with heavy boat traffic, and is a continuously busy port, compared to Timaru which is less well utilised in relation to the size and numbers of cruise ships, containers and tankers which pass through its harbour. It would follow that noise at Lyttelton was greater than that at Timaru and, therefore, presents a greater potential to affect Hector's dolphin behaviour. A combination of both anthropogenic and commercial activities may increase the risk of disturbing cetacean communication, and possibly even damage hearing (Rasmussen *et al.*, 2006).

A long-term study conducted over three consecutive 4½ year periods on bottlenose dolphins (*Tursiops sp.*) in Shark Bay, Australia showed that when tour operator numbers increased within a particular area there were significant decreases in dolphin abundance (Bejder *et al.*, 2006). Where no or one operator conducted tours there was no decline in dolphin abundance but where tour operators had increased to two there was a decline of one in seven individuals (Bejder *et al.*, 2006). The study did not show that the research vessel had a significant impact on dolphin abundance, nor were there any observed increase in the number of dolphins present at the control sites, which would have shown transfer of dolphins from the site where boats were present to the control site. Therefore, the number and types of boats operating in harbours may affect Hector's dolphin behaviour and distribution, as well as communication between individuals, group cohesiveness and spatial distribution.

The sperm whale (*Physeter macrocephalus*) in the Ligurian Sea showed no avoidance behaviour when subjected to sonar exposure up to 120 dB re  $\mu\text{Pa}$  (Zimmer, 2002). The harbour porpoise (*Phocoena phocoena*) and the striped dolphin (*Stenella coeruleoalba*) showed different reactions to an acoustic alarm, where the striped dolphin, showed no reaction to an acoustic alarm, but the harbour porpoise exhibited avoidance behaviour (Kastelein *et al.*, 2006). The study indicated that different cetacean species do not react equally to noise disturbance (Kastelein *et al.*, 2006).

Anthropogenic noise which is not water based also has the potential to alter dolphin behaviour. The harbour porpoises (*Phocoena phocoena*) and harbour seals (*Phoca vitulina*) in Fortune Channel, Vancouver Island, Canada are able to detect the low-frequency sound generation by offshore wind-turbines where species increased surfacing distances from the noise (Koschinski *et al.*, 2003).

The underwater noise of whale-watching boats in British Columbia are stated to be at critical level and are suggested to result in permanent hearing loss for the killer whale (*Orcinus orca*) if present over a prolonged period of time (Erbe, 2002). However, five whale-watching boats with engines ranging between 123 dB re 1 microPa at 315 Hz and, 127 dB re 315 Hz were investigated in Maui to determine any affect on the behaviour of humpback whales and found that these levels of sounds did not have any negative effects on humpback whale auditory ability (Au and Green, 2000). An investigation by light and scanning electron microscopy of ears of large bluefin tuna (*Thunnus thynnus*) showed that bluefin tuna probably do not detect sounds greater than 1000 Hz and that only very loud anthropogenic sounds have the potential to affect its hearing ability (Song *et al.*, 2006). Ice-breakers, which are estimated to be audible to belugia whales over a range between 35-78 km in the Beaufort Sea have been shown to mask beluga whale communication (Erbe and Farmer, 2000). The study suggests that temporary hearing damage can occur if a beluga whale remains within 1-4 km of the noise emitted by the ice-breaker for 20 minutes or more, and that serious problems could arise in heavily industrialized areas where animals are exposed to ongoing noise and where anthropogenic noise from a variety of sources accumulate over time (Erbe and Farmer, 2000).



It is not only marine animals which suffer from disturbance from human made noise. Studies on the effects of ambient noise from demolition work on the behaviour and cortisol secretion changes in giant pandas (*Ailuropoda melanoleuca*) found variable results (Powell *et al.*, 2006). The study found that Panda activity budgets differed significantly when demolition work was being undertaken and when it there were not. Although both sexes showed restless behaviour, there were male and female differences in behavioural responses with male's taking refuge and shelter significantly more than females. Demolition noise was associated with behavioural changes in giant pandas, and these changes were gender-specific (Powell *et al.*, 2006). Orangutan behaviour (*Pongo pygmaeus*) at Chester Zoo, UK changed when confronted with noisy visitors, where all orangutans looked more at the visitors, and where infants approached and children held onto adults significantly more (Birke, 2002).

Traffic noise has also been shown to be stressful to birds, and result in birds abandoning a particular site, and reducing breeding opportunities, increase stress hormones, and, interfere with sleep as well as result in permanent injury to the auditory system (Irwin *et al.*, 2005). In addition traffic noise has been shown to affect bird communication by masking important sounds (Irwin *et al.*, 2005). Sea turtles in the Peconic Bay Estuary in Long Island, New York live in a habitat which ranges in anthropogenic noise between 80 dB and 110 dB, resultant from boating and recreational activities (Samuel *et al.*, 2005). Concerns have been raised in that if noise levels were to increase sea turtle behaviour and ecology may be compromised (Samuel *et al.*, 2005).

Studies in the Netherlands and, the United States, showed that road noise has a negative effect on bird populations and reduce density of bird populations up to two to three thousand meters from the road, and that these distances increase with increased traffic density (Irwin *et al.*, 2005). However the study also showed, as with dolphin species, that reactions to traffic density are species specific and whilst some species reduce in numbers, some increase in number or remain unchanged, and that each of these scenarios is correlated with an increase in road traffic for specific species (Irwin *et al.*, 2005).

The Indo-Pacific bottlenose (*Tursiops aduncus*) and humpback dolphin (*Sousa chinensis*) were studied between 1999 and 2002 off the coast of Zanzibar, East Africa (Stensland *et al.*, 2006). The research concluded that without prompt conservation measures the disturbance by tour boat activity would have a significant negative impact on the species to such an extent that they may not be present in the future not be present and therefore the region would lose a source of income (Stensland *et al.*, 2006). Other areas where wildlife-human interactions exist have no set or enforced regulations governing tourist activity, in particular swimming with manatees (*Trichechus manatus latirostris*) at Crystal River, Florida, USA and, as a result tour operators operate on a free-for-all basis which has led to major issues with regard to water-quality, density, harassment, crowding and education and subsequently grave concerns about the affect on the manatee population (Sorice *et al.*, 2006). A regulatory approach was suggested but what was proposed instead was the setting up of an organisation by the tour operators themselves who would be expected to establish "best practice" in relation to manatee-tourism interactions (Sorice *et al.*, 2006). New Zealand in comparison to this has in place legislation, clear guidelines, governing bodies and local authorities as well as numerous education programmes, to serve in protecting and conserving not only marine species but other endemic species, culturally significant species and appears well ahead of Florida in protecting species which New Zealand has come to heavily rely on economically.

Other studies have suggested limiting boat traffic where cetacean species are present, as well as limiting the frequency and duration of interactions in order to reduce disturbance on the cetacean species of interest (Finkler *et al.*, 2004). Whale-watching guidelines in Johnstone Strait, British Columbia suggested that boats be encouraged to slow down around whales, when in 500 m vicinity of whales (Williams *et al.*, 2002). A decrease in boat speed is a current requirement of tour operators within New Zealand already. Although there are many factors still unknown and difficult to investigate, with technology and information becoming more available, the next decade of research should prove very exciting.

## **5.8 Conclusion**

Whether using count data or time data the Hector's dolphin at Lyttelton and Timaru as observed over a six month period do not appear to be negatively affected by the presence of tour boats and, in the case of Timaru, in the presence of a private recreational yacht. Changes in behaviour did not indicate a significant increase in any month for any boat in avoidance behaviour and hence, tour boat presence at both sites cannot be stated to have a detrimental affect on Hector's dolphin behaviour, nor increase stress. This would be particularly true for Lyttelton where dolphin behaviour showed more positive and neutral behaviour and no difference in avoidance behaviour. However, this study was conducted over a six month period only and therefore had no seasonal variation. Further study allowing for replication would be valuable in assisting to support these conclusions. A comparison between the count and time data revealed that more significant differences were revealed using the time data than purely counting the number of times a behaviour occurred. The count data indicated an overall difference between Lyttelton and Timaru, but failed to indicate differences between all boats at both sites, therefore time data was proved a more appropriate and informative method of data collection.

## **5.9 Further Research**

Behaviour may be species specific as well as individual specific; therefore I would suggest further research at both Lyttelton and Timaru regarding the behaviour of Hector's dolphin at varying distances from tour boats and recreational craft. This would provide site specific and population specific information about changes in behaviour at varying proximities from the boats. This would indicate any change in energy expenditure and subsequently biological implications such as, decreased foraging time and reproduction. The opportunity to observe and prepare a detailed ethogram of behaviour for populations, which are relatively naive in comparison to those already exploited should be taken advantage of, and would be invaluable in assessing change years or decades later. As commercial dolphin tour activity ceased at Timaru two years ago this may represent an opportunity to undertake more detailed behavioural studies on a fairly naive population, which are assumed to have not yet habituated or become sensitised to commercial dolphin watching tours.

It would be interesting to focus observations on Hector's dolphin behaviour at Lyttelton during periods of intense cruise ship, container and tanker traffic, and to correlate this with the resident bird population to determine if there are any correlations between bird and dolphin behaviours, such as an increase in abundance or decrease during periods of intense traffic and periods of light traffic flow. Details about the most intense time of vessel traffic could easily be obtained from the Harbour Master at Lyttelton Port.

In conclusion, despite not finding any effect on dolphin behaviour which could be attributed to the Black Cat, Caroline Cat or Henrietta, I would recommend research into the different anthropogenic noises at each harbour and their effect, if any, on the populations of Hector's dolphin behaviour, which may include port works, boat traffic, aircraft noise and commercial works surrounding the respective areas.

# **Chapter 6 – Behavioural Response of Hector’s Dolphin Towards Boats Over Several Breeding Seasons**

## **6.1 Abstract**

Hector’s dolphin orientation in relation to approach and departure from tour boats and behavioural responses to two tour boats was examined over a six year period, 1999-2001 and 2005. Behaviours were divided into avoidance, positive, or neutral behaviour groups. Dolphins consistently showed a preference to approach and departure from the boat, showing preference to the bow of the boat, and least preference to the stern. There were no significant changes in the proportions of behaviour exhibited within the groups, avoidance, positive or neutral behaviour. There were no suggestions of long term trends over the six years that indicated that the dolphin population was adapting to or being influenced by tourism (and other) boats.

## **6.2 Introduction**

Some long-term studies, (longer than one year), on dolphin behaviour, have included an assessment of the effects of boat interactions on the behavioural budget of two populations of bottlenose dolphins (*Tersiops truncatus*) at two sites in New Zealand (Lusseau, 2004a). This study included 137 days (879.2 hours) of observations in Doubtful Sound and 112 days (505.5 hours) of observations in Milford Sound, and covered the period June 2000-May 2002 (Lusseau, 2004a). The study showed that dolphins tend to avoid an area during times of high boat traffic (Lusseau, 2004a). Long-term correlation studies in relation to surface behaviour of bottlenose dolphins (*Tursiops* sp) in Doubtful Sound, New Zealand, have also been conducted (Ferrer i Cancho and Lusseau, 2006). This study ran between the years 2000 and 2002 and showed that even though two

behavioural patterns co-occur it does not necessarily mean, in general, that they were significantly correlated. The study also showed that long-term correlations cannot be explained by the repetition of the same surface behaviour many times in a row (Ferrer i Cancho and Lusseau, 2006). Both studies (Lusseau, 2004a; Ferrer i Cancho and Lusseau, 2006) were conducted over two years and considered to be long term. A study over four years from October 1994 to December 1998 based in South Carolina and investigated the use of home ranges by bottlenose dolphins (*Tursiops truncatus*) (Gubbins, 2002). Dolphins within the study were shown to exhibit strong site-fidelity and distinct patterns of core use within their home ranges (Gubbins, 2002). One of the earliest studies on Hector's dolphin was in regard to the incidental catch of *Cephalorhynchus hectori* in gillnets in Pegasus Bay and Canterbury Bight, New Zealand which were assessed over four years from 1984 to 1988 (Dawson, 1991).

Extensive studies have been undertaken on Hector's dolphin of which most have focused on the populations in Akaroa. Some of the research undertaken includes the high frequency sounds of Hector's dolphin (Dawson, 1988), incidental gill-net capture (Dawson, 1991), photo-identification (Slooten *et al.*, 1992), behaviour in response to boat traffic and distribution (Slooten and Dawson, 1994), diurnal movements (Stone *et al.*, 1995), genetic identification of populations (Pichler *et al.*, 1998), daily movement patterns as determined using radio-telemetry (Stone *et al.*, 1998), bird and dolphin associations (Hawkes and Dobinson, 2001), population and abundance estimates (Dawson and Slooten, 1988; DuFresne *et al.*, 2001; Clement *et al.*, 2001; Dawson *et al.*, 2000; Dawson, 2001; Gormley *et al.*, 2005), survivorship changes in relation to establishment of the Marine Mammal Sanctuary at Banks Peninsula (Cameron *et al.*, 1999), behavioural response to different gill-net pingers (Stone *et al.*, 1999; Stone *et al.*, 2000), theodolite tracking and boat preference (Nichols *et al.*, 2001) dolphin interactions with boats and people (Nichols *et al.*, 2001), site fidelity (Brager *et al.*, 2002), individual ranges (Dawson, 2002), and satellite tagging (Stone *et al.*, 2004; Stone *et al.*, 2005). Other than abundance estimates (Dawson and Slooten, 1988; DuFresne *et al.*, 2001; Dawson *et al.*, 2000; Dawson, 2001) and seabird-dolphin associations (Hawke, 1994), which have been made around the coast of New Zealand, research into the behaviour of Hector's dolphin at both Lyttelton and Timaru were lacking until my study commenced. Studies, although on going for more than two decades at Akaroa, generally focused on seasonal observations or have very specific questions to address. There has been little

systematic collection of long-term data, especially with regard to changes in behavioural responses between years with continued tourist activity.

Even though the research on Hector's dolphin has been extensive and studies at Akaroa covering two decades, nothing other than abundance estimates have been made for populations at both Lyttelton and Timaru. Until this thesis commenced any detailed information was lacking about the specific populations located at Lyttelton and Timaru. An opportunity arose during 2005 to undertake additional observations in October, November and December in addition to those which had already been undertaken between 1999 – 2001 at Lyttelton (see Chapters 3 and 4). This study therefore represents behavioural data which spans a total of six years.

### **6.3 Aims**

- To conduct a long term study on the behaviour of Hector's dolphin in relation to behavioural changes over a six-year period where there are regular and persistent commercially run dolphin watching tour activities.
- To show any preference or change of approach direction towards the Black Cat over a six year period and any preference in swimming behaviour during boat presence over time.
- To show if there is a significant difference in avoidance, positive or neutral behaviour for Hector's dolphin in the presence of the Black Cat between seasons, which span a six year period.

### **6.4 Objectives**

Dolphins may approach a boat from the stern, sides or bow. The null hypothesis is that dolphins show no preference to any swimming direction relative to the Black Cat, nor is there a preference when approaching or departing from the boat. Dolphins may exhibit avoidance behaviour in the presence of a tour boat. The null hypothesis is that dolphins show no difference between avoidance behaviour, positive behaviour or neutral behaviour over time.

## 6.5 Methods

Data collection methods for quadrant and direction data were the same as previously described in Chapter 4 and 5. Observations were made aboard the Black Cat at Lyttelton over three months for three seasons. Each season incorporated the months October, November and December in the years 1999: Season 1, 2000: Season 2, and 2005: Season 3. The results from the third season were reported to the Black Cat (Appendix G). A total of four trips each month were undertaken, of which trip duration varied between two and two-and-a-half hours each. The data sheets and methodology used were the same as reported in Chapter 3 and Chapter 4 where data sheets were designed so that dolphin presence could be marked according to dolphin approach relative to quadrant. There were two observers per trip, the author and a volunteer. Data from four successful trips per month per season were used in analysis. Where possible, data were taken from trips which took place on a Saturday for each of the months within each season. Where a Saturday rendered no observations, data were taken from the Sunday trip. All four trips were, therefore, spread over each month within each of the seasons, giving a total of twelve trips per season, and 36 trips overall.

All seasons' data were combined in order to determine any difference in dolphin preference to quadrant or any preference in swimming direction: towards the boat (t/b), away from the boat (a/w) or with the boat (w/b). Using combined data for all three seasons the average number of dolphin observations per quadrant, Q1, Q2, Q3 and Q4 were calculated. The average number of dolphin observations for each of the recorded swimming directions, to, away and with the vessel, were also calculated (see Chapters 3 and 4). These values were used for non-parametric analysis in order to show any significant difference between the number of dolphin observations and quadrant, or to determine any preference to or avoidance of a particular quadrant.

Observations were not made over a set time period or at the same time for each observer. Observations began when a dolphin was observed within the quadrant each individual observer was scanning. Observations continued for as long as the focal animal was present. Once that focal animal was no longer visible another focal animal, if present were sampled. The time each observation began and ceased were recorded. Once a dolphin was sighted it was marked on the data sheet in the relevant quadrant along with



the direction from which it came. Once that dolphin had disappeared from view, another dolphin was chosen and its behaviour recorded. Observations were undertaken in sequence with the direction data being collected and then the behaviour data being collected. At any one time, each observer had two quadrants to observe and mark on the data sheets. Once observations ceased, either due to the dolphin swimming away or the boat returning to harbour, the observer returned to deck and tabulated the observations according to quadrant, direction, and behaviours observed.

### **6.5.1 Statistical Tests: Quadrant Count Data**

The average numbers of observations per month were calculated for both quadrant and direction of swimming. Kruskal-Wallis and Friedman Tests were conducted on both the quadrant data and direction data in order to determine any preference to quadrant or preference in swimming direction. Further calculations were made using Zars statistical test for  $Q$  using the Sum of Ranks values returned by the Friedman Test. This showed any specific differences between quadrant preference and direction of swimming. Zars critical values of  $Q$  were used to determine significance.

### **6.5.2 Behaviour Count Data**

Behaviour data were also collected as per the methodology in Chapter 4. The number of dolphin observations per month per season were calculated and a Chi-Square test undertaken in order to determine if there was any greater chance of observing dolphins in any one month in any particular season. The number of dolphin observations/month were recorded and a Chi-Square test undertaken to determine if there were any greater chance of sighting a dolphin in any particular month for any season. The overall number of observations per season were also recorded and tested to determine any change in observation number over the six year period. The behaviour count data was divided into the behaviour groups' avoidance, positive and neutral behaviour (APN) for each season and a Chi-Square test undertaken to determine any difference between season and the exhibited behaviour. The transitional groups within the categories avoidance, positive and neutral behaviour (APN) were then analysed using a Log-linear model in order to determine any change in behaviour. Log-linear model analysis were undertaken in order to determine any difference in exhibited behaviour in relation to avoidance, positive and

neutral behaviour over six years. The Log-linear model analysis results obtained from the count data were compared to the General Linear Model (GLM) test results obtained from the time data which may indicate preferential data collection methods based on either count or time.

### **6.5.3 Time Data**

The time factor was also measured and the overall time a dolphin performed a particular behaviour, either avoidance, positive or neutral behaviour calculated along with the a breakdown of total time per month per site per season from which the average amount of time spent exhibiting behaviours was calculated. A GLM test was undertaken to show any significant difference in exhibited behaviour per month per season. This was broken down further in order to show the average amount of time dolphins spent exhibiting particular transitional behaviours within each behaviour category. Further GLM tests were undertaken on each behaviour group, avoidance, positive and neutral behaviour (APN) in order to determine which transitional behaviours may have changed between seasons over a six year period.

## **6.6 Results**

### **6.6.1 Quadrant and Swimming Direction**

The average number of times dolphins were observed within each quadrant versus month indicated that in six out of nine months dolphins exhibited a preference to Q1, the bow of the Black Cat, in two months a preference to Q2, starboard side and, in one month a preference to Q4, portside (Table 50). In no month was Q3, the stern favoured.

Table 50: Average number of times a dolphin was observed with Q1, the bow, Q2, starboard side, Q3, the stern, and Q4, portside of the Black Cat. Bold figures indicate the quadrant with the greatest number of observations for a specific month.

Average number of times a dolphin was observed with each quadrant per month per season				
Month	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
Season 1 Oct-00	<b>25.33</b>	1.33	3.33	3
Season 1 Nov-00	8.16	5.16	8	<b>9.33</b>
Season 1 Dec-00	<b>15.2</b>	11	1.2	5.6
Season 2 Oct-01	<b>10</b>	4.5	3.5	0.5
Season 2 Nov-01	<b>2</b>	1.5	0.5	1
Season 2 Dec-01	6.5	<b>9</b>	1.5	2.5
Season 3 Oct-05	1.05	<b>1.35</b>	0.5	0.1
Season 3 Nov-05	<b>1.54</b>	0.23	0.08	0.85
Season 3 Dec-05	<b>1.45</b>	0.79	0.36	0.67

Where Q1, bow, Q2, starboard, Q3, stern and Q4, portside. The greatest numbers of dolphins were observed in October 2000 within Q1, the bow (25.33) and least in October 2005 within Q4, portside (0.1) of the Black Cat.

A Kruskal-Wallis test showed that there was no significant difference over time in dolphin preference to quadrant ( $P = 0.079$ ). However, there was a difference between Average Rank values which varied between 13.4 for Q3, the stern to 25.0 for Q1, the bow (Appendix H, Table 51). A Friedman test blocked by month showed that there was a significant difference between observations and quadrant ( $P = 0.001$ ). Zars statistical test for  $Q$  using the Sum of Ranks returned by the Friedman test in a standard equation (Figure 24) showed a significant difference between Q1, the bow versus Q3, the stern ( $P = < 0.001$ ), Q1, the bow versus Q4, the portside ( $P = < 0.001$ ), and Q2, starboard versus Q3, stern ( $P = < 0.005$ ). There were no significant differences between Q1, the bow versus Q2, portside, nor Q2, portside versus Q4, starboard and, Q3, stern versus Q4, portside (Appendix H, Table 52).

There was no overall significant preference exhibited by dolphins to quadrant ( $P = 0.079$ ), but there were differences in the Average Rank values which varied between Q1, the bow and Q3, the stern (25.0 and 13.4 respectively). There was little difference between Q3, the stern and Q4, the portside of the Black Cat (13.4 and 15.1 respectively).

Zars test for  $Q$  showed that there was a significant difference between Q1, the bow versus Q3, the stern ( $P = < 0.001$ ) and, between Q1, the bow versus Q4, portside ( $P = < 0.001$ ), as well as Q2, starboard versus Q3, stern ( $P = < 0.005$ ) (Appendix H, Figure 24).

The average number of times dolphins were observed swimming away, swimming to and swimming with the Black Cat versus month indicated that in six out of nine month's dolphins exhibited a preference to swimming towards the Black Cat and in three months a preference swimming with the Black Cat (Appendix H, Table 53). There appears to be no preference in any month in any season to swimming away from the Black Cat (Appendix H, Table 53). The greatest numbers of dolphins were observed in December 2000 swimming with the boat (60.35) and least in December 2001 when no dolphins were observed swimming with the Black Cat.

A Kruskal-Wallis test showed that there was a significant difference over time in dolphin preference to swimming direction ( $P = 0.044$ ). Average Rank values reflected this with values which varied between 1.4 for swimming with the boat, w/b and 19.4 for swimming to the boat, t/b (Appendix H, Table 54). A Friedman test indicated no significant difference between observations and swimming direction ( $P = 0.155$ ). Zars statistical test for  $Q$  using the Sum of Ranks returned by the Friedman test in a standard equation (Figure 25) showed a significant difference between swimming towards the boat, t/b versus swimming away from the boat, a/b ( $P = < 0.05$ ). There were no significant differences between swimming to the boat, t/b versus swimming with the boat, w/b and swimming away from the boat, a/b versus swimming with the boat, w/b (Appendix H, Table 55). There is a significant difference between swimming direction ( $P = 0.044$ ) with the Average Rank value being greatest for swimming to the boat (19.4) and least for swimming with the boat (1.4)

There were no significant differences overall in swimming direction ( $P = 0.155$ ), but a significant difference between swimming towards the boat, t/b versus swimming away from the boat, a/w was returned ( $P = < 0.05$ ) when using Zars equation (Appendix H, Figure 25), in order to test the critical value of  $Q$  (Appendix H, Table 54).

### 6.6.2 Count Data: Oct-Dec 2000, 2001 and 2006

A Chi-Square test showed that the number of dolphin observations per month per season varied significantly ( $\chi^2 = 68.922$ ,  $DF = 4$ ,  $P = 0.001$ ). There were less than expected observations in the months October and December, during Season 1 (Table 57). During Season 2 there were less than expected observations during October and December, and during season 3 there were more than expected observations in October and less in December (Table 57).

Table 57: Chi-Square test results in relation to the number of dolphin observations versus month per season. Bold figures indicate a significant difference in relation to the number of expected ( $X^2$  value  $> 4$ ) dolphin observations and a specific month.

Site	Season	Month	# dolphins observed
BC	<b>S1</b>	Oct	<b>123</b>
BC	<b>S1</b>	Nov	238
BC	<b>S1</b>	Dec	<b>134</b>
BC	<b>S2</b>	Oct	<b>47</b>
BC	<b>S2</b>	Nov	30
BC	<b>S2</b>	Dec	<b>0</b>
BC	<b>S3</b>	Oct	<b>125</b>
BC	<b>S3</b>	Nov	114
BC	<b>S3</b>	Dec	<b>44</b>

There was a significant difference between dolphin observations within specific months of certain seasons ( $\chi^2 = 68.922$ ,  $DF = 4$ ,  $P\text{-Value} = 0.001$ ). There were less than expected

observations in two months during Season 1 and Season 2, but more than expected observations in two months of Season 3.

The overall number of observation periods per season varied between seasons (3261, 651 and 1920 observations for Season 1, 2 and 3 respectively) (Figure 26). The numbers of observations were greatest during Season 1, and least during Season 2. The line connecting Season 2 and Season 3 shows the possible increase in observed behaviour for the years 2001, 2002, 2003 and 2004 as suggested by the increase shown between Season 2 and Season 3 (Figure 26).

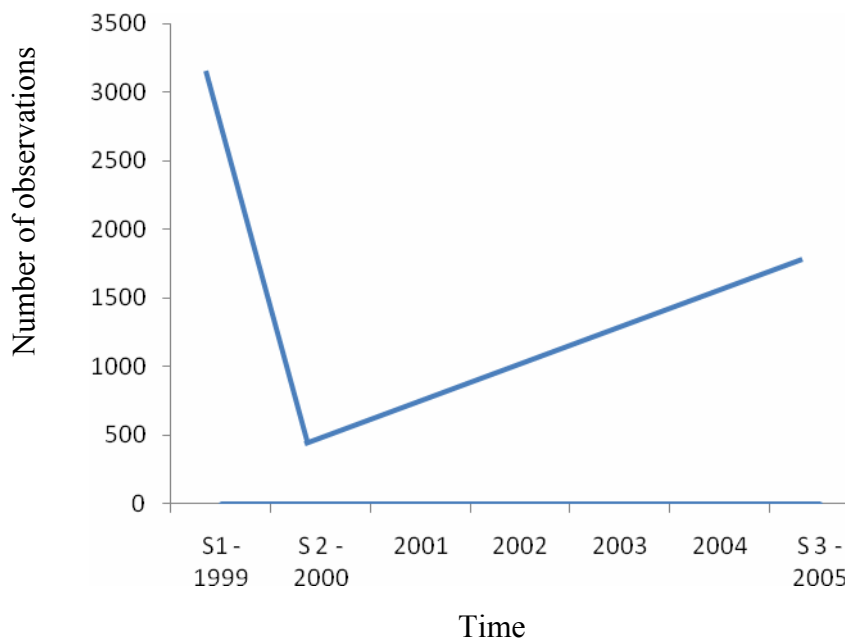


Figure 26: The total number of observation periods during Season 1, 2 and 3 (1999, 2000 and 2006 respectively) at Lyttelton as observed aboard the Black Cat.

A Chi-Square test showed a significant difference between exhibited avoidance, positive and neutral behaviours between seasons ( $\chi^2 = 472.147$ , DF = 4, P = 0.001). There were lower than expected avoidance behaviours in Season 1, but higher in Season 2. Positive behaviour was higher than expected in Season 1, but lower than expected in Season 2. Neutral behaviour was higher than expected in season two. Both avoidance and neutral

behaviours were lower than expected in Season 3 but positive behaviour was higher (Table 58).

Table 58: Chi-Square results in relation to the number of times a dolphin was counted exhibiting avoidance, positive and neutral behaviour per season (APN). Bold figures indicate a significant difference in count data over time in relation to expected numbers ( $X^2$  value > 4) dolphins exhibiting avoidance, positive or neutral behaviour.

Site	Season	Avoidance	Positive	Neutral
BC	<b>S1</b>	<b>782</b>	<b>1907</b>	572
BC	<b>S2</b>	<b>366</b>	<b>104</b>	<b>181</b>
BC	<b>S3</b>	<b>437</b>	<b>1182</b>	<b>301</b>
Total		1585	3193	1054

APN behaviours differ significantly between seasons ( $\chi^2 = 472.147$ , DF = 4, P = 0.001). Avoidance, positive and neutral behaviours differed significantly for each season.

A Log-linear model using count data per month, per season, versus avoidance, positive and neutral behaviour showed that there was a significant difference in overall behaviour between seasons (P = 0.001), with a significant difference between Season 1 and Season 2 (P = 0.001) and Season 1 and Season 3 (P = 0.001) with the greatest difference being between Season 1 and Season 2 for all behaviours, avoidance (t = 155.57, -17.49 and -9.74 for Season 1, 2 and 3 respectively), positive (t = 281.88, -28.92 and -12.92 for Season 1, 2 and 3 respectively), and neutral (t = 125.58, -13.51 and -9.02 for Season 1, 2 and 3 respectively) (Table 59).

Table 59: Results in relation to the number of times a dolphin was counted exhibiting avoidance, positive and neutral behaviour per month, per season, per site (APN). Bold figures indicate the greatest number of observations for a specific month with respect to each behaviour.

Behaviour				
Site and Season	Month	Avoidance	Positive	Neutral
Black Cat – Season 1	Oct	92	<b>218</b>	60
	Nov	239	<b>620</b>	202
	Dec	451	<b>1069</b>	310
Black Cat – Season 2	Oct	<b>171</b>	49	61
	Nov	19	55	<b>120</b>
	Dec	0	0	0
Black Cat – Season 3	Oct	110	<b>152</b>	129
	Nov	230	<b>550</b>	140
	Dec	97	<b>480</b>	32

### 6.6.3 Count Data Results: Individual Behavioural Transitional Changes Within the Three Categories Avoidance, Positive and Neutral Behaviours as Exhibited by Dolphins at Lyttelton (APN)

There was a significant difference between some behavioural transitions within the avoidance group ( $\chi^2 = 498.908$ , DF = 16, P = 0.001). In Season 1 there were four transitional behaviours which were exhibited more times than would be expected: p/s->sa; l/m-sa; lb-sa; bs-bs, and three that occurred less than expected: sa-sa; sa-h/t; sa-j. In Season 2 there were two behavioural transitions exhibited more than would be expected: p/s->sa and sa-j and two less than would be expected: sa-sa; sa-h/t. In Season 3 there were two behavioural transitions which occurred more than would be expected: sa-sa; sa-h/t, and six transitional behaviours which occurred less than would be expected: p/s->sa; sa-j; l/m-sa; l/m-sa; lb-sa; bs-bs (Table 60).



There were also significant differences between some behavioural transitions within the positive behaviour category ( $\chi^2 = 722.709$ , DF = 22, P = 0.001) and neutral category ( $\chi^2 = 513.674$ , DF = 6, P = 0.001). There were three transitional behaviours within the positive behaviour category which were exhibited less often in Season 1: g+sa-sb+tb; st-j-j; and s/p-st, and three more often: br/st/j/sw-br/st/j/sw; m-sw; sw/>st->sa. In Season 2 four transitional behaviours were observed less than expected: br/st/j/sw-br/st/j/sw; st-j-j; m-sw and sw/>st->sa, and four more than expected: st-lb; st-l/m; br-l/m and s/p-st. Season 3 also had less than expected occurrences of sw/>st->sa; br-l/m; st-lb and m-sw, but more s/p-st; st-j-j and g+sa-sb+tb. Within the neutral category there were two transitional behaviours exhibited more than would be expected: p/s/lb-l/lb and s/p-m and two less: j-s/p and p/s-p/s in Season 1. Season 2 had less occurrences of p/s-p/s and s/p-m but more j-s/p and season three less p/s-lb-l/lb and j-s/p but more p/s-p/s (Table 60).

Table 60: Total number of Hector's dolphin observations per season per site for the individual transitional behaviours which make up the avoidance, positive and neutral behaviour groups (APN). Bold figures indicate a significant difference in regard to transitional behaviours exhibited in relation to the number of transitional behaviours which were expected per season ( $X^2$  value > 4).

Avoidance		sa>-g	sa>-sb	sa-sa	p/s->sa	sa-h/t	sa-j	l/m-sa	lb-sa	bs-bs
	S1	33	9	<b>68 (&lt;)</b>	<b>81 (&gt;)</b>	<b>2 (&lt;)</b>	<b>20 (&lt;)</b>	<b>60 (&gt;)</b>	<b>45 (&gt;)</b>	<b>37 (&gt;)</b>
	S2	11	3	<b>9 (&lt;)</b>	<b>56 (&gt;)</b>	<b>0 (&lt;)</b>	<b>46 (&gt;)</b>	4	5	5
	S3	55	5	<b>241 (&gt;)</b>	<b>31 (&lt;)</b>	<b>76 (&gt;)</b>	<b>34 (&lt;)</b>	<b>4 (&lt;)</b>	<b>5 (&lt;)</b>	<b>5 (&lt;)</b>

		g+sa-sb+tb	sa-lb	g+sa-tb+br	sw->s	br/st/j/sw-v v	st-j-j	s/p-st	m-sw	st-lb	br-l/m	st-l/m	sw/>st->sa
	S1	<b>9 (&lt;)</b>	4	3	14	<b>480 (&gt;)</b>	<b>26 (&lt;)</b>	<b>189 (&lt;)</b>	<b>216 (&gt;)</b>	34	64	4	<b>42 (&gt;)</b>
	S2	12	1	3	6	<b>8 (&lt;)</b>	<b>0 (&lt;)</b>	<b>66 (&gt;)</b>	<b>8 (&lt;)</b>	<b>38 (&gt;)</b>	<b>34 (&gt;)</b>	<b>8 (&lt;)</b>	<b>0 (&lt;)</b>
	S3	<b>58 (&gt;)</b>	5	5	8	194	<b>82 (&gt;)</b>	<b>163 (&gt;)</b>	<b>12 (&lt;)</b>	<b>0 (&lt;)</b>	<b>0 (&lt;)</b>	0	<b>0 (&lt;)</b>

Neutral		j-s/p	p/s-p/s	p/s/lb-l/lb	s/p-m
	S1	<b>28 (&lt;)</b>	<b>88 (&lt;)</b>	<b>130 (&gt;)</b>	<b>12 (&gt;)</b>
	S2	<b>114 (&gt;)</b>	<b>28 (&lt;)</b>	30	<b>0 (&lt;)</b>
	S3	<b>22 (&lt;)</b>	<b>279 (&gt;)</b>	<b>0 (&lt;)</b>	<b>7 (&gt;)</b>

### 6.6.4 Time Data: Oct - Dec 2000, 2001 and 2006

The total amount of time, in seconds, spent exhibiting avoidance, positive and neutral behaviour indicated that dolphins spent most time exhibiting neutral behaviour in Season 1, positive behaviour in Season 2 and avoidance behaviour in Season 3 (Table 61). When time per behaviour was shown per month, and per season this showed that in two of the three months per season dolphins spent most time exhibiting positive behaviour, with the exception of October in Season 1 where dolphins spent the most time exhibiting neutral behaviour, and December of Season 2, where no dolphins were observed (Table 62). In Season 3 dolphins spent most time exhibiting avoidance behaviour. Calculating average time spent exhibiting behaviour also reflected this result (Table 62).

Table 61: Total amount of time spent exhibiting avoidance, positive and neutral behaviour (APN). Bold figures indicate the behaviour which dolphins spent the greatest amount of time exhibiting for each season.

		Avoidance	Positive	Neutral
Black Cat at Lyttelton	S1	2202 (6.9%)	8560 (26.8%)	<b>21139 (&gt;)</b> (66.3%)
	S2	105 (16%)	<b>449 (&lt;)</b> (68.8%)	101 (15.4%)
	S3	<b>4335 (&gt;)</b> (45.7%)	2828 (29.8%)	2319 (24.5%)

Table 62: Total amount of time, in seconds, and average amount of time per month per season spent exhibiting avoidance, positive and neutral behaviour (APN). Bold figures indicate the behaviour which dolphins spent the greatest amount of time exhibiting for each month within each season.

Total amount of time spent exhibiting behaviour					Average amount of time spent exhibiting behaviour				
BC	Month	Avoidance	Positive	Neutral	BC	Month	Avoidance	Positive	Neutral
S1	Oct	273	4172	<b>20124</b>	S1	Oct	4.11	35.25	<b>85.41</b>
S1	Nov	685	<b>2137</b>	569	S1	Nov	10.31	<b>18.05</b>	2.41
S1	Dec	1244	<b>2251</b>	446	S1	Dec	18.73	<b>19.01</b>	1.9
S2	Oct	46	<b>189</b>	35	S2	Oct	0.69	<b>1.6</b>	0.15
S2	Nov	59	<b>260</b>	66	S2	Nov	0.89	<b>2.2</b>	0.28
S2	Dec	0	0	0	S2	Dec	0	0	0
S3	Oct	<b>638</b>	420	340	S3	Oct	<b>9.61</b>	3.55	1.44
S3	Nov	<b>1414</b>	853	689	S3	Nov	<b>21.29</b>	7.21	2.92
S3	Dec	<b>2283</b>	1555	1292	S3	Dec	<b>34.37</b>	13.13	5.49

A General Linear Model (GLM) on avoidance behaviour versus season and month showed that there was a significant season effect ( $P = 0.008$ ) with the greatest change being in Season 2 (Appendix H, Table 63). There was no significant month effect ( $P = 0.348$ ). A GLM test on positive behaviour versus season and month showed no significant season effect ( $P = 0.022$ ) with the greatest change being in Season 3 (Appendix H, Table 64). There was no significant month effect ( $P = 0.932$ ). A GLM test on neutral behaviour versus season and month showed no season effect ( $P = 0.232$ ) but the same trend is evident in neutral behaviour for Season 2 as was seen for positive behaviour in Season 2 (Appendix H, Table 65). Again there was no month effect with neutral behaviour ( $P = 0.652$ ).

Table 66: Individual transitional behaviours within each category avoidance, positive and neutral behaviour (APN). Bold figures represent the transitional behaviour that was exhibited for the greatest amount of time per season.

Avoidance		sa>-g	sa>-sb	sa->sa	p/s->sa	sa-h/t	sa-j	l/m-sa	lb-sa	bs-bs	s/p-sa	sb/sa- sb/g	st-sa	
Black Cat	S1	17.12	1.18	<b>49.86</b> (<)	27.79	0.091	3.63	4.18	1.82	1.27	28.73	2.45	0.15	
	S2	13.41	5.71	0.00	22.86	0.00	2.87	5.13	5.71	6.78	<b>56.20</b> (>)	3.15	0.91	
	S3	27.15	4.13	<b>61.89</b> (>)	2.24	8.45	1.77	9.71	3.87	3.76	32.16	25.65	14.11	
Positive		g+sa- sb+tb	sa-lb	g+sa- tb+br	sw->s	br/st/j/sw- v v	st-j-j	s/p-st	m-sw	st-lb	br-l/m	st-l/m	sw/>st- >sa	g-br/j
Black Cat	S1	<b>43.11</b>	9.104	3.97	36.2	1.35	7.24	26.36	0.32	1.94	2.365	1.27	24.08	6.46
	S2	31.19	3.52	5.87	11.58	28.14	0	<b>42.54</b> (<)	12.03	3.2	1.11	9.52	0	9.11
	S3	28.07	5.20	8.91	42.96	22.65	15.86	<b>56.25</b> (>)	3.29	0	0	0	0	8.15
Neutral		j-s/p	p/s-p/s	p/s-l/lb	s/p-m	l/m-lb/l								
Black Cat	S1	19.55	4.07	6.75	<b>41.67</b> (>)	0.27								
	S2	23.76	51.30	0.95	0	<b>76.24</b>								
	S3	0.95	<b>99.05</b>	0	39.48	13.11								

There was a significant affect of season on avoidance behaviour where Season 3 showed the greatest avoidance overall, but where there was no month effect (Table 60). This indicated that dolphins were exhibiting avoidance behaviour regardless of month within Season 3, hence avoidance was exhibited throughout the season. A GLM on positive behaviour was also significant ( $P = 0.022$ ) where the mean values indicate positive behaviour was greatest during Season 1 and least exhibited in Season 2 (Table 60). This is a different result than was gained by looking directly at the overall time, that is, data for the whole season rather than data for the individual months within each season, which suggested that positive behaviour was greatest in Season 2. There was no month effect for any season indicating that positive behaviour was the predominant behaviour overall during Season 1. A GLM test on neutral behaviour showed no significant difference in any season for any month although the mean values were higher for Season 1 (Table 64). Again this was a different result than suggested by the overall time values.

The average amount of time spent exhibiting transitional behaviours within each group, avoidance, positive and neutral behaviour ranged from 0 to 99.05 seconds (Table 66).

## **6.7 Discussion**

### **6.7.1 Preference to Quadrant and Swimming Direction Exhibited by Dolphins at Lyttelton Using Count Data**

The preference to the bow and least to the stern as well as exhibiting preference to the starboard side relative to the stern and that there was no significant difference between Q2: starboard and Q4: the portside of the Black Cat gives strength to the methodology and indicates no bias in data collection. If bias were present towards one intersection or another it would most likely be to one of either of the quadrants Q2: starboard or Q4: portside of the vessel.

The results for swimming direction preference in the presence of the Black Cat showed that dolphins appear to exhibit swimming behaviour towards the Black Cat, but least for swimming with it as determined by the Kruskal-Wallis Test, or greater swimming away than towards the Black Cat, as shown using the Friedman Test. As there was not a significant difference in dolphins swimming towards and swimming with the Black Cat, it could be argued that those dolphins that wished to interact with the Black Cat remained constant over time, whereas those which do not wish to interact with it quickly vacate the vicinity. However, these results indicate that there are significantly more dolphin occurrences of avoidance than interaction.

The analysis of the number of observations per month per season shows that for both Season 1 and Season 2 there were fewer dolphins observed than would be expected in the months October and December. In Season 3 there were more observations than expected in October but December was consistent with Season 1 and 2 with lower than expected observations ( $P = 0.001$ ). November appears to have remained constant for all seasons showing no change in expected observations. This may be reflective of mating or calving season which would explain the lower than expected observation in all three seasons, 1999, 2000 and 2005, for the month of December.

A Log-linear model indicated that a change in dolphin behaviour occurred across all categories where dolphins exhibited the greatest avoidance, positive and neutral behaviour in Season 1 and the least in Season 2, but where Season 3 which represented the six year showed less behaviour in all categories compared to either Season 1 or Season 2 (Table 60). This suggests that during Season 1, dolphins exhibited more overall behaviours in the presence of the Black Cat and possibly an effect on dolphin behaviour as shown by the decrease in behaviours exhibited within each category during Season 2, which represents the least number of behaviours not only within each behavioural group but over all six years (Figure 26). Behaviours increased between Season 2 and Season 3 (Figure 26), indicating that dolphins adjusted to the presence of the Black Cat, which may be the result of tolerance to its presence over time.

### **6.7.2 Individual Behavioural Transitional Changes Within the Three Behaviour Groups Avoidance, Positive and Neutral Behaviour as Exhibited by Dolphins at Lyttelton Using Count Data (APN)**

The individual behaviour transitions within each behavioural group changed significantly within all three seasons, but these changes were for specific transitional behaviours within each group, avoidance, positive and neutral behaviour. The overall numbers of behaviour changes appear not to vary significantly. In Season 1 and Season 2, the overall number of transitional behaviours which changed numbered nineteen in each season, compared to only ten in Season 3. For Season 1 there were four transitional behaviours, which occurred more often than would be expected and three less. Season 2 saw an increase in two and decrease in two of the transitional behaviours, but Season 3 appears to have the most behavioural changes with a decrease observed in six of the transitional behaviours compared with only an increase in two. This may indicate a decrease in avoidance behaviour over time inferred from a reduction in six of the transitional behaviours within the avoidance category relative to only an increase in two. However, a GLM test showed that avoidance behaviour was exhibited over all months during season 3, which would suggest that that even though there was a decrease in the number of transitional behaviours within the avoidance behaviour category the two transitional behaviours that increased did so significantly in relation to those that decreased. The positive and neutral categories appear to remain constant with specific behaviours within each category increasing and decreasing but where there are generally equal numbers of behaviours increasing as there are decreasing. The exception to this was Season 3 where within the positive behaviour category there was a decrease in three of the transitional behaviours relative to an increase in two, and where in the neutral behaviour category there is a decrease in two behavioural transitions compared to only one increase. Overall it appears that the transitional behaviours within each category are flexible between seasons, but the overall changes within each behaviour group with respect to more of one transitional behaviour being observed and less of another transitional behaviour being observed, are cancelled out suggesting that behaviour remains relatively constant over time. The change in Season 3 within the avoidance category, which represents the greatest number of changes with six



decreases within the avoidance behaviour category and two increases may indicate habituation or sensitisation to the Black Cat, but this would be hard to substantiate on the basis of change within only one category for one season and only three months.

### **6.7.3 Individual Behavioural Transitional Changes Within the Three Behaviour Groups Avoidance, Positive and Neutral Behaviour as Exhibited by Dolphins at Lyttelton Using Time Data (APN)**

There were more neutral behaviours exhibited than positive or stress behaviours at Lyttelton during Season 1, whereas in Season 2 there was more positive behaviour (449 minutes) compared to avoidance or neutral behaviour. In Season 3, avoidance behaviour was greatest followed by positive and neutral behaviour. Accordingly, there was a shift from exhibiting more neutral behaviour in Season 1, to more positive behaviour in Season 2 and greater avoidance behaviour in Season 3 relative to all other behaviours. This suggests dolphins that performed neutral behaviour during Season 1 in the year 1999, possibly moved their focus to performing positive behaviour during Season 2 in year 2000, and by Season 3 in 2005 were exhibiting avoidance as their primary behaviour in the presence of the Black Cat.

There were differences when analysing overall time data, that is comparing season to season rather than comparing individual months within each season. The latter indicated that avoidance behaviour was significant throughout Season 3 which could lead to the suggestion that over time dolphins transit from exhibiting neutral and positive behaviour to exhibiting avoidance behaviour most often. This would subsequently indicate management concerns for dolphin watching tours at Lyttelton. However, analysis of the data did not indicate a decline in neutral behaviour between the Seasons, although positive behaviour increased in Season 2. The predicted means indicate that overall dolphins at Lyttelton exhibited the greatest avoidance behaviour in Seasons 3, 1, and 2, in that order. Both positive and neutral behaviour were exhibited, greatest to least, in Season 1, 3 and 2.

To conclude that the Black Cat is causing stress to dolphins in the form of increasing avoidance behaviour to the vessel on the basis of a change in one of the categories

would be remiss. There is a suggestion within these tests to indicate that the Black Cat overall is affecting dolphin behaviour adversely within Lyttelton Harbour.

The results, rather than reflecting any impact on dolphin behaviour with the presence of the Black Cat, may simply show that dolphins exhibited more of one particular type of behaviour in one season than another, and that this could be due to factors other than the presence of the Black Cat, for example, courting behaviour, or an environmental factor such as predator presence.

## **6.8 Overall Conclusion**

The results suggest that the presence of the Black Cat over six years does not significantly change dolphin responses with regard to quadrant preference or swimming direction. The responses of dolphins to the presence of the Black Cat are, therefore, the same regardless of the number of years tour operations have been conducted. However, the results suggest that behavioural changes do occur as shown in the amount of time spent exhibiting particular behaviours. The transition from exhibiting more neutral behaviour in the second year that the Black Cat commenced tour operations to more positive behaviours in the third year of tour operations and finally in the sixth year dolphins exhibiting greater avoidance behaviour indicates that persistent and regular long term tour operations do have an effect on overall dolphin behaviour, which in turn could detrimentally influence biological fitness.

The results obtained from count data could be used to argue that the presence of the Black Cat does not influence the overall behaviour of Hector's dolphin over time. When applying time as a factor the analysis showed that dolphin behaviour is affected by the presence of the Black Cat over time. Time data collection suggested that not only was Hector's dolphin behaviour affected, but also indicated within which transitional behaviours these changes took place. The methodology used to collect data appears to be significant. Simply counting the number of times a particular behaviour occurs is not sufficient in order to determine impacts on behaviour, but rather that time is an important factor in determining any effects and arriving at final

conclusions. The results herein seem to contradict those found in earlier research, which states that it is unlikely that the presence of boats will greatly affect the behaviour of this species (Slooten and Dawson, 1994).

## **6.9 Further Research**

### **6.9.1 Education of Tourists**

For twelve years between 1993 and 2005 observations were made of the southern right whales along the south-eastern Brazilian coast of Rio de Janeiro State (Lodi, 2007). The study showed not only accidental harm to marine mammals but also intentional harm. Lodi (2007), showed that conflicts exist between the southern right whale and human activities that included whale-boat collisions during rescue attempts, accidental entanglement in fishing nets and also intentional mortality (Lodi 2007). Although no incidents of actual harm were observed in the course of this study towards Hector's dolphin there were isolated incidents aboard the Black Cat where tourists threw objects into the ocean when dolphins were present, and which had the potential to cause harm to dolphins. On one occasion a polystyrene cup was thrown overboard, on another a drink can, and on six occasions cigarette butts were flicked overboard even in view of the non-smoking policy aboard the Black Cat. All were reported to the attendant on board and the individuals spoken too, of which most were apologetic. On two occasions visitors from overseas could not understand the importance of using the provided rubbish receptacles, nor the harm that a small amount of rubbish could illicit should it become lodged inside a dolphins blow hole, intestinal tracts or stomach. Only on one occasion at Timaru aboard the Caroline Cat was there an incident similar where a child dropped overboard part of an ice-cream because he wanted to share it with the dolphins. A valuable contribution to dolphin welfare may be the education of visiting tourists about the importance of maintaining litter free oceans as far as is possible with regard to tour activities. Research into cultural understanding as well as attitudes towards dolphins and the marine environment in general may well allow tour operators an upper hand in recognising potential problems or disregard for the Marine Mammal Protection Act (1978), and,

the Marine Reserves Act (1971) which serve to protect marine mammals from any activity which may result in mortality, either directly or indirectly, and, the Resource Management Act (1991), which prohibits any hazardous substance from entering the water that may “impair human, plant or animal health or may adversely affect the health or safety of any person or the environment” (see Appendix A). Simple posters or pamphlets could make clear the potential dangers of disposing of waste overboard, however seemingly insignificant.

### **6.9.2 Ongoing Monitoring**

Ongoing monitoring of Hector’s dolphin behaviour at Lyttelton would be advisable. The monitoring should include a time factor for analysis and which is able to account for changes in both individual and group transitional behaviours over time. This may not only reveal changes in behaviour relative to the presence of boat activity, but also changes which may occur should such events as global warming heat the inner harbour waters and affect food resources, bird-dolphin associations and other environmental factors, as yet unforeseen.

# **Chapter 7 – Issues Central to Behaviour Research, Improvements and Recommendations Regarding Voracity of Research and Analysis**

## **7.1 Introduction**

Dolphins have often been considered of equal intelligence or at least capable of communicating with or helping humans (Fraser *et al.*, 2006). Dolphins have been shown to be self-aware and have learning capacity in excess of other animals (Sickler *et al.*, 2006). Dolphins have also been shown to have recognition skills and exhibit grieving behaviour (Dudzinski, 1998). Dolphins approaching a dead male dolphin body have been shown to engage in inquisitive behaviours such as echolocation, head-scanning, and nudging (Dudzinski, 1998). Studies of bottlenose dolphins (*Tursiops truncatus*) have shown that that they understand human-given commands, gazing cues and object retrieval tasks, instructions to transport one object to another area, and joint tasks (Pack and Herman, 2006). These studies suggest dolphins possess comprehension and understanding skills as well as an ability to learn and that these abilities exceed the same skill as tested in apes (Pack and Herman, 2006). Other studies have even argued for the presence of mind reading skills in dolphins as determined from neuroanatomical and behavioural data used to assess dolphins completion of set tests without providing any visual or sound cues (Tschudin, 2001). False killer whales (*Pseudorca crassidens*) have been shown to react more strongly to

sounds which are new in the environment than sounds for which there has been prior experience (Akamatsu *et al.*, 1993), showing an ability to differentiate between sounds and therefore cognitive ability and memory. Mirror self-recognition has also been shown in dolphins as well as elephants and apes (Plotnik *et al.*, 2006). The mirror self-recognition tests has been argued to provide compelling evidence that cognition and consciousness is present in other species other than *Homo sapiens* (Sagan, 2002), and that the ability to distinguish one's self from other individuals and other species evolved independently in primates, dolphins and elephants and that this is now coded in to their DNA cells (Sagan, 2002). Gordon Gallup (1977) showed that orang-utans recognised themselves in a mirror and are self-aware, but gorillas are not. He then went on to show self-awareness in dolphins. His definition of being conscious is based on an ability to know that we exist, and that we have a mind when we are able to monitor our own mental states. Using this definition he concluded that chimpanzees, orang-utans, and dolphins are conscious and all have minds. In the last few decades studies have focused on tour operator and dolphin interactions and imply conscious decisions made by dolphins about interaction. For example, it has been reported that dolphins actively avoid boat interactions and try to maintain an interaction level below a certain level (Lusseau, 2004a). Studies presently suggest, even if indirectly, that dolphins are able to make conscious decision-making choices.

## **7.2 Difficulties and Improvements**

There was a general view that dolphin research was inaccessible and dolphins themselves too difficult a subject to study successfully (Pryor and Norris, 1991). Many graduate students have dropped ideas of studying dolphins or other marine mammal research because university academics deem such study impractical, as was the case with this research. Although dolphin research is difficult, time-consuming and can be expensive, it is worthwhile and possible, and will eventually add something new to existing knowledge about dolphin societies (Pryor and Norris, 1991).

### **7.2.1 Fieldwork is Problematic**

Most animal fieldwork is highly problematic, especially in relation to observing animals in the wild and specifically with regard to dolphin research where the environment cannot be controlled and where genuine controls are impossible to find. It is also difficult to follow individuals and/or much of what they do cannot be seen. Behaviour patterns can be recorded and analysed, yet they rely on observations that are impossible to verify precisely (Bekoff, 2000). All behavioural research to some degree involves leaps of faith from what is observed, in the data drawn up and the conclusions we draw from them (Bekoff, 2000).

Canadian psychologist Donald Hebb wrote: "the difficulties of finding order in behaviour are great enough to require all one's attention" (Hebb, 1949). This is an understatement today as we now recognise the necessity to understand behaviour in the light of environmental, physiological, genetic and ecological perspectives (Bekoff and Jamieson, 1990). Even taking as many factors as we are able in to account there will always remain factors which we are unable to account for. Francis Bacon (1920) stated that we can never say what things are, but only what our measurements show them to be (Bekoff and Jamieson, 1990).

It is clear that no one discipline of study can fully answer all the important questions of animal behaviour, cognitive development or emotion (Bekoff, 2000). What is needed is an array of interdisciplinary research which can draw together many factors and provide an overall picture from environmental, physiological, neurobiological, genetic, and biological perspective to mention a few. What is also clear is that it is invaluable to acquire base line data from which to determine any significant changes, whether they be due to adaptation, sensitisation, habituation, domestication or other influencing factors.

### **7.2.2 Lack of Control**

As tour operations commenced in 1999 at Timaru with the launch of the Caroline Cat it can be argued that Timaru is as close to a normal site as is possible when studying a

wild population. The Caroline Cat did not operate over a constant duration of time or to a specific timetable. Therefore, Timaru could be viewed as a control site whereas the Black cat at Lyttelton can be viewed as representative of a population of dolphins whose behaviour can be measured against that of the population of Timaru, due to tour operations having commenced two years earlier and running to a regular timetable. As there are no captive Hector's dolphins in New Zealand a control group in the form of contained dolphins was not an option. Although captivity may provide an environment making it easier for the observer to view dolphins, a dolphin's behaviour whilst held in captivity may not be wholly indicative of behaviors exhibited by wild populations.

### **7.2.3 Problems Measuring and Possible Bias in Recording Dolphin Behaviour**

There are more precise ways to measure dolphin behaviour such as running trips at the same time at different sites, identifying each individual within a pod or timing the length of each observation period, but these are impractical for most dolphin research as trips are not established to run to the same timetable at alternative sites. Tagging dolphins is time consuming, financially expensive and resource demanding and can lead to infection should an inadvertent injury occur, and dolphins generally do not adhere to being present for a standard length of time. Hence, theodolite observations were reliant on weather and sea state and boat-based observations were reliant on individual tour operator schedules, and observations were not made over a set time period or at the same time at each site. An effort to make as many observations as possible was made as well as to balance sampling across the intersections of the boats. However, difficulties still exist with dolphin research in that it is still often impossible to tell whether the same dolphins are being observed. As in a study in New England on *Lagenorhynchus acutus* where it was reported that it was impossible to determine if it were the same dolphins leaping repeatedly (Weinrich *et al.*, 2001). It should be noted that as sampling was made of dolphins which were in the vicinity of the tour vessels the samples may appear random but in fact be biased toward those individuals moving nearest the boat. However, this was taken into account, hence the reason for movement between, and observations from, alternating quadrant-intersections of the



tour boats and scanning alternate quadrants within each intersection to minimise the chance of sampling the same individual repeatedly. Also, if a point of reference is chosen, for example the intersection of the bow of the boat, and the sample taken of the individual nearest that point, then the sample will not be random as the individuals at the edges of the population will be more likely to be selected than those further away. So the dolphins nearest the boat will be chosen rather than an individual farther away. There is also an assumption that each individual was measured only once. However, this is difficult to verify and it is likely that the same individuals were in fact remeasured. However, this factor would have been present over the whole of the study period and be in common to both sites, and not just for one dolphin within the group but for all those present at the time behaviour was being recorded. Hence the observation of the same dolphin at the same site is not considered a major issue in this study. If an individual was re-sampled this could be argued to strengthen the results, inasmuch that should a change in behaviour occur in a dolphin that is repeatedly observed then this change would be reflected in the data collected and therefore provide the data sought.

#### **7.2.4 Variable Factors**

Behavioural studies are important tools in the preservation of wildlife, including marine mammals. I state ‘tool’, as behavioural studies alone do not reveal the whole picture. It appears that in order to gain real insight into behavioural changes and the relevance of these changes, behaviour needs to be viewed alongside physiological data as well as other factors, such as environmental and social. Focal animal sampling alone appears not to reveal important changes in group dynamics and social structure which may indicate important changes within a social group, whereas focal group sampling may cause an observer to overlook an individual’s behaviour which group sampling does not examine, for example, identification of individuals under stress, or being isolated from a group or being antisocial, which may indicate illness. Short-term studies are useful for identification of individuals and groups and to gain an estimation of population and distribution as well as to begin building a record of behavioural repertoires, but for any real conclusion to be drawn, research needs to be

maintained over long periods and bring in as many facets of science as can be employed.

It is clear that there are so many variables and factors involved in observing and collecting data from any source of wildlife and more so with wildlife that can run, fly or swim away at speed. There are therefore many factors which cannot be wholly accounted for, if, in fact, they can be accounted for at all. The best a researcher can hope for is to attain a balance between issues such as a lack of a control population or even the lack of control of the population as with dolphins and good data collection methods and statistical analysis. However, interpretation may then pose a problem, especially where ambiguity with terms may exist, as with the word 'stress'.

The issue with a control group is not easily overcome and has been acknowledged as a problem when studying wild populations. Creel (2001), notes this difficulty but says this can be suitably addressed by coupling observation of wild populations with good statistical analysis. He points out the benefit of studying wild population compared to the study of captive animals. He states that data collected from wild populations is gathered from naturally assembled groups from a natural environment, not confined to cages, that there are no issues with crowding, enforced and constant interaction, imposed group compositions, and that there are no limits to dispersal. He, therefore, supports non-invasive studies but points out that they may need larger sample sizes to detect any changes. Whether an animal is wild or in captivity, stress remains as a natural part of life for all animals (Waples and Gales, 2002).

Whether in captivity or in the wild, the presence of a dominant individual can lead to reduced immunological responses and death. This is particularly true of bottlenose dolphins whose social groupings change frequently in relation to composition, size and membership (Waples and Gales, 2002). Such observations in captivity may not directly be observable in the wild as it is often by chance that aggression is seen or isolation of a particular individual is noted due to the expanse of the ocean, but observations of social change taking place in captivity may allow for an explanation in changes which may be observed in wild populations for which there may be no apparent explanation.

They may also provide an insight into the less obvious measures of health, including a depressed immune system, and reduced food intake, both of which can be present long before any physical symptoms appear. In view of this suggestion, studying behaviour and physiology in unison may be a valuable way forward in order to gain a full picture of animal welfare (Dawkins, 2006).

Studies show fishery operations in the eastern tropical Pacific Ocean have been found to result in stress to dolphins (Curry, 1999). Lars Bejder *et al.*, (2006b), has shown in a study on dolphin behaviour that research vessels can have an impact on dolphin behaviour at different sites of 17 km separation, where one site experienced little vessel activity and the other had consistent vessel activity. This is not unlike Lyttelton and Timaru, where Lyttelton had constant regular vessel activity and Timaru had more sporadic vessel traffic.

Both control and impact sites resulted in behavioural changes in dolphins due to the vessels' presence, but the most persistent or long-lasting effect was seen at the control site. Not only was there a change in behaviour and the expression of stress behaviours such as a change in grouping behaviour, increased rates of membership change and erratic speeds and direction of swimming, but group spacing decreased, swimming speed increased and swimming direction changed frequently with group spacing having the greatest effect. It was also found that dolphins within the low impact site changed their behaviour in response to the presence of the experimental boat. This change in behaviour persisted even when the experimental vessel departed the area. The overall behavioural response of dolphins to the presence of the experimental vessel at the control or low impact site was longer lasting (Bejder *et al.*, 2006b). Even though both control and impact sites resulted in behavioural changes in dolphins due to the experimental vessels presence with dolphins in the control site having the most long lasting behavioural responses, there was also an overall difference in behavioural responses between sites (Bejder *et al.*, 2006b).

Due to the distance between Lyttelton and Timaru, it was assumed that there was a complete segregation of populations and individuals hence the results being site-specific. If this is correct and the populations are isolated from one another, then overall behavioural differences that were observed were due to the difference in boat

vessel activity in tour operators at Lyttelton and Timaru. Moreover, the results of the count data revealed that overall the presence of the Black Cat and Caroline Cat have site-specific effects on transitional behaviour and that these differences varied between sites. Due to the distance separating Lyttelton and Timaru, the population can be deemed to be socially isolated.

With marine mammal research there are many limitations including financial, time, locations, weather, controls, boat types, invasive versus non-invasive observations, suitable sites, access to sites, equipment, resources and the unpredictability of the research subject that may not appear at all, and can swim off out of sight. Added to the logistic difficulties of research, there are the hidden systems at work that may shed light on what is seen and recorded but are not collected, such as physiological, geological and environmental data.

In order to build a true and complete portrait, it is necessary to involve scientists from physiological, neurobiological, behavioural, ecological, and geographical backgrounds to ascertain as much as possible what biological and environmental factors and variables are playing a part in an animal's behaviour. It seems to me that science steams ahead on its individual pathways with clear-cut and decisive separation of the many facets which would serve each of the others well.

### **7.2.5 Ethogram**

An ethogram or an inventory of behaviours taken prior to any changes or addition of any factors such as tour operators within a dolphin habitat would provide information which could assist an environmental impact assessment (EIA). A baseline survey would provide an idea of the state of an ecosystem before it is developed and give a guideline to the behaviours of the animals present within it. In the case of dolphin research it would then be possible to monitor the ecosystem and animal behaviours prior to and after the introduction of tour operators, and then provide a means by which to determine the degree to which behaviours are pre-set or are modified with experience (Ellis, 1986).

## **7.2.6 Environmental Impact Assessment**

In consideration of this, an EIA should be performed before any development or introductions of tourism take place. Impact assessors should collect data to determine the ability of populations to adapt to human encroachment into their habitat (Ellis, 1986). This is especially important where there are endangered, unique or endemic species.

Endangered species require a scientifically-based recovery action plan to attain suitable population sizes and avert extinction (Restani *et al.*, 2002) and agencies should feel justified in using environmental legislation to protect species before population numbers decrease (Restani *et al.*, 2002). In addition the public need educating about the importance of maintaining a healthy eco-system in order to protect the environment (Bjorkland *et al.*, 2001).

Subsequent human impact on animal behaviour by developments which affect the environment and allow contact with wildlife through personal interaction via tour operations should therefore be closely monitored.

## **7.2.7 Finance**

This study was hindered by finance, but where I was told by many people and academics that it would be impossible without substantial funding, and, therefore, was actively discouraged, the research was in fact possible. Dolphin research is certainly an expensive and time-consuming activity and the only way this research was possible was to secure full-time work at the same time as continuing with full-time study. In addition, support was gained from both local communities in Timaru and Lyttelton as well as from the tour operators themselves. It was because of the support of the Black Cat Group and Caroline Cat who allowed access to the vessels for free that the bulk of this research was made possible. In addition, the YHA in Timaru, kindly allowed daily use of their personal yacht for a minimal fee and maintenance work, and this allowed collection of data for the purpose of comparison between sites and boat types.

The theodolite chapter was made feasible by the loan of a theodolite from New England Aquarium in Boston, USA.

### **7.2.8 Problems with Terms**

The word habituation is also problematic as it often indicates to conservation managers that tour operations have little or no effect, or possibly a neutral effect on behaviour. Another important factor to note is that animal consciousness is central to all studies of animal welfare, but there is not one single independent test to determine animal welfare. Behavioural ecologists thus have a major contribution to make connecting responses, such as behaviour and physiology (Dawkins, 2006).

As the previous sections have touched on habituation, animal consciousness, genes and anthropomorphism these factors are discussed further in the next section.

## **7.3 Other Issues to Consider**

### **7.3.1 Anthropomorphism**

Anthropomorphism is the suggestion that a non-human animal might experience subjective emotions such as fear, love, play, stress or even think consciously (Bekoff and Jamieson, 1990a). This includes even the simplest thought, such as believing food is in a particular location. Researchers and the population in general anthropomorphise what is observed by inferring a direct link between our own mental processes and those of the animal being observed, thus using our own experiences to describe what we see. In order to describe what is observed we use our own language and words in order to project feelings and thoughts that are common to us on to the animal of interest.

Anthropomorphism, and deliberations over animal thought processes, have been a problem associated with animal research for centuries. The French naturalist George Louis Leclerc, Comte de Buffon, believed mammals to be purely material beings, motivated solely by mechanical causes, with no soul or thought processes. Yet he

credited mammals with feelings such as pain, fear, jealousy, anger and love (Bekoff and Jamieson, 1990a). Le Roy in 1768 stated that animals could compare, judge, feel, reflect and choose, and that these behaviours changed with experience (Bekoff and Jamieson, 1990b). Some scientists have tried to address the problem of anthromorphism by looking at brain anatomy.

Many animal brains are anatomically similar to our own. This alone can give us reason to believe that mental events that take place “within” are to some degree similar to those which occur in ours (Bekoff and Jamieson, 1990a). Yet as human beings we are unable to enter the animal’s umwelt in order to interpret any mental processes or deduction, so the only mental processes we can refer to are our own. Therefore, the question of anthropomorphic thinking arises (Bekoff and Jamieson, 1990b), and is present to some degree in all behavioural research.

All multicellular animal brains are made of the same matter and the fundamental characteristics are the same including neurons and synapses - it is only the number and structure that differ (Bekoff and Jamieson, 1990a). There are billions of neurons in the human brain and thousands in an ant’s brain. The brains of whales and dolphins are close in size to human brains, both absolutely and in relation to size of body. All vertebrate brains consist of the same three main parts: hind brain, mid brain and fore brain (Bekoff and Jamieson, 1990a). On the basis of anatomy it is possible to argue that only humans are conscious whereas others consider that all vertebrates are conscious (Dawkins, 2006).

Rollin (1990) acknowledges that there is little activity within an animal mind that is directly observable, least of all measurable or verifiable. Hence, the concentration of study lies in observing behaviour, as this is an overt action which can be seen, measured objectively and verified. However, denying emotions to animals because they cannot be studied directly does not constitute a reasonable argument against their existence (Bekoff, 2000). Darwin argues that there is ‘continuity between humans and other animals in their cognitive lives’. His argument that the differences are in degree rather than in kind, and that there are transitional stages amongst species, not large gaps (Bekoff, 2000). Animals may think things through, have intentions and have complex behaviour but mind processes and thought processes are difficult to test

scientifically (Slater, 1999). We cannot do this between human beings and the difficulties between species are even more complex.

The opinion that humans are the only animals capable of thought-action, emotion and deductive reasoning may be incorrect when we consider brain similarities and add to that the theory of convergent evolution. A study showed that bottlenose dolphins may have long term with a long collective memory which extends back to at least the seventh-th past event (Ferrier i Cancho and Lusseau, 2006). Cognition is also implied by direct observation where dolphins have been observed struggling to save a dead infant. Elephants stand for days over a stillborn calf with their heads and ears down and rocking slowly. Elephant calves who have seen their mothers killed wake from sleep screaming. Traumatized orphan gorillas refuse to eat and they die (Bekoff, 2000). Surely if animals were not cognitive or able to have thoughts and actions they would continue life without these 'divergent' behaviours (Bekoff, 2000).

To claim that one cannot understand elephants, dolphins, or other animals because we are not one of them leads us nowhere. It is difficult to 'not' understand animals from our own perspective. A greater degree of success may be achieved if we try and understand how animals live in their own worlds, and try to perceive their perspectives (Bekoff, 2000). By engaging in anthromorphism, humans make other animal worlds accessible to themselves (Bekoff, 2000). I would argue that anthropomorphism may be a valid factor that serves its purpose across species, and may actually provide evidence that there are in fact shared 'feelings' across them. All modern species descended from a common ancestral species and were subject to evolutionary changes as well as behavioural changes. So, it follows that behavioural evolution can be inferred by comparing the behaviour patterns of species known to be descended from a recent common ancestor (Ridley, 1986). Even if human joy is not the same as elephant joy or chimpanzee joy, or gorilla grief the same as human grief, it is not to say that elephant joy or gorilla grief does not exist (Bekoff, 2000).

Even though it can also be argued that observers intuitively know what an animal is doing or how an animal is feeling (Ellis, 1986) and a clear argument can be made to support this in some cases, it is still necessary to make clear observations rather than purely give descriptive accounts of what is observed as this alone can lead to



problems of context. Borrowing words which describe human behaviour to describe animal behaviour (Ellis, 1986) can lead to ambiguous data (Ellis, 1986). Stress, for example, is a very ambiguous word and generally conjures up negative connotations, but some stress when observed in context could portray not a derogatory or negative situation but a positive one. Therefore it is best to describe the overall situation and all the observed behaviour an animal may exhibit rather than apply a single word such as stress, even in cases where we believe it is possible to intuitively explain what an animal is feeling or thinking.

For example, when an animal bites and swallows, it can be said to be eating, when it flees quickly it can be said to be escaping what it may deem a potentially dangerous situation (Ellis, 1986). However, an animal that is observed to be biting and swallowing may appear to be eating but in fact may only be masticating its food for its young, or a dolphin that increases speed may not be fleeing a potentially dangerous situation but be playing, or swimming to food. If evidence is gained that shows an animal responds more strongly to one aspect of its environment than another, such as the presence of a tour boat, then it can be assumed that the animal has made a choice or preference to do so, but in testing the same animal many times the risk is that the animal may stop responding (Bekoff and Jamieson, 1990b). Determining whether this is due to habituation, sensitisation, adaptation or tolerance is difficult as too are any internal thoughts or process that may have lead to the unresponsiveness. For this reason it is necessary to view behaviour in context rather than as individually occurring units or actions.

This is particularly important since behaviours can be somewhat obscure, for which every behaviour has the potential to be at some time. What we may see or hear on a specific occasion may not have an apparently clear cause or explanation (Ellis, 1986), but if it is followed through to completion the situation becomes clearer. For this reason it is invaluable to specifically observe and record the range of behaviour exhibited by a particular species (Ellis, 1986). This is particularly true with dolphin behaviour. It is necessary to place any behaviour observed in context by also observing what behaviour follows and if possible what behaviour precludes the one of interest. This would then allow for a more accurate determination of what was occurring.

Observing a complete range of behaviours poses a problem in itself as the sequence of behaviours observed needs to be measured in some way. It 'requires the conversion of continuous sequenced activities which in the case of all animals are the result of locomotion and the movement of body parts into a set of measurable parameters' :a method by which to record the behaviour quantitatively (Ellis, 1986). An example is how many times a particular behaviour occurred and for what duration, but even in this situation the issue of anthropomorphism cannot be completely removed as our own experiences still govern our perceptions. The best we can do is observe and collect data to try and form an understanding and determine some meaning for any exhibited behaviour. For dolphins, this includes many hours of observation and analysis in order to conclude if there is a significant chance that tour operators have either an adverse, positive or non-effect on behaviour, regardless of whether our eyes and perception tell us that dolphins 'appear' to be happy or stressed, playful or resting.

Behaviourists may never come to an absolute agreement as regards anthropomorphising observations, but what behaviourists do agree on is that for any conclusions to be drawn at all, an animal is best observed in its natural and wild environment rather than in captivity.

Buffon (1771), states that "animals observed in captivity or museums gave nothing more than an imperfect view of nature. Animals whose behaviour was altered, constrained or in the case of museums, 'dead', gave nothing but inanimate and superficial observations". In his opinion the only observations worth considering were those observed when the subject was "free, independent and wild". Charles Darwin also held this view (cited in Bekoff and Jamieson 1990a). Yet, whatever method is used with regard to observing animals, whether they are in the wild or in captivity, the same issue of anthropomorphism will exist as well as many other difficulties and challenges.

Other factors to take into account when observing and recording data which is behaviour-related include the domestication, adaptation, habituation and sensitisation of animals. These factors are also difficult to quantitatively measure, especially without baseline data or an ethogram of behaviours prior to these factors taking place.

### **7.3.2 Captive versus Wild Population Studies**

The Atlantis Marine Park in Western Australia conducted experiments on captive dolphins to determine stress from blood profiles, loss of appetite, and gastric ulcers, but states that behavioural records are important as early indicators of health issues and in recognition of potential stressful social changes and circumstances. (Waples and Gales, 2002). In captivity clinical signs of stress include weight loss, susceptibility to infection, decreased number of white blood cells and an increase in antisocial behaviour (Waples and Gales, 2002). Stressors which lead to the death of dolphins in captivity include limited environment, restricted social grouping and limited dispersal and resources which also lead to aggression, which in turn results in injury and possibly lead to mortality (Waples and Gales, 2002). The study of captive dolphins at Atlantis Marine Park suggests that behavioural response may be the first indicator of illness. The study conducted at Atlantis Marine Park was the first to use quantitative behavioural indices with physiological measures of stress in dolphins.

Although based on captive dolphins, the results show some insight into stressors in the form of social dominance, isolation and ill-health. Behavioural observations were made on three dolphins using focal animal sampling and standardised times for observation periods between April-Sept 1991. Two dolphins died and one became ill but later fully recovered. In all three case studies, each dolphin experienced behavioural changes on becoming sick.

Blood tests were taken from a dolphin named Karleen who had become inactive, disinterested, and experienced appetite reduction, but the overall blood tests revealed nothing untoward. Whilst she was unwell, dolphin group dynamics changed within her group and she no longer had the attention of the dominant male whose attention turned toward two other female dolphins. She became the object of aggressive attacks by the other dolphins. A second dolphin, Lulu, fell ill and lost her appetite and aggression toward her increased by the other dolphins as was also the case with the third dolphin named Rajah. Rajah fell ill and was alienated from his group but even when making a full recovery remained alienated. All three became inactive and socially isolated as well as experiencing a loss in appetite and loss of social support, group structure and experiencing aggression. Group associations and the results of

captive studies could possibly be used to determine stress in wild populations (Waples and Gales, 2002).

There is a lot of debate about captivity versus wild populations, but without captive animals some behaviours and especially physiological changes and social interactions may be overlooked in observations of wild populations. Although not a great supporter of captive animals, it is hard to imagine a world without zoos, wildlife parks and farmyard parks, some of which have assisted in breeding programs and in fights to save species from extinction, when if left in the wild, they may have become extinct. The division between captivity and the wild is not clear-cut. There is much to be gained from both, and it is possible that as pollution increases, habitats are destroyed and more species fight for survival, there will be an increasing need to place animals in captivity in order to preserve breeding stock to enable future generations to survive (Donoghue and Wheeler, 1990). This is true for animals which have a low reproductive rate, like Hector's dolphin.

## **7.4 Main Conclusions**

Overall dolphins prefer small water craft, the bow of all vessels and most often avoid the stern, with no difference in preference to either the portside or starboard sides of boats, and also exhibit no overall preference in direction of swimming. Dolphins are located in clusters at both Lyttelton and Timaru although clusters are more numerous and cover more distance at Timaru Harbour than Lyttelton Harbour.

On the basis of two years data, the overall count data results suggest that the presence of the Black Cat at Lyttelton and the Caroline Cat at Timaru had no lasting detrimental effects on Hector's dolphin behaviour with regard to stress or, more precisely, avoidance behaviour, which supports existing literature. A study on bottlenose dolphins in Shark Bay, Australia, found no difference in dolphin abundance over time where no or only one operator existed (Bejder *et al.*, 2006a), although the same study states that dolphin abundance did decline in a site where tourism and vessel activity was more frequent and that this contributed to a decline in

dolphin numbers. A further study in New South Wales found that dolphin behaviour changed in the presence of powerboats, but that these changes were short term, with dolphins returning to their preceding behaviour as well as to the swimming direction prior to the presence of the boats (Lemon *et al.*, 2006), indicating that short-term behavioural changes are quickly rectified when a boat leaves the vicinity.

However, throughout this study, time data indicated that there are significant effects on dolphin behaviour where dolphins move toward avoidance behaviour if the presence of a tour boat is persistent over time, as demonstrated for the Black Cat. In view of this it would be remiss to conclude that boat presence has no long lasting effect on behaviour. The major problem with making any solid conclusions is that the majority of studies cover only short periods of time and, rather than provide conclusive evidence about the impact of tour boats on populations of dolphins, allow only a brief insight into the subject of behaviour which is complex on many levels, with numerous unaccountable factors such as environmental, pathological, and physiological interactions and, often having no baseline data from which to work. It is important to recognise that individuals within a group are just that, individual, and hence may respond or react to a particular stimulus in one way at a particular time, but in another way at an alternative time, and that these reactions vary not only at an individual level but also between individuals at the same site and between sites, the situation becomes even more complex.

This study spans a total of six years at one site and uses the same methodology and analysis throughout, giving an insight into behavioural changes that have not previously been investigated at Lyttelton or Timaru over an extended period of time. It not only provides information on the most basic behaviour change, that is from one behaviour to another, but also behaviour changes which relate to larger more complex sequences of transitional behaviours, thus allowing an insight into both subtle and overall changes in behaviour over time. Factoring a time element has what could be considered severe repercussions for the results and their interpretation, and this should be taken in to account in any future research.

At best, what can be derived from such studies is verification that behaviour is complex and any interpretation made more so by using ambiguous terms, which

represent our own experiences, for what we think we observe and perceive in another species. Whether a population or an individual in a population has adapted to a particular situation, such as dolphins to the introduction of tour boats, or whether individuals have become habituated or sensitised, or simply learned to tolerate boat presence, may never be known for certain. There are arguments for intuition towards, understanding of, and empathy with another species, especially where a human has spent some time with the animal of interest, such as is common with the domesticated dog and cat, but intuition, or genuine understanding or empathy with another species that cannot be measured, nor can we experience firsthand species' *umwelt*. In view of this, I agree with Bekoff (2000), Hebb (1949) and Bejder (2006a) in that behavioural research requires a leap of faith, not only in what is observed, but in how it is interpreted (Bekoff, 2000). This is complex enough to require no less than all of one's attention (Hebb, 1949), but more so that the effect that tourism has on wildlife, in particular dolphins, 'should never be presumed to be benign' (Bejder, 2006a). I would add to this that it is not sufficient to draw conclusions on the basis of one season's or a few months' observations and that long-term studies are required which utilise a number of methodologies in order to obtain data which would allow for the best conclusion to be drawn and hence management plans and conservation suggestions and legislation.

What are needed are long-term studies, not over two or four years, but over decades, in order to ascertain genuine and certain changes on individual and group behaviours at the most simple basic levels as per the x-x observations, and also more complex behaviours such as the x+x-x+x behaviours. This would enable any subtle behavioural changes that are made by individuals to be identified over time, as well as also show changes within group dynamics and dolphin society overall. Most of the behaviours observed are not fixed action patterns, but do have complex variations not only between individuals within the same population, but also appear to vary between individuals of different populations as well as between populations. Which behaviour or behaviours change in response to stimuli may alter on a daily, or even an hourly, basis dependent upon the individual observed, and this individual may itself respond very differently to the same stimulus at a different time. For any real conclusions to be firm, it is necessary to undertake research continuously on the population of interest, using methods which allow direct comparisons to be made in order that a time-line

can be drawn showing any changes that have taken place. I believe that the research contained within this thesis is an example of this.

Incorporating methods which are non-invasive as well as boat-based observations from vessels that are already in operation rather than introducing research vessels especially in areas which already experience high boat traffic, may be best employed so as not to increase or contribute to any effects boat presence may have, in particular where research vessels may be used. With the advancement of theodolite technology and 'gadgets' which are easily transportable and often have waterproof casings, these are possible alternatives to launching research vessels, which may themselves impact or contribute to a change in dolphin behaviour. Of course, this would be impractical for research which is reliant on specific scientific equipment which is not transportable, or requires care in handling, such as the use of biopsy poles or submersibles, where a research vessel would be needed. Using both methods simultaneously would provide an overview of dolphin movements, abundance and behaviour both with and without boat presence.

#### **7.4.1 Data Collection and Analysis**

Data collection had an impact on the results obtained in this study. Count data was valuable and in some cases revealed similar results to data collected which incorporated a time factor. However, much of the analysis returned different results for both sets and led to the conclusion that in order for data to reflect any real change in behaviour, time is an important factor. Not only did time data provide more information overall with respect to differences between sites, but also differences within sites and across specific months. Statistical analysis also returned some surprising results, where one or both utilised non-parametric tests showed no overall significance difference, but when applying Zars test for  $Q$ , significant differences between quadrants and swimming direction were revealed. I would suggest in view of this data be thoroughly scrutinised, in several ways, if possible, before being presented as evidence for which serious managerial or conservation measure decisions are based up on.

## **7.5 Further Study**

Further data collection is needed to identify any on going changes in dolphin behaviour, in particular with regard to any detrimental effects of tour operator activities on the behaviour of Hector's dolphins and the effects of detrimental behaviour by passengers. These can then be used for a detailed analysis in order to justify management decisions and conservation strategies as well as review recommendations for future management, protection and legislation which can be added to the existing Marine Mammal Protection Act. In addition a review of the permit issue guidelines for ocean-based tour operators could be undertaken to incorporate passenger education prior to sailing.

### **7.5.1 Stress**

It is clear that words such as stress will continue to provide scientists with a challenge, and more-over that measuring stress, disturbance, habituation, sensitisation, adaptation or changes in behaviour are not simple tasks. Throughout the chapters in this thesis literature has shown that many responses are not only species specific but also gender specific, age specific and also dependant on an individual. Therefore, studies of the same species and their reactions to particular stimuli does not necessarily translate across the same species or even within the same genus. It is necessary to conduct research that is site specific and population specific drawing on expert findings of research across varied fields but not becoming reliant on what one population of dolphins, for example, reveal with regard to responses to a particular stressor. The actual results may prove to be entirely different to what has previously been reported at another location. With such variations in responses from within a particular species it is imperative that studies be focused on individual populations in order to understand the population as a whole.



## 7.6 What Does This Study Add?

This study adds to spatial and behavioural knowledge not previously known for Hector's dolphins at Lyttelton and Timaru. Specifically, it is the first comprehensive study undertaken at Lyttelton and Timaru, using both theodolite and boat-based observations, in order to record Hector's dolphin responses to tour boats at both sites as well as a private yacht at Timaru. Hector's dolphins were known to inhabit Lyttelton harbour, and the Black-Cat operators are aware of the general areas which may result in successful dolphin sightings, but these had never been scientifically investigated or recorded. Locals at Timaru were generally unaware of the presence of dolphins in Timaru harbour, even though there was no greater chance of sighting a dolphin at one site over the other. Theodolite tracking confirmed the presence of clusters of dolphins within each harbour, and also showed that a more naive population of dolphins have more clusters over a wider area than dolphins, at Lyttelton, which had been subjected to tour-operations for a year prior, something that has not previously been reported. In regard to behavioural data, this study clearly shows that dolphins exhibit a preference to the bow of boats and least to the stern, which in itself is not new information, but the results confirm that this is the case regardless of water-craft size and that dolphins at these sites appear to adhere to the findings of other studies in this regard. Hector's dolphins at Lyttelton and Timaru showed specific preference to certain water-craft which also agrees with other research, as already discussed in earlier chapters. Although not arriving at absolute conclusions this study indicates that over time dolphins at Lyttelton, according to the six year study, are impacted by the presence of the Black Cat, but not sufficiently enough to warrant major concern, in that a reduction in neutral behaviour may indicate a change to other behaviours, such as positive/interaction behaviour with boat presence, which is indicated by the results. Overall, the results suggest that Hector's dolphin behaviour is not negatively impacted by the presence of tour boats: the Black Cat at Lyttelton or the Caroline Cat at Timaru, and nor are dolphins at Timaru detrimentally affected by the presence of a private yacht. The major result is that this research suggests that there are no major concerns for the welfare of Hector's dolphins at Lyttelton and Timaru. However, should tour-operator numbers or trip frequency increase, Hector's dolphin behaviour may change. This study provides a basis from which to progress.

## **7.7 A Way Forward**

A positive way forward would be for scientists in all aspects of research to undertake studies together, looking at as many variables as possible. Each specialist would then be researching in their area of expertise but in the end everyone would come together to draw on all the knowledge collected to pull out across the board conclusions about animal welfare in order to prepare management plans. This would be a fascinating development for the future.

There needs to be a balance between conserving marine wildlife and human interaction. Anthropogenic activities undertaken by individuals also need to be taken into account as well as tourism which may aid in nature awareness as well as increasing the profile of endemic species in order to attract visitors and even to draw attention to the species for the purpose of funding and research.

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# Appendix A

## A1.1 Existing Legislative Framework

Management of the marine environment occurs within a legislative framework. The relevant guidelines are found within the Resource Management Act and the Marine Mammal Protection Act (NOAA, 1992). Both emphasise that the marine environment must be managed in such a way as to be ‘sustainable’. They also emphasise that the effect of human activities does not create detrimental ongoing effects that cannot be remedied, mitigated or furthermore avoided. In order to make suggestions or proposals with regard to tour operators, or to be able to understand the seriousness of tour boats and / or passengers flouting the legislation and the effect on Hector’s dolphin behaviour that this may have an overall understanding of both Acts is required.

## A1.2 Resource Management Act (1991)

The most prevalent legislative law referring to the environment is the Resource Management Act, which was passed and came into force on 1<sup>st</sup> October 1991 and subsequently updated in recent years. It is a comprehensive legislative guideline which now incorporates 57 separate independent acts.

The Act identifies five resource consent types of which three are directly relevant to the marine environment.

These are:

- Land use consent
- Subdivision consent
- Coastal permit consent
- Water permit consent
- Discharge permit

Although the first two are not specifically pertinent, it is important to have an understanding of the Act as a whole and its relevance to the marine environment before suggestions and proposals are submitted. This is especially pertinent where an integrated catchment management approach (with respect to sustainability) shows that each of the five consents above has the potential to effect the marine environment either directly or indirectly. Therefore The Resource Management Act's main focus is to regulate the effects of activities rather than regulating the activities themselves. It has a flexibility to allow management decisions to be changed, the extent of regulations and for what activities and reasons legislation may be required. Overall, the Act promotes sustainable management of natural resources.

The Act itself is contradictory in places, especially with regard to management within the coastal marine area, though it attempts to define specific words and phrases with respect to its main focus. The relevant sections of the RMA, 1991, along with definitions as shown therein are given below.

### **A1.2.1 Part 1 – Short Title and Commencement**

The beginning of the Act aims to make clear definitions which otherwise would be ambiguous. The two definitions relevant to this report are 'open coastal water' and 'effect'. 'Coastline water' includes seawater in harbours (Part 1 – 6). 'Open coastal water' means water that is remote from estuaries, inlets, fiords, harbours and embayments (Part 1 – 14).

'Effect' refers to:

- any positive or adverse effect
- any temporary or permanent effect
- any past, present or future effect
- any cumulative effect which arises over time or in combination with other effects
- any potential effect of high probability
- any potential effect of low probability which has a high potential impact (Part 1 – 21-22).

It should be noted that the term ‘effect’ includes any adverse effects regardless of scale.

### **A1.2.2 Part 2 – Outlines the Purpose of the Act.**

Primarily this part deals with ‘sustainable management’ of natural and physical resources. The RMA, 1991 permits people to provide for their own social, economic, and cultural wellbeing. It also provides a safeguard for inhabitants by setting out guidelines for managing the natural and physical environment with the main aim of protecting both. The aim is to avoid or remedy any adverse effects caused by activities on the environment (Part 2 – 1). The RMA, 1991, also provides for the needs of tourists (Part 2 – 10. s5), and matters of national importance (Part 2 – 11. s6). In section 6 of the RMA, 1991, the preservation and natural character of the coastal environment and marine areas is emphasised, with the focus being on protecting them from inappropriate development. However, it goes on to outline that the natural environment is to be protected in terms of ‘sustainable management’, which means that the natural environment is not to be protected at ‘all costs’ (Part 2 – 12. s6a).

### **A1.2.3 Parts 3 Onward – Responsibilities Under the Act**

Restrictions are placed on the use of coastal marine areas with the aim of protection (Part 3 – 12). It prohibits discharge of ‘any contaminant into the environment from any place’ (Part 3 – 17. 15 (2) a/b). This is further clarified as: ‘a person allows a contaminant to escape who fails to take precautions that a reasonably prudent person in the position would take to prevent that escape’ (Part 3 – 18. s15 (1) b).

Some of the most relevant statements under the RMA, 1991, for reasons which will be made clear when discussing tour operator’s activity, are the following:

- ‘No person may in the coastal marine area a) dump any waste or other matter from any ship.....’ (Part 3 – 19. 15A(1)a).

The prevention of discharge of anything overboard which in turn would result in ‘any significant adverse effects on aquatic life’ or is likely to be dangerous or have an adverse effect on the environment (Part 3 – 20. 15B (1) b.iv).

- ‘Every person has a duty to avoid, remedy, or mitigate any adverse effect on the environment arising from an activity carried on by or on behalf of that person’ (Part 3 – 23. 17 (1)).

It is made clear that the Minister is able to consider any proposal which is of national significance. ‘National significance’ means that the proposal has aroused public concern or interest, and it affects an area of natural significance which is relevant to New Zealand’s international obligations to the global environment. In addition to this, if a proposal is relevant to Section 8 of The Treaty of Waitangi, the Minister is obliged to consider any proposal (Part 5 – 45. 140:1+2 a-h).

#### **A1.2.4 Part 9 – Water Conservation Orders**

The purpose of this part is to both recognise and sustain water, and keep water in a natural state. It pertains to water that offers amenity or intrinsic value or is considered ‘outstanding’ in some way. Any water body is considered outstanding if it offers a habitat for terrestrial or aquatic organisms or is valued for its wild, scenic, natural or scientific value. Furthermore, it can be valued in the terms of recreational, historical, spiritual or cultural purposes including Māori.

#### **A1.2.5 Part 12 – Enforcement Orders**

The Environment Court can process an enforcement order to prohibit a person from commencing anything which may have an adverse effect on the environment. It also states a requirement to remedy or mitigate any adverse effect on the environment caused by or on behalf of that person (Part 12 – 5. 314 (1+2)).

Under the RMA, 1991, if an offence is committed by any employee of a ship the owner of that ship is personally liable, as if he/she had personally committed the

offence. The only exception to this is if all reasonable precautions had been taken to prevent the offence or the owner of the ship could not reasonably expect the offence to occur (Part 12 – 38. 340 (1)). This part of the RMA, 1991, reiterates contaminants, reinforcing that for any contaminant released or discharged into coastal water the person is liable. It should be noted that it is not necessary to prove that the defendant intended to commit the offence, only that the offence occurred (Part 12 – 44. 341B).

### **A1.2.6 Part 13 – Hazardous Substances**

A ‘hazardous substance’ is any substance which may impair human, plant or animal health or may adversely affect the health or safety of any person or the environment (Part 13 – 1.344).

Overall, the combination of the individual acts into a comprehensive document allows managers to focus on the effects of activities on the environment, including effects of activities on inhabitant species. It also provides guidelines which allow policy and decision makers to use the natural resources available in a ‘sustainable’ manner. Legislation dealing more specifically with the marine environment and marine mammal protection is the Marine Mammal Protection Act (1978). Together the RMA, 1991, and MMPA form a firm basis from which to work, and both have clear guidelines and statements which will be referred to again in latter sections.

What the RMA, 1991, lacks is a definitive outline of safeguards and contingency plans, explanations of the scales of activity permitted, and which organisation or legislative body has responsibility for monitoring, policing and funding activities.

### **A1.3 Obligations Under the Marine Mammal Protection Act (1978) and Marine Reserves Act (1971)**

There is an obligation under the Marine Mammal Protection Act (1978) and The Marine Reserves Act (1971) to protect dolphins from any activity that may result in mortality, either directly or indirectly. There is an assumption that the marine

mammal sanctuary already provides adequate protection. This may be true as far as reducing mortality due to set nets or by-catch, but there may be a trade off with increasing eco-tourism. Whether the marine sanctuary lends itself to protecting Hector's dolphin or whether there is a 'trade-off' with eco-tourism requires investigation. It is interesting to note that there was no evidence that dolphin survival rates increased following establishment of the sanctuary (Cameron *et al.*, 1999), which would indicate that other factors in addition to set net restrictions influence dolphin survivorship. An investigation would allow any problems to be addressed and suitable solutions applied. This research will contribute to existing knowledge with regard to any effects on Hector's dolphin behaviour at both Timaru and Lyttelton as the result of eco-tourism.

The Marine Mammal Protection Act (1978) deals extensively with fishing nets, for example, set nets, flounder nets and all other nets with the exception of drag nets that are designed to entangle or enmesh fish.

Section 22, Part 3, clause 6 explicitly lists regulations as regards the placing of the above nets. In particular, a net shall not be set one hour prior to sunset and one hour after sunrise and at any time between these periods. In addition, Part 4 states that no net shall be set between the 1<sup>st</sup> day of March and the 31<sup>st</sup> October the following year.

The Marine Mammal Protection Act (MMPA) deals with extensively with marine mammal mortality through fishing nets and fishing activity. It states that any person incidentally killing a marine mammal shall report this within 48 hours (Section 16).

Human-induced mortality, as defined by the above Act means ' the death of any marine mammal that can be attributed directly or indirectly to any human activity' [Section 2 (1)].

On-board boat-based observations and field note referencing revealed disregard for both the RMA, 1991 and MMPA, 1978 on several occasions.



# Appendix B: Theodolite Instruction Manual

## B1.1 Observation Manual

### Cliff Based Observations

**Quick Reference Section – Theodolite Set-up** - Overview for trained team leaders

<b>Section 1</b>	Theodolite use / recording data / down loading information / cleaning data and theo.exe & T-trak use
<b>Section 2</b>	Behaviour codes Boat codes
<b>Section 3</b>	Emergency Numbers
<b>Section 4</b>	Volunteers emergency information

## B1.2 Quick Reference Section – Theodolite Set-up, Overview for Trained Team Leaders

The theodolite itself when being handled should be supported by at the top and the base and be secured to the tripod using a centre screw, which is tightened from below the base of the tripod and goes through to the base of the theodolite. The battery is separate from the theodolite at this time and is attached just before the theodolite is ready to use. The base of the theodolite should be secured preventing it from any movement. Once the theodolite is attached to the tripod the palmtop can be connected.

There are several cords and leads to be attached each with characteristic plugs. These are connected to the palmtop and the theodolite. Several of the plugs have delicate pin-like projections, which can only be attached in a specific way and should not be forced as they are easily damaged. Attention should also be given to the cords, as the theodolite will not work correctly if they are obstructed or twisted. Once everything is attached and 'hooked up' the theodolite requires levelling.

### B1.2.1 To Level the theodolite

There are a total of three 'levels' on this model. Two are similar. They are rectangular windows containing liquid and an air bubble. One lies vertically, and one horizontally. The aim is to centre both bubbles. The third is a circular window, which also contains

an air bubble and is centred last. This one is situated above the LCD display to the left.

To centre the bubbles there are three black wheel-like knobs which lie horizontally just above the base of the theodolite. The first level to be centred is the vertical one. The wheel to the left of the theodolite moves clockwise and the wheel to the right of the theodolite moves anti-clockwise. Patience and small movements are required to centre the bubble. Once centred, the horizontal level can be attended to in the same way. The third wheel can also be used to help centre the horizontal bubble. Both vertical and horizontal levels must remain centred.

If the vertical bubble falls out of alignment then the levelling procedure must begin again. Occasionally the vertical level will be centred but will become dislodged while trying to centre the horizontal one. Both must remain centred.

The third level is contained in a circular window and lies flat. To centre this one it is necessary to look directly down from above the theodolite to determine if it is centred correctly. This is also centred in the same way as the other two. Once levelling is complete the battery can be inserted into the theodolite and the on/off switch set to 'on'.

If everything is in order two beeps will sound and the LCD display will show:

V 0  
H 0 00' 00 . >

The palmtop can now be switched on by pressing the on / off key for three seconds. A menu appears. Click on 'filer' and a '.dat' programme opens. The theodolite now requires information from the surrounding area in order to record longitude and latitude co-ordinates.

There are two telescopes on the theodolite. One large with a smaller one attached to it. They are turned a complete 360 degrees. The LCD display shows numbers corresponding with degrees as the scope is moved. These numbers are shown next to the 'V' reading (vertical reading). To obtain a horizontal reading the theodolite needs to be set to 'zero'.

### **B1.2.2 To Set a Zero Reference**

The small scope has a triangular figure in its sight that is used to focus on a particular object, in this case a prominent landmark, which will be used to zero the theodolite. Once the triangular figure is focused on the chosen landmark, the same should be viewable in the larger scope with more detail. If not, adjustments are required so that

both scopes correspond with what is viewed. Once this is complete the '0 set' button to the right of the LCD display is pressed resulting in the zero reference being set. A 90 degree angle now needs to be set. Turn the theodolite 90 degrees and lock the theodolite in position.

Turn back to the palmtop and scroll down to the programme file 'theo.exe' and return. Type in 000 and the zero reference will be recorded in the palmtop. Type in 999 and the 90 degree angle will also be recorded. If all is in order the palmtop will display:  
Behaviour [3]

This indicates the equipment is ready to record data.

### **B1.2.3 Recording Observations**

Both longitude and latitude co-ordinates in relation to the zero reference point were recorded. The time in hours, minutes and seconds, of each observation was automatically recorded and downloaded to the palmtop in the field and later transferred to a desktop. Each observation is allocated a three digit numerical code. If the sighting was of a vessel and not a dolphin, the three-digit code consisted of two numerical digits and a letter for the third digit. The first digit represents the number of the observation period for the day. The second digit represents either the number of dolphins sighted or denoted the type of boat / the boat code. The third digit is the behaviour of the dolphin or y/n letters denoting whether there were dolphins present with a vessel or not.

For example:

The code	123	1 = the first dolphin sighting for the day 2 = the number of dolphins sighted (two dolphins) 3 = particular behaviour of the dolphin (e.g. swimming)
----------	-----	------------------------------------------------------------------------------------------------------------------------------------------------------------

The code	12n	1 = first boat sighting for the day 2 = the code of the boat (e.g. recreational power) n = there were no dolphins associated with this boat
----------	-----	---------------------------------------------------------------------------------------------------------------------------------------------------

To finish observations and save data:

The palmtop is always close down first by pressing 'Alt + Q'. The screen displays

'saving data'

Pressing 'return' exits the theo.exe programme and pressing 'Alt + Q' twice more exits all programmes and closes the palmtop. The palmtop can now be un-hooked from the theodolite safely without the loss of any data.

## **B1.3 Section 1 - Theodolite Use / Recording Data / Down Loading Information / Cleaning Data and Theo.exe and T-Trak Use**

### **B1.3.1 Set-up Tripod**

Dig feet into the ground so it is secure and sturdy  
Ensure the height is even. Ensure the clamps are down on all three legs

Place theodolite near to tripod with the top of the case reading 'SOKKIA DT5A' facing upwards and to the top. The locks should be on your left.

Unlock the case and pick the theodolite up as if moving a microscope, supporting the top and bottom. Gently place the theodolite onto the tripod. DO NOT LET GO of it.

Once the theodolite is secure, move the theodolite case to one side, so it is not causing any obstruction. There should be free access to a full 360 degrees around the theo.

Click the battery into place.

### **B1.3.2 Hooking up the Palmtop to the Theodolite:**

Remove the plastic plug on the theo and place it below the yellow waterproof emergency cover in the theo case. Do not lose this plastic plug.

Place the connection labelled A into the theodolite. If it does not fit, it is twisted in the wrong direction. Turn it gently in the socket until it 'clicks' securely into place. Untwist any wires. Twisted wires prevent the transfer of data. Now connect the connection labelled B to the connection on the theo labelled C. Gently screw this connection together. Ensure all wires are untwisted.

Keep the palmtop dry. Under no circumstances place it on the ground, wet grass or on rocks near the ocean. Keep it off the ground at all times.

Now put connection C into the palmtop. The theo and palmtop should now be fully connected. Using the strap on leg 3 of the tripod attach and secure connection B to the leg. Do not allow this wire to hang loose.

### **B1.3.3 To Level the Theodolite**

There are three levels in total on the SOKKIA DT5A.  
The level above the LCD display and the level above the on/off switch are levelled first. To level these use the black 'horizontal wheels' of which there are three.

Level the bubble above the LCD first. Ensure the bubble is exactly centred.

Level the bubble above the on/of switch. Ensure this bubble is exactly centred.

Now look for the bubble contained within a circular window. It is to the left of the LCD display. Using the wheels again ensure this bubble is exactly centred. For this you need to look down on the circular window. If you look at an angle the bubble will not be correctly centred.

Stand back and look at the theodolite to check everything is attached and there are no loose wires.

Measure the height of the theodolite. This is the distance between the ground and the base of the theodolite. Make a note of this measurement in the field note book.

Turn on the palmtop NOW.

Open the palmtop and turn it on by

*Press* the key labelled

Off

On for three seconds

*Click*

Filer (should open the .dat program)

*Scroll down to*

Theo.exe

*Press*

Return

Turn on the theodolite (need to obtain a frame of reference before observations commence)

Using the on/off switch turn the theodolite on.

There should be two beeps. (If not, re-do set up procedure from palmtop connection)

Look at the LCD display. It should read

‘V0

H0 00 00’

Using the black knobs unlock the scope of the theodolite.

Turn the scope a full 360 degrees slowly. The LCD display should show a reading for a vertical axis

‘V \*\*\*\*\*’

To get an horizontal reading the theodolite requires ‘zeroing’

Choose a landmark (the same one will be used at each site. Make sure you know which one it is).

Use the small scope (you should see a triangle inside the scope) to site the landmark.  
Lock the scope into position using the relevant black knob.

Loom through the main scope and the landmark should be centred in the cross lines. If it is not 'centred', you must centre it using the black knobs.

Once centred and fixed in place this represents the 'zero reference'

On the theodolite:

*Press*  
0  
Set (key on the right of the LCD display)

On the palmtop

*Press*  
Tab (this will record and mark this position)

The palmtop displays the word 'Mark' indicating that a 'code' is now needed

*Enter*  
(zero reference)

Now turn the theodolite 90 degrees and lock it into position.

*Press*  
Tab (again to record and mark this position)  
*Enter*  
999

You are now ready to make observations.

To record observations using the theo hooked up to the palmtop

Codes are entered at the 'Mark' prompt on the palmtop

\*When sighting a boat:

*Press*  
Tab  
*Enter*  
3 digit code (boat number of the day/type of boat/y or n for dolphin presence)

\*When sighting a dolphin:

*Press*  
Tab  
*Enter*

3 digit code (dolphin number for the day/number of dolphins sighted/behaviour of focal animal).

Between observations check that the bubbles on the theodolite are centred. Amend if necessary using the black knobs as before.

Repeat this procedure until finished for the day.

### **B1.3.4 Examples of 3 digit codes to enter before making a mark:**

1 <sup>st</sup> digit	2 <sup>nd</sup> digit	3 <sup>rd</sup> digit
Number of boat of the day, or Number of dolphin sighting for the day E.g 1, 2, 3 etc	Type of boat, or Number of dolphins present	If a boat sighting the 3 <sup>rd</sup> digit should be a y or n indicating dolphin presence or absence. If a dolphin sighting enter the behaviour code for the focal animal
E.g 1 Boat sighted and it is the first boat of the day. Digit = 1	Use the boat codes given to you. This boat is a recreational power boat. Digit = 3	There are dolphins present Digit = Y
E.g 2. Dolphin spotted for the third time today. Digit = 3	There are seven dolphins in the pod. Digit = 7	The focal dolphin is bow riding Digit = 5

### **B1.3.5 To Finish and Pack up for the Day**

It is important that the palmtop is closed down first, or data will be lost.

On the palmtop

*Press*

Alt & Q together

The screen displays

Saving data

To exit DOS

*Press*

return

To get to the opening palmtop window

*Press*

Alt & Q TWICE

The introduction is now displayed and shows

‘Greg Stone.....’

*Press*

On/off

The screen goes blank

Close the palmtop

Turn off the theodolite using the on/off switch

Unhook the palm from the theo. Do not twist the cords. Place the palm and the cords in the original packaging and unhook all other wires.

Before removing the theo from the tripod ensure that both scopes are aligned vertically and locked into position.

Remove the battery and package away.

Unscrew the theo from the tripod. With both hands support the theo at the top and bottom as if moving a microscope and place it sideways in the box. If it does not fit easily the base is twisted incorrectly. Twist the base around until it lies in its correct orientation. Remember it is \$20, 000 worth of equipment and accessories.

Close and lock the box. Always double check the locks before carrying.

Pull up the tripod, but do not alter the legs. Leave them at the same height. Secure these with the Velcro straps.

Back at the accommodation download the data. This must be done at the end of each day.

### **B1.3.6 How to Transfer Data From the Palmtop to the Laptop, Clean up Data and Sort by Parameters.**

Palmtop = Palmton PC – 4MB RAM	REMOTE
Laptop = Hewlett Packard 200LX	LOCAL

#### **INSTRUCTIONS**

To turn on the palmtop and transfer data to the laptop

*Press*

On/off

*Press*

Filer

*Double Click*

Sigma Plot



*Double Click*

HP Connectivity Pack

*Click*

Filer = C:\\*

*Click Connect*

F10

Message on the palmtop now reads

In server mode: Processing remote commands only

Now split the screen on the laptop (so it shows files on both the palmtop and laptop simultaneously)

*Click*

F7

*Click Remote*

F6

Message now reads "Please wait....."

The files from the palmtop should show on one side of the screen and the files from the laptop on the other side of the screen.

To copy files from the palmtop

*Press*

F2

The message box appears

Type in the name of the file data to be moved to

When the files have been successfully moved

*Press*

Alt Q (takes you to a window)

Close 'filer' and open word

The data is now transferred and can be viewed in word

\*If problems occur at anytime

*Press*

Ctrl & Break (exit the program and I will attempt later)

### **B1.3.7 Cleaning Up Theo Data Files in WORD**

*Click*

All Files

Open up data and put spaces between the digits entered and also between the angles (marks).

After 'cleaning' the data save as a .dat file under the observations date. E.g 21.7.69.dat.

\*IMPORTANT. Files must be saved as a .dat file

Close WORD and open EXCEL

Working with the data in EXCEL

*Look in*

All files

The 'Text Import Wizard' opens

*Click*

Delimited (Sometimes defaults to this automatically)

*Click*

Next

*Click*

Tab & Space (should be checked / have crosses in the boxes next the words)

*Click*

Next

Ensure that 'General' is automatically chosen

*Click*

Finish

Now the files can be worked with and parameters chosen

For example, to sort data by parameter.

Highlight from the bottom of the data set to the top

*Click*

Data-sort

*Click*

Header row  
Sort by column f

*Click*

OK

### B1.3.8 Using T-trak

T-trak will not accept words. The middle column needs to be numbers and needs to be saved as text. After being 'cleaned' in word and checked in Excel the data can now be used in T-trak.

Once in T-trak the following configuration and formats must be present or be manually entered:

For data configuration the following must be present:

Eg

Time	Species Code	Identity Code	Behaviour Code	Vertical Angle	Horizontal Angle
1	2	3	4	5	6

The window shows:

In format      4  
Format          3  
                    3

Spaces between columns      1  
Do we wish to store settings   y

To accept these settings

*Click*

Ctrl & A

### B1.3.9 Station Files

This is where you need the height measurements of the theodolite, and the observation date. The station file should resemble this:

Insert observation date      21/7/69

Observation status          Godley

Platform height (in meters from the ground to base of theo)  
                                         1.17m

Eyepiece ht (cm)            28

Vertical Scale                1

Horizontal scale            1

Station x value (M)	0
Station y value (M)	0
Baseline zero angle	0000
Baseline n angle	90
Name of this file	godleyjune1
Choose analysis	

## **B1.4 Section 2 - Behaviour Codes and Boat Codes**

### **B1.4.1 Behaviour Codes**

With boat	Without boat	Definitions
A	1	Bow riding
B	2	Jump/breach
C	3	Grouping together
D	4	Milling
E	5	Porpoising
F	6	Swimming
G	7	Swim away from the boat
H	8	Swim towards the boat
I	9	Increase swimming speed
J	0	Tail/head slaps

### **B1.4.2 Watercraft Codes**

Black Cat / Caroline Cat	1
small commercial boat	2
recreational power boat	3
kayak/dinghy	4
large commercial	5
dredge / trawler	6
commercial fishing	7
yacht under sail	8
recreational fishing	9

## **B1.5 Section 3 - Emergency Numbers**

Police/ Coastguard/ Ambulance: 111

Georgia

Georgia at Timaru    03 684 5067  
                                 021 123 2101

Georgia at Godley    03 377 4176  
                                 021 123 2101

Supervisor at Lincoln

    Adrian Paterson    03 325 2811

    Sue Worner         03 325 2811

Tour Operators

    Black Cat            03 328 9078  
                                 0800 436574

    Caroline Cat        03 686 6885  
                                 025 203 0818

YHA Backpackers      03 684 5067

## **B1.6 Section 4 - Volunteers Personal Emergency Information**

Your personal detail sheet including emergency contact details

# Appendix C

## C1.1 Behaviour Data Sheet

Date \_\_\_\_\_

Location \_\_\_\_\_

Observers Name \_\_\_\_\_

Vessel Name \_\_\_\_\_

Skipper \_\_\_\_\_

Time From \_\_\_\_\_ To \_\_\_\_\_

Passenger Capacity \_\_\_\_\_

Weather Conditions \_\_\_\_\_

Other info \_\_\_\_\_

Sea State \_\_\_\_\_

Temperature \_\_\_\_\_

### Behaviour Codes:

Number of dolphins = #

Logging = **l**

Swimming = **S**

Blow Bubbles = **bb**

Milling = **m**

Swimming away from boat = **s/a**

Bow Riding = **br**

Porpoising = **p**

Swimming to boat = **s/t**

Breach/Jump = **j**

Swimming Speed Increases = **>**

Breaths-long = **bl**

Group Together = **g**

Breaths-short = **bs**

Tail/Head Slap = **t or h**

**Behaviour Codes:**

**Blow Bubbles =bb**  
**Bow Riding = br**  
**Breach/Jump = j**

**Breaths-long = bl**  
**Breaths-short = bs**  
**Grp Together = g**

**Logging = l**  
**Milling = m**  
**Porpoising = p**

**Swimming = s**  
**Swimming away from boat = s/a**  
**Swimming to boat = s/t**  
**Swimming Speed Increases = >**  
**Tail/Head Slap = t or h**

#	Time	Behvr

#	Time	Behvr

#	Time	Behvr

#	Time	Behvr



# Appendix D

## D1.1 Count and Time Data Used in Analysis

Table 5: Total number of observation periods and actual number of dolphins observed per month per site over two seasons.

Number of dolphin observations and actual number of dolphins observed				
MONTH	Black Cat		Caroline Cat	
	Number of observation periods	Number of actual dolphins observed	Number of observation periods	Number of actual dolphins observed
<b>Season 1</b>				
Sept	18	45	0	0
Oct	31	123	4	14
Nov	42	238	29	200
Dec	34	134	1	2
Jan	46	212	12	19
Feb	32	355	37	117
Mar	8	43	11	17
<b>Total S1</b>	211	1150	94	369
<b>Season 2</b>				
Sept	6	16	0	0
Oct	14	47	5	45
Nov	8	30	10	29
Dec	0	0	3	1
Jan	39	113	11	65
Feb	18	31	3	17
Mar	20	190	0	0
<b>Total S2</b>	102	427	32	157
<b>TOTAL S1 &amp; S2</b>	<b>313</b>	<b>1577</b>	<b>126</b>	<b>526</b>

A Freidman test on the number of observations per month based on 7 blocks (months) of 4 treatments (seasons: 2 seasons per site) per site returns no significant difference

( $P = 0.307$ ). There is no greater chance of sighting a dolphin at either site for any month in either season.

Table 6: Total number of observation periods and actual number of dolphins observed per site per season

Number of dolphin observations and actual number of dolphins observed				
MONTH	Black Cat		Caroline Cat	
	Number of observation periods	Number of actual dolphins observed	Number of observation periods	Number of actual dolphins observed
Total S1	211	1150	94	369
Total S2	102	427	32	157

When combining individual season data per site a Kruskal-Wallis one-way analysis of variance on the number of observations per season per site shows that there is no greater chance of sighting a dolphin at either site for either season ( $P = 0.244$ ).

Table 7: Total number of observation periods and actual number of dolphins observed per site over two seasons.

Number of dolphin observations and actual number of dolphins observed				
MONTH	Black Cat		Caroline Cat	
	Number of observation periods	Number of actual dolphins observed	Number of observation periods	Number of actual dolphins observed
TOTAL S1 & S2	313	1577	126	526

When combining both seasons data for each individual site and conducting a Kruskal-Wallis one-way analysis of variance for the overall number of observations per site the return is also insignificant ( $P = 0.490$ ), showing that there is no greater chance in sighting a dolphin at any time at one site over the other.

Table 8: Number of observations per site per month per season for the Black Cat and Caroline Cat

Count of behaviours: Stress, Association and Neutral behaviour per month per site						
No.obs per month				Stress	Association	Neutral
23	BC	S1	Sept	4	40	23
35	BC	S1	Oct	28	96	40
46	BC	S1	Nov	46	124	84
26	BC	S1	Dec	50	120	28
46	BC	S1	Jan	76	87	42
26	BC	S1	Feb	33	66	32
8	BC	S1	Mar	17	14	6
				254	547	255
6	BC	S2	Sept	0	0	0
14	BC	S2	Oct	14	84	2
8	BC	S2	Nov	8	2	11
0	BC	S2	Dec	0	0	0
39	BC	S2	Jan	48	92	9
15	BC	S2	Feb	23	22	16
20	BC	S2	Mar	23	4	27
				116	224	65
0	CC	S1	Sept	0	0	0
4	CC	S1	Oct	6	15	1
29	CC	S1	Nov	38	16	28
1	CC	S1	Dec	8	3	0
12	CC	S1	Jan	8	24	5
37	CC	S1	Feb	15	21	21
11	CC	S1	Mar	9	21	7
				84	100	62
0	CC	S2	Sept	0	0	0
5	CC	S2	Oct	8	18	6
10	CC	S2	Nov	13	9	20
3	CC	S2	Dec	3	5	4
11	CC	S2	Jan	18	17	6
3	CC	S2	Feb	3	17	5
0	CC	S2	Mar	0	0	0
				45	66	41

Table 14: Count Data: Number of times negative and positive stress, association and neutral behaviour occurred per month, per season at Lyttelton and Timaru (NPAN).

Count Data: negative, positive, association and neutral behaviours per month per site							
No.obs per month				Negative	Positive	Association	Neutral
23	BC	S1	Sept	2	2	40	23
35	BC	S1	Oct	18	18	96	40
46	BC	S1	Nov	51	6	124	84
26	BC	S1	Dec	48	2	120	28
46	BC	S1	Jan	66	10	87	42
26	BC	S1	Feb	23	10	66	32
8	BC	S1	Mar	16	1	14	6
<b>Total</b>				<b>224</b>	<b>49</b>	<b>547</b>	<b>255</b>
6	BC	S2	Sept	0	0	0	0
14	BC	S2	Oct	13	1	84	2
8	BC	S2	Nov	7	1	2	11
0	BC	S2	Dec	0	0	0	0
39	BC	S2	Jan	39	9	112	9
15	BC	S2	Feb	20	3	22	16
20	BC	S2	Mar	18	8	4	27
<b>Total</b>				<b>97</b>	<b>22</b>	<b>224</b>	<b>65</b>
0	CC	S1	Sept	0	0	0	0
4	CC	S1	Oct	5	1	15	1
29	CC	S1	Nov	28	10	16	28
1	CC	S1	Dec	4	4	3	0
12	CC	S1	Jan	4	4	24	5
37	CC	S1	Feb	9	6	21	21
11	CC	S1	Mar	7	2	21	7
<b>Total</b>				<b>57</b>	<b>27</b>	<b>100</b>	<b>62</b>
0	CC	S2	Sept	0	0	0	0
5	CC	S2	Oct	2	2	18	6
10	CC	S2	Nov	5	3	9	20
3	CC	S2	Dec	9	2	5	4
11	CC	S2	Jan	15	3	17	6
3	CC	S2	Feb	1	3	17	5
0	CC	S2	Mar	0	0	0	0
<b>Total</b>				<b>32</b>	<b>13</b>	<b>66</b>	<b>41</b>

Table 17: Total number of observations per season for the Caroline Cat in relation to negative and positive stress, association and neutral behaviours (NPAN).

Site	Negative	Positive	Association	Neutral
Caroline Cat S1	57	27	100	62
Caroline Cat S2	32	13	66	41

Table 18: The initial transitional behaviours within the negative behaviour group within the NPAN category.

Negative stress	Behaviour transition
sa>-sb	Swimming away at speed to short breaths
sb/sa-sb/g	Short breaths or swimming away to short breaths or grouping
p/s->sa	Porpoising or swimming to and increase in swimming speed away from the boat
sa->sa	Swimming away to an increase in swimming speed
s/p-sa	Swimming or porpoising to swimming away
sa-j	Swimming away to jumping
lb-sa	Long breaths to swimming away
bs-bs	Short breaths to short breaths

Table 20: Total number of observations per site in relation to negative avoidance, positive, and neutral behaviour (APN).

Site	Avoidance	Positive	Neutral
BC	321	820	320
CC	89	206	103

A Chi-Square test shows no significant difference between the Black Cat and Caroline Cat in relation to avoidance behaviour, positive behaviour and neutral behaviour. ( $\chi^2 = 3.276$ , DF = 2, P-Value = 0.194)

Table 21: Total number of observations per season for the Black Cat in relation to avoidance, association and neutral behaviours (APN)

	Avoidance	Positive	Neutral
BC S1	224	574	255
BC S2	97	246	<b>65</b>

A Chi-Square test shows a significant difference between Black Cat observations in Season 1 and those in Season 2 in relation to avoidance behaviour, positive behaviour and neutral behaviour ( $\chi^2 = 11.806$ , DF = 2, P-Value = 0.003), with less neutral behaviour observed in Season 2 than would normally be expected.

Table 22: Total number of observations per season for the Caroline Cat in relation to avoidance, association and neutral behaviours (APN).

	Avoidance	Positive	Neutral
CC S1	57	127	62
CC S2	32	79	41

A Chi-Square test shows no significant difference between Caroline Cat observations in Season 1 and Season 2 in relation to avoidance behaviour, positive behaviour and neutral behaviour ( $\chi^2 = 0.3.04$ , DF = 2, P-Value = 0.859).

Table 24: Total duration of time, in minutes, dolphins spent exhibiting stress, association and neutral behaviour at Lyttelton and Timaru (SAN).

Total duration of time spent exhibiting behaviours			
Site	Stress	Association	Neutral
BC	3437	15206	6659
CC	470	1051	372

Table 25: Average amount of time in minutes dolphins spent exhibiting stress association and neutral behaviour at Lyttelton and Timaru (SAN).

Average time in minutes spent exhibiting stress, association and neutral behaviour per month per site						
No.obs per month				Avoidance	Association	Neutral
23	BC	S1	Sept	0.57	6.30	10.70
35	BC	S1	Oct	5.60	23.86	5.46
46	BC	S1	Nov	2.61	8.24	3.07
26	BC	S1	Dec	5.65	33.19	15.96
46	BC	S1	Jan	10.33	48.30	21.59
26	BC	S1	Feb	28.54	133.23	59.58
8	BC	S1	Mar	170.50	818.63	369.63
6	BC	S2	Sept	0.00	2.83	0.00
14	BC	S2	Oct	2.43	10.36	0.29
8	BC	S2	Nov	1.38	5.75	2.13
0	BC	S2	Dec	0.00	0.00	0.00
39	BC	S2	Jan	4.72	9.59	1.87
15	BC	S2	Feb	3.33	1.00	1.33
20	BC	S2	Mar	5.05	7.60	2.65
0	CC	S1	Sept	0.00	0.00	0.00
4	CC	S1	Oct	5.75	5.75	0.25
29	CC	S1	Nov	11.10	11.10	5.31
1	CC	S1	Dec	2.00	2.00	0.00
12	CC	S1	Jan	7.00	7.00	1.08
37	CC	S1	Feb	11.03	11.03	1.32
11	CC	S1	Mar	3.18	3.18	0.91
0	CC	S2	Sept	0.00	0.00	0.00
5	CC	S2	Oct	4.80	4.80	3.60
10	CC	S2	Nov	5.60	5.60	1.10
3	CC	S2	Dec	13.33	13.33	31.33
11	CC	S2	Jan	2.36	2.36	0.64
3	CC	S2	Feb	10.33	10.33	5.00
0	CC	S2	Mar	0.00	0.00	0.00

Table 26: A General Linear Model (GLM) test investigating the average amount of time in minutes dolphins spent exhibiting stress behaviour (SAN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.73158	0.08377
CC	0.66525	0.08377
<b>Season</b>		
1	0.86774	0.08377
2	0.52909	0.08377
<b>Month</b>		
December	0.51405	0.15671
February	1.06035	0.15671
January	0.81026	0.15671
March	0.90930	0.15671
November	0.70910	0.15671
October	0.73689	0.15671
September	0.04897	0.15671

A General Linear Model (GLM) was used to test for significance between stress versus site, season and month as well as any interaction between factors site, month and season. Stress versus site, and stress versus site and season effects combined were not significant ( $P = 0.0586$  and  $P = 0.063$  respectively). However, there was a significant season effect ( $P = 0.014$ ) with Season 1 showing more stress behaviour than Season 2. Month was also significant ( $P = 0.017$ ). There is a difference between site and month ( $P = 0.043$ ) but the actual effect varies between sites.



Table 27: A General Linear Model (GLM) test investigating the average amount of time in minutes dolphins spent exhibiting association behaviour (SAN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	1.1586	0.1186
CC	0.6653	0.1186
<b>Season</b>		
1	1.1776	0.1186
2	0.6463	0.1186
<b>Month</b>		
December	0.7918	0.2219
February	1.1408	0.2219
January	1.0368	0.2219
March	1.1173	0.2219
November	0.9243	0.2219
October	1.0109	0.2219
September	0.3616	0.2219

A General Linear Model (GLM) was used to test for significance between association versus site, season and month as well as any interaction between factors site, month and season. Association versus site was significant with the Black Cat exhibiting more association behaviour than the Caroline Cat ( $P = 0.012$ ). Season 1 showed more association behaviour than Season 2 ( $P = 0.008$ ), and the factors site and season have an interaction ( $P = 0.024$ ) where there is a large decrease in association behaviour in Season 2 at Lyttelton when compared to Timaru (Figure x). Association behaviour versus month is not significant ( $P = 0.265$ ), nor is the interaction between site and month ( $P = 0.197$ ).

Table 28: A General Linear Model (GLM) test investigating the average amount of time in minutes dolphins spent exhibiting neutral behaviour (SAN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.8154	0.1197
CC	0.3821	0.1197
<b>Season</b>		
1	0.8060	0.1197
2	0.3915	0.1197
<b>Month</b>		
December	0.6848	0.2239
February	0.8233	0.2239
January	0.5862	0.2239
March	0.8531	0.2239
November	0.5568	0.2239
October	0.4201	0.2239
September	0.2670	0.2239

There is a significant site effect ( $P = 0.025$ ) with Lyttelton having higher observations of neutral behaviour than Timaru (Figure x). There is also a significant season effect ( $P = 0.031$ ) where Season 1 shows more neutral behaviour than Season 2. Neutral behaviour v month is not significant ( $P = 0.534$ ) and site and month do not interact ( $P = 0.290$ ) but Site and Season do ( $P = 0.002$ ) where Lyttelton shows a large decrease in neutral behaviour when compared to Timaru (Figure x).

Table 30: The duration of time in minutes that dolphins exhibited negative and positive stress, association and neutral behaviour at Lyttelton and Timaru over two seasons (NPAN).

Site	Duration of time in minutes			
	Negative	Positive	Association	Neutral
Black Cat	546	2891	15206	6659
Caroline Cat	337	133	1051	372

Table 31: The mean duration of time in minutes per month dolphins spent exhibiting negative, positive, association and neutral behaviours (NPAN).

		Duration of time: mean number of minutes			
Site and Season	Month	Negative	Positive	Association	Neutral
Black Cat – Season 1	September	1.11	0	9.89	19.44
	October	5.94	0.39	26.94	6.16
	November	1.69	1.17	9.02	3.36
	December	3.74	0.59	23.47	12.21
	January	4.98	0.17	6.48	2.67
	February	7.81	7.97	20.91	14.66
	March	3.63	5.25	2.63	0.88
Black Cat – Season 2	September	0	0	2.83	0
	October	1.71	0.71	10.36	0.29
	November	1.25	0.13	5.75	2.13
	December	0	0	0	0
	January	4.41	0.31	10.15	1.41
	February	2.67	0.11	0.83	1.11
	March	4.55	0.15	8.05	2.65
Caroline Cat – Season 1	September	0	0	0	0
	October	0	0	0	0
	November	2.76	1.86	12.24	5.55
	December	5	6	5	0
	January	1.25	1.58	7	1.08
	February	1.51	0.51	11.03	1.32
	March	0.91	0.18	3.18	0.91
Caroline Cat – Season 2	September	0	0	0	0
	October	1	1.8	5.4	4.6
	November	2.4	0.8	2	5
	December	1	0.33	2	0.67
	January	1.82	1.64	3	0.64
	February	0.33	2.67	10.33	5
	March	0	0	0	0

Table 32: A General Linear Model (GLM) test investigating the occurrence of negative stress versus site, season and month (NPAN)

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.53470	0.04962
CC	0.29242	0.04962
<b>Season</b>		
1	0.50319	0.04962
2	0.32392	0.04962
<b>Month</b>		
January	0.57808	0.09284
February	0.50829	0.09284
March	0.42273	0.09284
September	0.08107	0.09284
October	0.39384	0.09284
November	0.47215	0.09284
December	0.43874	0.09284

A General Linear Model (GLM) was used to test for significance between negative stress versus site, season and month as well as any interaction between factors site, month and season. Negative stress versus site and negative stress versus season were significant ( $P = 0.005$  and  $P = 0.025$  respectively). Month was not significant ( $P = 0.054$ ). There was no significant interaction between factors: site versus season ( $P = 0.264$ ) nor site versus month ( $P = 0.053$ ). There is a difference between site and season with the negative stress being greatest during Season 1 than Season 2 for the Black Cat and negative stress being greater with the Black Cat than the Caroline Cat overall.

Table 33: A General Linear Model (GLM) test investigating the occurrence of positive stress versus site, season and month (NPAN)

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	1.21071	0.5478
CC	1.24071	0.5478
<b>Season</b>		
1	1.83357	0.5478
2	0.61786	0.5478
<b>Month</b>		
January	0.92500	1.0249
February	2.81500	1.0249
March	1.39500	1.0249
September	0.00000	1.0249
October	0.72500	1.0249
November	0.99000	1.0249
December	1.73000	1.0249

A General Linear Model (GLM) was used to test for significance between positive stress versus site, season and month as well as any interaction between factor: site, month and season. Positive stress versus site, season and month were not significant ( $P = 0.970$ ,  $P = 0.149$  and  $P = 0.623$  respectively). There was no significant interaction between factors: site versus season ( $P = 0.321$ ) nor site versus month ( $P = 0.506$ ).

Table 34: A General Linear Model (GLM) test investigating the occurrence of association behaviour versus site, season and month (NPAN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.8844	0.1080
CC	0.5658	0.1080
<b>Season</b>		
1	0.8680	0.1080
2	0.5822	0.1080
<b>Month</b>		
January	0.8566	0.2020
February	0.9344	0.2020
March	0.5344	0.2020
September	0.4051	0.2020
October	0.8269	0.2020
November	0.8573	0.2020
December	0.6610	0.2020

A General Linear Model (GLM) was used to test for significance between association behaviour versus site, season and month as well as any interaction between factor: site, month and season. Association versus site, season and month were not significant ( $P = 0.059$ ,  $P = 0.086$  and  $P = 0.498$  respectively). There was no significant interaction between factor: site versus season ( $P = 0.410$ ) nor site versus month ( $P = 0.459$ ).

Table 35: A General Linear Model (GLM) test investigating the occurrence of neutral behaviour versus site, season and month (NPAN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.5596	0.09093
CC	0.3231	0.09093
<b>Season</b>		
1	0.5529	0.09093
2	0.3231	0.09093
<b>Month</b>		
January	0.3699	0.17011
February	0.6657	0.17011
March	0.2794	0.17011
September	0.3276	0.17011
October	0.4284	0.17011
November	0.6824	0.17011
December	0.3359	0.17011

A General Linear Model (GLM) was used to test for significance between neutral behaviour versus site, season and month as well as any interaction between factors: site, month and season. Neutral behaviour versus site, season and month were not significant ( $P = 0.091$ ,  $P = 0.108$  and  $P = 0.499$  respectively). There was no significant interaction between factor: site versus month ( $P = 0.682$ ). There was a significant interaction between site versus season ( $P = 0.016$ ). Neutral behaviour at the Black Cat is higher than for the Caroline Cat with a significant difference between Season 1 and no significant difference between Season 2 per site. The Black Cat had a very big decline in neutral behaviour (Figure x).

Table 39: Mean time, in minutes per month, that dolphins spent exhibiting avoidance, positive and neutral behaviour at Lyttelton and Timaru (APN).

		Mean time in minutes observed undertaking -, + stresses v neutral behaviour		
Site and Season	Month	Avoidance	Positive	Neutral
Black Cat – Season 1	September	0.87	7.74	15.22
	October	5.26	24.20	5.46
	November	1.54	9.30	3.07
	December	4.88	31.46	15.96
	January	4.98	6.65	2.67
	February	9.62	35.54	18.04
	March	3.63	7.88	0.88
Black Cat – Season 2	September	0.00	2.83	0.00
	October	1.71	11.07	0.29
	November	1.25	5.88	2.13
	December	0.00	0.00	0.00
	January	4.41	10.46	1.41
	February	3.20	1.13	1.33
	March	4.55	8.20	2.65
Caroline Cat – Season 1	September	0.00	0.00	0.00
	October	0.00	0.00	0.00
	November	2.76	14.10	5.55
	December	5.00	11.00	0.00
	January	1.25	8.58	1.08
	February	1.51	11.54	1.32
	March	0.91	3.36	0.91
Caroline Cat – Season 2	September	0.00	0.00	0.00
	October	1.00	7.20	4.60
	November	2.40	2.80	5.00
	December	1.00	2.33	0.67
	January	1.82	4.64	0.64
	February	0.33	13.00	5.00
	March	0.00	0.00	0.00



Table 40: A General Linear Model (GLM) test investigating the occurrence of avoidance behaviour v site, season and month (APN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.54264	0.05217
CC	0.29242	0.05217
<b>Season</b>		
1	0.50695	0.05217
2	0.32811	0.05217
<b>Month</b>		
January	0.57808	0.09760
February	0.54322	0.09760
March	0.42273	0.09760
September	0.06796	0.09760
October	0.38264	0.09760
November	0.46592	0.09760
December	0.46214	0.09760

A General Linear Model (GLM) was used to test for significance between avoidance behaviour versus site, season and month as well as any interaction between factor: site, month and season for the Black Cat. avoidance versus site, and season were significant ( $P = 0.005$ , and  $P = 0.032$  respectively), with the site effect being greater for Season 1 than Season 2 and with the difference between Season 1 and Season 2 being greater for the Black Cat than the Caroline Cat. Avoidance versus month was not significant ( $P = 0.052$ ), nor were there any significant interactions between factor: site versus month ( $P = 0.682$ ), site v season ( $P = 0.289$ ), or site versus month ( $P = 0.070$ ).

Table 41: A General Linear Model (GLM) test investigating the occurrence of positive behaviour versus site, season and month (APN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.9368	0.1124
CC	0.6351	0.1124
<b>Season</b>		
1	0.9457	0.1124
2	0.6262	0.1124
<b>Month</b>		
January	0.9189	0.2103
February	1.0339	0.2103
March	0.6379	0.2103
September	0.3812	0.2103
October	0.8492	0.2103
November	0.9023	0.2103
December	0.7782	0.2103

There were no significant differences at either site for positive behaviour versus site ( $P = 0.082$ ), Season ( $P = 0.068$ ), month ( $P = 0.434$ ) or any interaction between factor: site and season ( $P = 0.313$ ) or site and month ( $P = 0.495$ ).

Table 42: A General Linear Model (GLM) test investigating the occurrence of neutral behaviour versus site, season and month (APN).

Least square mean values		
Site/Season/Month	Mean	SE Mean
BC	0.9368	0.09146
CC	0.6351	0.09146
<b>Season</b>		
1	0.9457	0.09146
2	0.6262	0.09146
<b>Month</b>		
January	0.9189	0.17111
February	1.0339	0.17111
March	0.6379	0.17111
September	0.3812	0.17111
October	0.8492	0.17111
November	0.9023	0.17111
December	0.7782	0.17111

Neutral behaviour versus site, season, month and the interacting factors site and month were not significant at either site ( $P = 0.087$ ,  $0.113$ ,  $0.462$  and  $0.683$  respectively), but site and month were significant ( $P = 0.017$ ) where the biggest decline in neutral behaviour is shown at Lyttelton for the Black Cat from Season 1 to Season 2 (Figure x).

# Appendix E

## E1.1 Advert, Volunteers Wanted for Dolphin Research

The effect of tourism on the behaviour of Hector's dolphin at Lyttelton and Timaru.

Study:

This study represents an opportunity for individuals to take part in research that has historically been difficult for students to gain access to. Marine mammal research is an exciting but time-consuming activity. Although it sounds attractive, the truth is that many days will be spent sitting on a cliff top or on a boat without actually sighting any animals of interest. The success of this research has much to do with patience and determination. Research on marine mammals is difficult, as their appearance is neither guaranteed nor predictable. However, it is a very rewarding and unique work experience.

### E1.1.1 Experience Required

There is no experience necessary to volunteer for this fieldwork. Full training will be provided and any technical or difficult instructions repeated until everyone is confident with that which is required. A field manual has been prepared ready for referral in case of doubt or query. Initially I will supervise observations from all sites and boats. Eventually teams will be formed through which I shall rotate one to another on particular days and / or weeks.

A 'team leader' will be appointed to each group. Although not a pre-requisite, team leaders will ideally possess a first aid certificate and have good organisational skills and possess an understanding of how and why the data sheets require completion in a

particular way. This will arm them with the confidence to answer any question about the fieldwork in my absence. The team leader will change each month until everyone who wishes to have had the chance to organise observations and the 'team'. Teams will consist of between 2-5 individuals.

### **E1.1.2 Team Leaders**

The team leader will be expected to deal with any problems as they arise and deal with them quickly, efficiently and with the minimum of fuss. This will include dealing with any equipment breakdown, accidents and unforeseen situations. Training and health hazard sheets will be organised, along with emergency telephone numbers and each individual's whereabouts. Emergency contact numbers are readily available to every volunteer. Team leaders will report directly to me before and after every shift. They will take notes about the day that will outline how the group worked together, any problems within the group, medical conditions, accidents, near misses and any concerns, observations made, the number and success. These will be addressed immediately at the end of each day.

### **E1.1.3 Training**

Everyone will be trained on how to make and record observations aboard boats, and also using the theodolite. Anyone who suffers from seasickness or has poor eyesight but who wishes to partake in the research will have the chance to take field notes. This role is important because it allows the data to be analysed in reference to the weather, the Sea State and changes that take place in environmental conditions throughout the day. In addition, field notes give details other than that observable through a telescope. The theodolite can mark only one boat or dolphin at a time. The field notes will give an indication of any other vessel(s) which are present, activities taking place, any problems and any solution applied. The field note taker will be equipped with binoculars.

## **E1.2 Theodolite Observations**

The theodolite requires 2-3 people. October – March represents the most intense period of observations and is also when the dolphins are present in large numbers.

The data from the theodolite will need to be downloaded, cleaned and saved every evening after observations have ceased. Full instructions are available and training will be given for this. It is imperative that this process is completed at the end of every day and the procedures carried out exactly as instructed. There will be the opportunity for everyone to download data, clean it and save it to disk and to laptop. There may also be a chance to analyse some of the data when weather prevents either cliff-based or boat-based observations. All volunteers are supervised until they are confident and efficient in making accurate observations. If anyone should cancel or fall sick there will be room for two more boat observers. Please call me if you would like to be on 'stand-by'.

### **E1.2.1 Boat-Based Observations**

If any volunteers live in or near to Timaru, they will be given first option of making observations aboard the Timaru tour operator's boat for as long and as often as they would like from August 2000 onwards. However this must be a minimum of 12 tours per month.

Each boat trip lasts between 1.5-3 hours in duration. On average only 15-20 minutes of this time is spent making observations, although occasionally dolphins are present for several hours. The rest of the time is spent purely as a non-paying passenger or in the case of Timaru, a 'wildlife commentator'. There is no cost associated with boarding the tour operator vessels. Both tour operators are friendly and supportive of the research. There should be no problems boarding the vessels but if you are faced with any confrontation or problems call me immediately. Do not try and rectify problems with the tour operators yourself.

### **E1.2.2 Personal Behaviour**

It is important at all times to conduct yourselves in a polite and quiet manner. Under no circumstances should you interfere with the actual tour itself, unless requested to do so by the skipper of the vessel. Be as inconspicuous as possible and answer any questions you receive honestly and as politely as possible. Remember that these tours are the operators' livelihood and we have been granted access as a privilege not a right.

Anyone causing disturbance or actions resulting in complaints will not be permitted to continue boat-based studies.

Overall, it is expected that all the individuals in a group will work together as a team, each having a chance to give ideas and suggestions. Due to the long days and sometimes very inactive non-appearance of dolphins it is important that all the volunteers are patient, have an open mind and an accepting attitude to others. The emphasis is on teamwork and accurate data collection. Long days on a boat or a cliff means that close working relationships are necessary. There are already 12 volunteers to date working very happily on this study. I hope you will choose to join us.

### **E1.2.3 Associated Costs**

Transport to and from the observation sites will be provided. Each volunteer will meet his or her personal food costs. However, accommodation will be provided at Timaru. The only cost to each volunteer would then be the cost of food.

### **E1.2.4 Vacancies**

Volunteers are presently needed for 4 boat-based observation days at Lyttelton, 4 days of theodolite observations at Godley and, 4 days of theodolite observations at Timaru each month from January 2001 to March 2001. There may be an opportunity for both dinghy-based and tour boat operator-based observations at Timaru – but these are at the moment full. Further opportunities exist each month for making both boat-based and cliff-based observations from September – December 2001.

I look forward to meeting with anyone interested in volunteering for this study. Although it often consists of long days the work is mainly outdoors and is very rewarding. In addition to this your efforts will be an invaluable contribution towards the understanding of Hector's dolphin behaviour.

### **E1.2.5 Contact Details**

If you remain interested please contact Georgia-Rose Travis directly by e-mail.

[Travisg1@tui.lincoln.ac.nz](mailto:Travisg1@tui.lincoln.ac.nz)

[Georgiaroset@hotmail.com](mailto:Georgiaroset@hotmail.com)

Alternatively by phoning (03) 377 4176.



# Appendix F - Statistical Tests

## F1.1 Statistical Tests Applied to Each Set of Data:

### F1.1.1 Kruskal-Wallis Test

Kruskal-Wallis Test can be used to test for two samples. They are one-way analyses (Bradley, 1968). The Kruskal-Wallis Test can be used when conditions for the use of a classical test are not fulfilled (Dijkstra, 1988). This test is specifically designed for unequal variances and as such is termed a non-parametric test (Dijkstra, 1988). The Kruskal-Wallis Test gives a response to the question ‘Is there any difference among treatments?’ (Lehmann and D’Abrera, 1975). In this study the Kruskal-Wallis Test answers the question of whether there is a difference between the number of dolphins in respect to different boat types and sites.

The Kruskal-Wallis Test, tests the hypothesis of  $H_0$ , that being that there is no difference between treatments. An indication that there is a difference is given by calculating the average rank of the treatment. All observations are ranked from smallest to largest and any tied ranks are allocated mid-rank values, from which the average rank is determined (Sprent, 1993). If the average rank of the treatments being tested differs greatly between each other then this denotes a significant difference and the hypothesis of  $H_0$  can be disregarded (Lehmann and D’Abrera, 1975). If, however, the average ranks are similar then this denotes no significant difference between the treatments. In this study the difference between the numbers of dolphins in response to type of boat is tested. Overall, Kruskal-Wallis tests for equality of population means or medians where there are inequalities for some of the  $x_i$ .

The problem with this test is that it assumes that the response, that is the number of dolphins, is unaffected by some other factor (Lehmann and D’Abrera, 1975). For example, it is hoped that weather need not be distinguished between treatments.

Because of such assumptions it is necessary to undertake further statistical tests to determine whether other factors, such as weather affect the response, number of dolphins, thus allowing the Kruskal-Wallis Test to be applied with more confidence. In support of the Kruskal-Wallis Test is its optimal power when applied to samples containing not more than 15 observations each (Dijkstra, 1988). In this study all observations are averaged resulting in a maximum of 15 observations per sample, therefore allowing the Kruskal-Wallis Test to be applied with confidence.

The Kruskal-Wallis statistic is shown as:

$$V_1 = \frac{12}{n(n+1)} \sum_{i=1}^k n_i \left( R_i - \frac{n+1}{2} \right)^2$$

This gives an overall test for equality if populations means or medians were there are inequalities for some of the x. All observations are ranked from smallest to largest any tied ranks are allocated mid-rank values [Adapted from Randles and Wolfe (1979)]

### **F1.1.2 Wilcoxon / Mann-Whitney Test**

Wilcoxon in 1945 and Mann and Whitney in 1947 independently studied and proposed the rank sum statistic (Randles and Wolfe, 1979). Both tests are based on the assumption that independent observations are drawn from two populations with the null hypothesis being that they are equivalent (Pratt and Gibbons, 1981). The Mann-Whitney test determines confidence intervals for differences between measured means or medians taken from these populations (Sprent, 1993). Observations from two samples are ranked giving a mix of low, medium and high ranks in each sample. For the  $H_0$  to be valid there would need to be an even distribution of ranks. If low or high ranks dominate in one sample then we can reject the null hypothesis  $H_0$  that there is no difference between populations (Sprent, 1993). This test statistic is reputed to give a ‘highly meaningful estimate’ (Bradley, 1968).

The Wilcoxon statistical test is shown as:

$$W = \sum_{i=1}^n Ri$$

$W$  is the sum of the ranks for the samples of observations  $Y$  when ranked among all  $m$  and  $n$  observations. [Adapted from Randles and Wolfe (1979)].

The Mann and Whitney statistical test is

$$V = \sum_{i=1}^m \sum_{j=1}^n \Psi((y_j - x_i))$$

Where  $\Psi(t) = 1, 0$  as  $t >, < 0$ . This represents the total number of times an observation of  $Y$  is larger than an  $X$  observation (Randles and Wolfe, 1979).

### **F1.1.3 Average/Means**

This is the measure of central tendency. An average is a value that is either typical or representative of a set of numbers (Samson *et al.*, 1970). The result is that an arithmetic mean or average gives the most significant single statistic that can be used to describe a distribution. However it gives no indication about how all the other measurements vary about the mean or average, and it does not show the spread of numbers or indicate how the figures are grouped about the mean (Samson *et al.*, 1970). In order to determine whether there is a large variability between the measurements or little variability; all measurements are closely clustered around the mean it is necessary to use statistics (Samson *et al.*, 1970).

The 'range' is determined by calculating the difference between the lowest and highest measurements. This is easily obtained from data sets but is only reliable where there are less than 15 measurements within a sample. For small samples this is a

satisfactory statistic for indicating dispersion (Samson *et al.*, 1970). As the maximum number of measurements in this study is 15 this is a suitable and reliable method to use.

#### **F1.1.4 Efficiency of and Justification for Using Non-Parametric Tests**

It has long been thought that non-parametric methods are more unreliable than parametric methods. Examples of the value and efficiency of both the Kruskal-Wallis Test and the Mann-Whitney tests are supported and outlined in detail in several publications and specialised texts (Randles and Wolfe 1979; Noether, 1967; Sprent, 1993). The Kruskal-Wallis Test can be compared to the two sample *t*-test but whereas the two sample *t*-test is not distribution free, the Kruskal-Wallis Test is (Noether, 1967). It has been determined that the efficiency of the *W*-test relative to that of the *t*-test is never less than 0.86. In other words, for every 100 observations expanded on the *W*-test there has to be at least 86 observations on a *t*-test to achieve the same power (Noether, 1967). Often there are more observations required by the *t*-test than required for the *W*-test. Hodges and Lehman (1956) investigated the problem of large deviations in samples and determined that that the *W*-test is less likely to reject the (true) null hypothesis than is the *t*-test if large deviations are present within samples as a result of errors. They showed that any rank test is insensitive to the size of large deviations, thus resulting in efficiency equal to if not more than a comparative parametric test where samples are equal (Noether, 1967).

# Appendix G

Georgia-Rose Travis

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Lincoln University

## **G1.1 A report to outline the number of successful observations of Hector's Dolphin at Lyttelton Harbour, Christchurch, New Zealand between October – December 2005**

### **G1.1 Introduction**

Eco-tourism is now a very popular and growing industry. The Black Cat Group commenced marine wildlife tours at Lyttelton Harbour in November 1999. In addition to Black Cat tours, Sea Tours New Zealand operates a Dolphin Adventure tour and Lyttelton Harbour Cruises operate wildlife cruises and other excursions including trips to Diamond Harbour, Ripapa Island and Quail Island.

'Eco-tours' have become increasingly popular at Lyttelton Harbour as they present an opportunity to take part in many activities that allow close encounters with Hector's dolphin. As Lyttelton Harbour is easily accessible from Christchurch City for tourists and the surrounding resident population of the Canterbury region of 468 042, it is important to determine any affects of tours on the behaviour of the wildlife present. By undertaking such research the livelihood of tour operators can be protected as well as that of the dolphins which can be monitored to determine any affects and also ensure their protection into the future.

It is important to monitor the effects of both boat presence and human presence so that an overall and combined effect on Hector's dolphin behaviour can be determined.

Monitoring of individual dolphins and overall group dynamics is therefore required. The information derived from such research will provide invaluable information about Hector's dolphin behaviour in response to various watercraft as well as the effect of human interaction within the Harbour. This is the main aim of the thesis to which this minor report will contribute.

## **G1.2 Aims**

The aim of conducting research between October and December 2005 is to first and foremost, add to existing data collected from previous years to determine any change in the number of successful observations and approach of dolphins to tour vessels. The second main aim of the research conducted October to December 2005 is to supply an over-view of the data collected during these months to the Black Cat Group that include the following:

To determine any preference to the bow, stern, portside or starboard side of the Canterbury Cat.

To determine any preference exhibited by dolphins in their approach to the Canterbury Cat.

To determine any significant difference in the number of dolphin observations made during the months October, November and December.

## **G1.3 Objective**

Although not addressed in this report, the main objective of this research is to tie together previous years' observations to those more recent with regards to dolphin behaviour around Black Cat run tours at Lyttelton.

## **G1.4 Methods**

Dolphin observations aboard the Canterbury Cat at Lyttelton were made over two days each month for three months between October – December 2005. Two researchers made observations: one researcher was situated at the starboard side of the bow and the other at the portside of the stern in order to view as much of the vessel as possible and record dolphin observations from all approach angles.

The vessel was split into four quadrants:

Bow

Portside

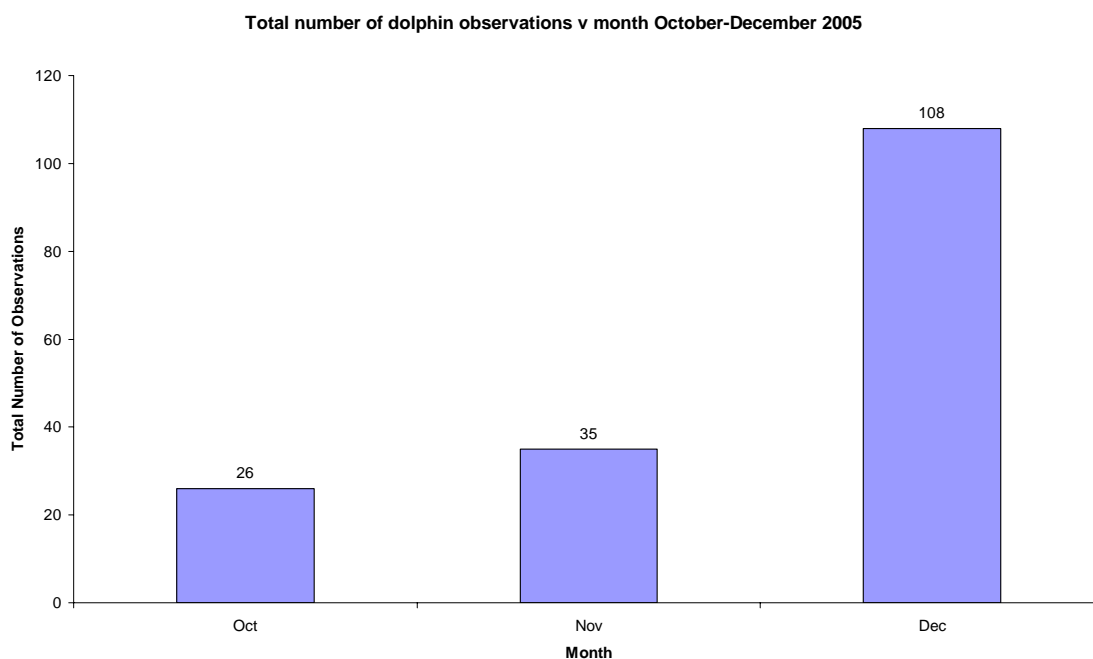
Starboard

Stern

On sighting a dolphin data sheets were marked showing the position of the dolphin relative to the boat and within one of the quadrants. Also recorded were details of whether the dolphin was approaching or swimming away from the vessel and any behaviour which may have been of interest, such as tail slaps, head slaps, and jumps.

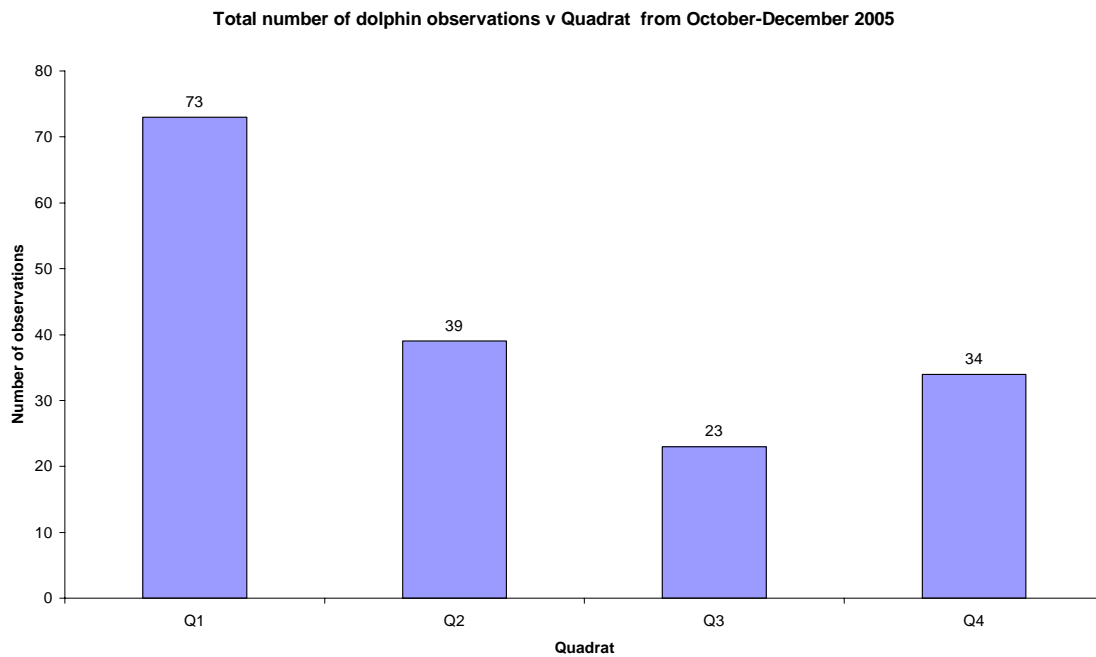
## Results

Dolphin observations v month



There were 26 dolphin observations in October, 35 in November and 108 in December. Dolphins were more often sighted in December and least observed in October.

## Dolphin observations v quadrant



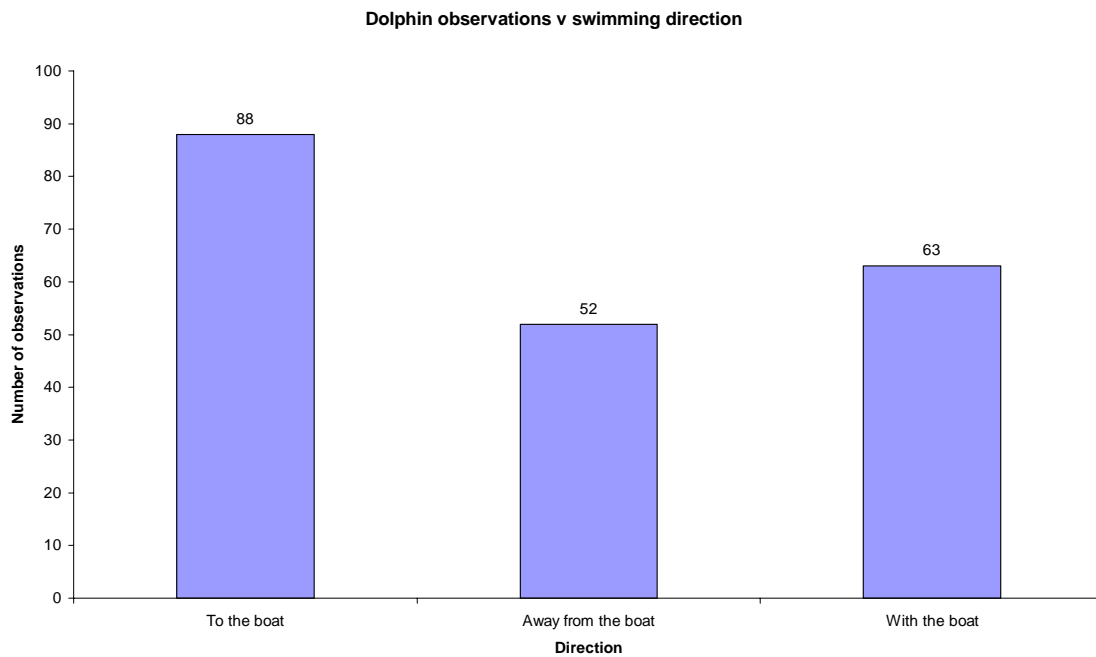
Dolphins were observed 73 times at Quadrant 1, 39, 23 and 34 times with quadrant 2, 3 and 4 respectively. More observations were associated with the bow of the boat: Q1, than with the Stern: Q3 with 23 observations. There was not a significant difference between dolphin observations at the port side and starboard side of the vessel with 39 and 34 observations respectively.

Analysis using the Kruskal-Wallis Test for quadrants versus observations shows significance  $P=0.084$ . The average ranks showed similar results to the chart.

Based on the number of observations over the period October – December 2005 the Average Rank for each quadrant was Q1: 2.31, Q2: 0.09, Q3: -1.76 and Q4 -0.65. The Bow had consistently higher numbers of observations whereas the port-side, starboard side and stern of the boat had consistently lower numbers of dolphin observations. The stern had the lowest number of observations overall.



## Dolphin observations v swimming direction relative to the Canterbury Cat



Dolphins were more often observed approaching the boat and least often observed swimming away from the boat.

The Kruskal-Wallis Test for Quadrants versus Direction shows significance  $P=0.561$ . Based on the actual number of observations over the period October – December 2005 the Average Rank for swimming direction are: ‘away from the boat’: -0.77, ‘swimming to the boat’: 1.03 and ‘swimming with the boat’: -0.26. Dolphins were observed consistently swimming towards the boat with little difference between movements away from the boat and swimming with the boat.

The same result is reflected when using percentages to reflect the amount of time dolphins spent moving away, to and swimming with the boat. Using percentages in the analysis the results for Average Ranks are, away from the boat: -0.77, swimming to the boat: 1.55 and swimming with the boat: -0.77 ( $P=0.301$ ).

### G1.5 Discussion

As it was often difficult to record all dolphins present at any one time, the data collected is referred to as dolphin observations. That is, those dolphins that were actually observed and recorded rather than attempting to record every individual

present. Dolphins often swam under the boat and appeared within a quadrant as well as appeared in numbers too great to count within a few seconds. Due to their constant movement it was decided to count only the dolphins that could confidently be seen at any one time. This reduced the error of counting the same dolphin again should it swim to another position and appear alongside other dolphins being counted. As dolphins were observed more often swimming to the Canterbury Cat than swimming away from or swimming with the vessel may indicate that dolphins have become habituated to the presence of the Canterbury Cat.

### **G1.6 Conclusion**

The data shows a higher chance of observing dolphins on the bow of the boat than the sides of the boat or the stern. There is a significantly greater chance of observing dolphins in the month of December than October or November. Dolphins were more often observed swimming to the boat than with the boat or away from the boat.

### **G1.7 Further Study**

The results appears to be upheld by previous research I conducted at Lyttelton but in order to substantiate the findings observations during October-December would need to be made each year to identify any real pattern that may exist. This would also apply to dolphins being observed more often swimming to the boat than away or with it. Studies over several years with a larger repetition may provide insight into whether the dolphins at Lyttelton are becoming habitualised to the presence of the Canterbury Cat.

# Appendix H

Table 51: Kruskal-Wallis test results in relation to the average number of dolphin observations versus quadrant.

Kruskal-Wallis Test on the Average Number of Dolphin observations for three seasons aboard the Black Cat				
Quadrant	N	Median	Average Rank	Z
Q1	9	6.500	25.0	2.14
Q2	9	4.500	20.5	0.66
Q3	9	1.200	13.4	-1.68
Q4	9	1.000	15.1	-1.11
Overall	36		18.5	
H = 6.80 DF = 3 P = 0.079				
H = 6.80 DF = 3 P = 0.078 (adjusted for ties)				

Table 52: Friedman Test results in relation to the average number of dolphin observations for all seasons versus quadrant. Bold figures indicate a significant difference in relation to the average number of dolphin observations between specific quadrants.

Quadrant	N	Est Median	Sum of Ranks
Q1	9	5.1950	33.0
Q2	9	4.4775	26.0
Q3	9	3.4925	13.0
Q4	9	3.8050	18.0
Grand median = 4.2425			
S = 15.53 DF = 3 <b>P = 0.001</b>			
Test Value as per equation Square of $9 \times 4 \times 5 / 12 = 3.8790$			
Q1-Q2 / 3.8730 = 1.807		No significant difference	
<b>Q1-Q3 / 3.8730 = 5.164</b>		<b>significant at &lt; 0.001</b>	
<b>Q1-Q4 / 3.8730 = 3.873</b>		<b>significant at &lt; 0.001</b>	
<b>Q2-Q3 / 3.8730 = 3.356</b>		<b>significant at &lt; 0.005</b>	
Q2-Q4 / 3.8730 = 2.065		No significant difference	
Q3-Q4 / 3.8730 = - 1.290		No significant difference	

Zars test for  $Q$  showed that there was a significant difference between Q1, the bow versus Q3, the stern ( $P = < 0.001$ ) and, between Q1, the bow versus Q4, portside ( $P = < 0.001$ ), as well as Q2, starboard versus Q3, stern ( $P = < 0.005$ ).

$$SE = \sqrt{\frac{ba(a+1)}{12}} \qquad SE = \sqrt{\frac{9 \times 4(4+1)}{12}} = 3.8730$$

Figure 24: Equation employed in order to complete Zars Statistical Test for  $Q$  for quadrants where b is the number of blocks (total number of months: 9), a was the number of treatments (quadrants: 4) and (a+1) was the number of treatments plus one.

The average number of times dolphins were observed swimming away, swimming to and swimming with the Black Cat versus month indicated that in six out of nine month's dolphins exhibited a preference to swimming towards the Black Cat and in three months a preference swimming with the Black Cat (Table 53). There appears to be no preference in any month in any season to swimming away from the Black Cat (Table 53).

Table 53: Average number of times a dolphin was observed swimming away, a/w, swimming towards, t/b, and swimming with, s/w the Black Cat. Bold figures indicate the month for which there were the greatest numbers of observations in regard to swimming direction.

Percentage observations that dolphins were recorded swimming away, swimming to and swimming with the Black Cat			
	a/w	t/b	s/w
Oct-00	33.15	<b>52.7</b>	14.15
Nov-00	27.54	<b>41.58</b>	30.88
Dec-00	10.98	28.67	<b>60.35</b>
Oct-01	29.7	<b>51.3</b>	19
Nov-01	30	30	<b>40</b>
Dec-01	39	<b>61</b>	0
Oct-05	13.34	<b>68.33</b>	18.33
Nov-05	28.57	<b>54.29</b>	17.14
Dec-05	31.48	25.93	<b>42.59</b>

The greatest numbers of dolphins were observed in December 2000 swimming with the boat (60.35) and least in December 2001 when no dolphins were observed swimming with the Black Cat.

Table 54: Kruskal-Wallis test results in relation to the average number of dolphin observations versus swimming direction. Bold figures indicate a significant difference in relation to the average number of dolphin observations and swimming direction.

Quadrant	N	Median	Average Rank	Z
a/w	9	29.70	11.2	-1.31
t/b	9	51.30	19.4	2.49
w/b	9	19.00	1.4	-1.18
Overall	27		14.0	
H = 6.23 DF = 2 <b>P = 0.044</b>				
H = 6.23 DF = 2 <b>P = 0.044 (adjusted for ties)</b>				

There is a significant difference between swimming direction ( $P = 0.044$ ) with the Average Rank value being greatest for swimming to the boat (19.4) and least for swimming with the boat (1.4)

Table 55: Friedman Test results in relation to the average number of dolphin observations versus swimming direction. Bold figures indicate a significant difference in relation to the average number of dolphin observations between paired directions of swim.

Friedman Test for the average number of observations versus swimming direction blocked by month for the Black Cat			
Quadrant	N	Est Median	Sum of Ranks
a/w	9	52.70	22.5
t/b	9	27.79	14.5
w/b	9	25.76	17.0
Grand median = 35.42			
S = 3.72 DF = 2 P = 0.155			
S = 3.83 DF = 2 P = 0.147 (adjusted for ties)			
Test Value as per equation Square of $9 \times 3 \times 4 / 12$			
<b>tb-aw / 3 = 2.666</b>			<b>significant at &lt; 0.05</b>
tb-wb / 3 = 1.833			No significant difference
aw-wb / 3 = -0.833			No significant difference

There were no significant differences overall in swimming direction ( $P = 0.155$ ), but a significant difference between swimming towards the boat, t/b versus swimming away

from the boat, a/w was returned ( $P = < 0.05$ ) when using Zars equation (Figure 25), in order to test the critical value of  $Q$  (Appendix H, Table 54).

$$SE = \sqrt{\frac{ba(a+1)}{12}} \qquad SE = \sqrt{\frac{9 \times 3(3+1)}{12}} = 3.000$$

Figure 25: Equation employed in order to complete Zars Statistical Test for  $Q$  for swimming direction where  $b$  was the number of blocks (total number of months: 9),  $a$  was the number of treatments (swimming direction: 3) and  $(a+1)$  is the number of treatments plus one.

Table 56: Critical values of  $Q$  for non-parametric multiple comparison testing. Used to determine significance in quadrant preference and swimming direction preference.

<b>Critical Values of Q for Non-parametric Multiple Comparison Testing (Table B.15 of Zar)</b>											
k	$\alpha$	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002	0.001	
3		1.383	1.834	2.128	2.394	2.713	2.936	3.144	3.403	3.588	Direction
4		1.732	2.128	2.394	2.639	2.936	3.144	3.342	3.588	3.765	Quadrants

Table 63: A General Linear Model (GLM) test investigating the occurrence of avoidance behaviour over six years, versus season and month, for the Black Cat at Lyttelton (APN).

Least Squares Means for LOGAV		
Season	Mean	SE Mean
S1	1.0190	0.1324
S2	0.1681	0.1324
S3	1.3075	0.1324
Month		
Oct	0.6540	0.1324
Nov	0.8927	0.1324
Dec	0.9479	0.1324

A General Linear Model on avoidance behaviour versus season and month show that there is a significant season effect ( $P = 0.008$ ) with the greatest change being in season 2. There was no month effect ( $P = 0.348$ ).

Table 64: A General Linear Model (GLM) test investigating the occurrence of positive behaviour over six years, versus season and month, for the Black Cat at Lyttelton (APN).

Least Squares Means for LOGPos		
Season	Mean	SE Mean
S1	1.3802	0.1591
S2	0.3067	0.1591
S3	0.9075	0.1591
Month		
Oct	0.8774	0.1591
Nov	0.8998	0.1591
Dec	0.8171	0.1591

A General Linear Model test on positive behaviour versus season and month show that there is a significant season effect ( $P = 0.022$ ) with the greatest change being in Season 3. There was no month effect ( $P = 0.932$ ).

Table 65: A General Linear Model (GLM) test investigating the occurrence of neutral behaviour over six years, versus season and month, for the Black Cat at Lyttelton (APN).

Least Squares Means for LOGNeu		
Season	Mean	SE Mean
S1	0.97724	0.3155
S2	0.005597	0.3155
S3	0.59764	0.3155
Month		
Oct	0.79488	0.3155
Nov	0.41108	0.3155
Dec	0.42488	0.3155

A General Linear Model test on neutral behaviour versus season and month show that there is no season effect ( $P = 0.232$ ), but the same trend is evident in neutral behaviour for Season 2 as was seen for positive behaviour in Season 2. There was no month effect ( $P = 0.652$ ).