
**New Zealand fur seals in the Kaikoura region:
colony dynamics, maternal investment and
health**

Laura J. Boren

A thesis submitted
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy in Biological Sciences,
At the University of Canterbury

University of Canterbury

2005

Declaration of Originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except when due acknowledgement is made in the text of the thesis.

Laura J. Boren

Declaration by candidate

I certify that this thesis represents an original and independent piece of research. All of the significant aspects of analysis and interpretation of the results were done by myself.

This thesis is being presented as a series of papers to be submitted. The nature of the collaborations indicated by the co-authorship of these papers takes three forms:

1. Supervisors: (Gemmell, Caudron and Chilvers). As senior author I wish to recognise the contributions of my advisors in my training by including them as co-authors.
2. Many of the field components involved a large time commitment contributed by others over a series of 3+ years, as well as a contribution of supporting data (some pup birth dates - Dowell) and a significant amount of technical contributions (Muller). For these reasons I have chosen to recognise the collaboration of Caudron, Muller and Dowell as co-authors.
3. Finally, historical data collection from Kaikoura, (Morrissey), colony comparison information from Open Bay Islands (Stratton), and training in histological analysis (Stratton and Duignan) are also recognised.

Further manuscripts that have not been included in this thesis but that have originated from collaboration at this field site include but are not limited to:

- Caudron A.K., Negro S.S, Muller C.G, Boren L.J. & Gemmell N.J. (Submitted) Hair sampling and genotyping from follicles : A minimally-invasive alternative for genetics studies in small, mobile pinnipeds. (Submitted to Marine Mammal Science).
- Boren, L.J. and Caudron, A.K. The reliability of different methods for short- and long-term identification of fur seals : adult males, females and pups.
- Boren, L.J., Muller, C.G., and Dowell, S. A comparison of techniques: the effectiveness of behavioural and telemetry data to determine the foraging behaviour of adult female fur seals at a large boulder colony.
- Boren, L.J., Connolly, J. and Gemmell, N.J. The potential for Salmonella in fur seals on the East Coast.
- Immunological health of pups at Ohau Point
- Caudron A., Negro S., Fowler M., Boren L., Poncin P. & Gemmell N. Diversification of male breeding strategies and their success in a polygynous mammal, the NZ fur seal *Arctocephalus forsteri*.

- Caudron A., Cockrem J., Boren L., Sulon J., Poncin P. & Gemmell N. How stressed are our study pups? A preliminary study in wild fur seals using free cortisol in pup saliva.
- Caudron A., Boren L. & Gemmell N. Differences between cortisol and corticosterone concentrations in the faeces of adult versus pup fur seals.
- Caudron A., Boren L. Cockrem J., & Gemmell, N. The potential for use of cortisol and corticosterone concentrations in the faeces of New Zealand fur seals to detect the effect of tourist disturbance on stress levels.

Laura J. Boren

Table of Contents

Declaration of Originality	2
Declaration by candidate.....	3
Table of Contents	5
List of Figures.....	10
List of Tables	14
Abstract.....	18
<u>Chapter 1: Introduction</u>	<u>21</u>
Pinnipeds.....	21
New Zealand fur seals.....	22
Distribution	22
Natural history and colony dynamics	25
Maternal investment.....	25
Colony status and health	27
Reproductive and morphological parameters	27
Mortality and disease	29
New Zealand fur seals and the Kaikoura region.....	31
Kaikoura history.....	31
Kaikoura's appeal to marine mammals.....	32
Re-colonisation of fur seals in Kaikoura	35
Breeding biology of <i>A. forsteri</i> in Kaikoura	36
Global and local concerns for marine mammals including <i>A. forsteri</i>.....	36
Tourism	36
Fisheries interactions	37
Re-colonisation effects on global and local marine industries	38
Thesis Aims.....	39
References:.....	41
<u>Chapter 2: Colony growth and pup condition on the Kaikoura coastline; a comparison with other East Coast colonies</u>	<u>51</u>
Abstract.....	51
Introduction.....	52
History of harvesting.....	52
Re-colonisation history	52
Condition of pups.....	54
Re-colonisation in Kaikoura	54
Methods.....	56
Study sites	56
Sample sizes and dates.....	58
Pup production estimates	58
Gender, Morphology, and Condition	59
Results	60
Colony growth and estimates of pup production	60
Kaikoura Coastline.....	60
Banks Peninsula	60
General colony growth.....	60
Sex ratios.....	61
Morphological Characteristics	62
Mass	62

	6
Dorsal Straight Length.....	62
Condition Index 1: M/DSL.....	63
Condition Index 2: Observed / Expected Mass.....	63
Discussion.....	67
Colony growth and estimates of pup production.....	67
Morphological Characteristics.....	68
Conclusions.....	70
References:.....	71
<u>Chapter 3: Breeding biology of New Zealand fur seals at Ohau Point,</u>	
<u>Kaikoura.....</u>	<u>76</u>
Abstract.....	76
Introduction.....	77
General maternal investment and lactation theory.....	77
New Zealand fur seal Range.....	78
New Zealand fur seal breeding cycle.....	78
Ohau Point, Kaikoura.....	79
Methods.....	80
Site Description.....	80
Census counts.....	81
Birth/copulation observation.....	81
Sightings of known females and pups.....	81
Estimation of Weaning Dates.....	82
Results.....	83
Numbers of seals ashore.....	83
Proportion of seals in each age/sex category.....	83
Comparison between seasons.....	84
Weaning times.....	84
Births.....	85
Weaning Age.....	85
Colony Comparison.....	85
Discussion.....	86
Breeding biology.....	86
Lactation duration / Weaning age.....	86
Within site variation.....	91
Colony comparisons.....	92
Conclusions.....	95
References:.....	96
Intermission 1.....	100
<u>Chapter 4: Maternal attendance patterns of lactating New Zealand</u>	
<u>fur seals, <i>Arctocephalus forsteri</i>, in Kaikoura.....</u>	<u>102</u>
Abstract.....	102
Introduction.....	103
Maternal attendance theory.....	103
Methods.....	106
Site description.....	106
Sample sizes and identification of breeding age females.....	107
VHF radio telemetry and marking of caught females.....	108
Behavioural sampling of maternal attendance.....	109
Data analysis.....	109

Results	110
VHF results	110
Do females at Ohau Point show distinct maternal attendance patterns?	117
Seasonal differences.....	117
Grouping of females	117
Proportion of time spent ashore based on days post-partum	122
Female attendance patterns in consecutive years.....	122
Discussion.....	124
Female attendance patterns	124
Grouping of females	124
Night-time foraging and location of food source.....	127
Flexibility of maternal attendance patterns.....	128
Conclusion	129
References:.....	129
<u>Chapter 5: Pup growth patterns in the Kaikoura region and implications of maternal attendance patterns on pup growth and behaviour</u>	<u>133</u>
Abstract.....	133
Introduction	134
Methods.....	138
Site description.....	138
Marking of study animals	139
Capture and measurement.....	139
Maternal foraging trip duration.....	140
Behavioural data collection.....	140
Data analysis	141
General Mass and Growth rates	141
Adult female size in relation to pup size.....	142
Pup mass and growth in terms of maternal foraging trip duration	142
Behaviour: General analysis	142
Pup behaviour by month in relation to mass and condition.....	143
Behaviour between years	143
Results	143
General patterns- mass, growth and behaviour.....	143
Mass	144
Rate of Growth.....	144
Pup Behaviour.....	145
Relationship between pup behaviour and condition	145
Comparisons between years.....	149
Mass	149
Growth	149
Behaviour.....	150
ENSO effects	150
Influence of maternal traits	154
Adult female mass and condition.....	154
Pup mass and condition related to mother's mass and condition	154
Maternal mass and foraging trip duration related to pup size and growth....	154
Discussion.....	156
General Patterns	156
Comparison between years	158

Maternal influence	160
Conclusion	161
References:.....	162
Appendix:.....	166
Intermission 2	168
<u>Chapter 6: Common causes of mortality to New Zealand fur seals in the Kaikoura region with special reference to pups and juveniles ..</u>	<u>170</u>
Abstract.....	170
Introduction.....	171
Methods.....	173
Study sites	173
Review of historical data	175
Sightings of mortalities along the coast	175
Post mortems.....	176
Histology.....	176
Data analysis	176
Results	176
Common report types pertaining to seals on Kaikoura Coast.....	177
Historical common causes of death known versus unknown	179
Levels of mortality - general.....	181
Pups.....	182
Common causes of death – from post mortems and sightings.....	182
Human-related concerns – from all combined data	185
Entanglements.....	185
Human interactions	189
Road	190
Comparison of body condition for road hits and emaciated pups	190
Discussion.....	192
General trends in mortality	192
All mortality.....	192
Pup mortality.....	193
Potential error.....	193
Natural mortality.....	195
Starvation	195
Density effects	195
Parasites	196
Disease/Infection.....	196
Predation	197
Human influenced mortality	197
Entanglement	197
Public Interactions	198
Road	199
Concern for zoonotic transfer	200
Conclusion	201
References:.....	202
Appendix 1:.....	206
Appendix 2:.....	207
Appendix 3:.....	209

Chapter 7: Ivermectin as a tool to examine the potential for intestinal parasites to affect pup growth in New Zealand fur seals.....	211
Abstract.....	211
Introduction.....	212
Parasitology in pinnipeds.....	212
Population dynamics.....	214
Techniques for exploring parasite loads in a colony.....	215
Chapter Aims.....	217
Methods.....	217
Study site.....	217
Identification and number of pups sampled.....	218
Selection of IVOMEK and control pups.....	218
Dosing of IVOMEK pups.....	218
Weight trials.....	219
Post mortem.....	219
Data analysis.....	220
Results.....	220
Raw data.....	220
Differences in mass between treatments.....	221
Differences in rate of growth between treatments.....	222
Results of post mortem.....	223
Discussion.....	225
References:.....	230
Appendix:.....	234
Chapter 8: General Discussion.....	237
Revisiting the objectives.....	237
Maternal investment / foraging strategies used by lactating females in the region, and how they may be affected by disturbance.....	238
Food source proximity.....	239
Disturbance.....	241
Implications of maternal attendance patterns on pup condition and growth.....	243
Food Source Proximity.....	243
Disturbance.....	246
Current colony status and health of pups in the Kaikoura region, specifically in terms of pup production, intestinal parasite loads, and causes of mortality.....	247
Food Source Proximity.....	248
Disturbance.....	249
Further research and/or recommendations for management.....	251
Summary.....	253
References:.....	253
Acknowledgements.....	259

List of Figures

Chapter 1: Introduction 21

Figure 1: Distribution of *A. forsteri* in A) the late 1970's (from Wilson 1981) and B) with recently established colonies added in colour 24

Figure 2: Bathymetry around the coast of New Zealand. The line shown is the 1000 m isobath (from Lalas and Bradshaw 2001). Note how close it is to the shore in Kaikoura, versus the Banks Peninsula, and other areas around New Zealand. 34

Figure 3: The Kaikoura coast showing the location of the Kaikoura peninsula, Ohau Point and Barney's Rock. 35

Chapter 2: Colony growth and pup condition on the Kaikoura coastline; a comparison with other East Coast colonies 51

Figure 1: Locations of *A. forsteri* breeding colonies along the Kaikoura coastline and on the southern coastline of Banks Peninsula. Note: Both Banks Peninsula and Kaikoura Coast are on the same scale 57

Figure 2: Estimated number of pups in early February at *A. forsteri* colonies between 1990-2005. Historical data sourced from: Kaikoura colonies 1990-1995, from Mike Morrissey, Kaikoura Dept. of Conservation; Kaikoura colonies and HSB 1996-1998, from Dr. Corey Bradshaw; and Ohau Point 2000-2001, from Boren 2001. The line for Horseshoe Bay is not continuous as there is a data point missing for 2004. 61

Figure 3: Mean observed A) Mass (kg) and, B) Length (cm), for 612 male (m) and 600 female (f) *A. forsteri* pups in February (approximately 58 days old) at each of the four colonies from 2002-2005. Error bars represent 95% confidence intervals. Note that the y-axes do not start at 0. 64

Figure 4: Mean observed A) Condition index 1: M/DSL and, B) Condition index 2: Observed/Expected Mass, for 612 male and 600 female *A. forsteri* pups in February (approximately 58 days old) at each of the four colonies from 2002-2005. Error bars represent 95% confidence intervals. Note that the y-axes do not start at 0. 65

Chapter 3: Breeding biology of New Zealand fur seals at Ohau Point, Kaikoura 76

Figure 1: Map of the Kaikoura coastline on the eastern coast of the South Island of New Zealand, showing the location of Ohau Point seal colony. The colony is divided into sectors: N, C, NS, S, and L for the purposes of this study. 80

Figure 2: Percentage of seals ashore each year at Ohau Point colony by age/sex category: A) Males, B) Adult females, C) Newborns, and D) Pre-weaners during the breeding season. Note that the y-axis scale for newborns is different than for the other age/sex categories. Also, for reference to the proportion of

pre-weaners ashore, lines demarcating 10% and 20% of all age/sex categories are shown. 89

Figure 3: The decline in maximum number of pre-weaners seen ashore within the census areas from 30-Oct to approximately 20-Dec over three breeding seasons. For each year the regression models displayed were found to be significant for $x = \text{day}$, when 30 Oct = day 1 ($p < 0.0001$). 90

Chapter 4: Maternal attendance patterns of lactating New Zealand fur seals, *Arctocephalus forsteri*, in Kaikoura 102

Figure 1: The Kaikoura coast showing the location of Lynch's Reef on the Kaikoura Peninsula and the Ohau Point breeding colony to the North. 106

Figure 2: The presence and absence of 13 females fitted with VHF transmitters in 2004 for A) 0-50 days post partum, and B) 51-100 days post partum. Blue bars denote when the female is present on the colony. Each day is divided into two time blocks to show when overnight foraging trips occurred. Arrows denote the days in which these occurred. 112

Figure 3: The presence and absence of 11 females fitted with VHF transmitters in 2005 for A) 0-50 days post partum, and B) 51-115 days post partum. Blue bars denote when the female is present on the colony. Each day is divided into two time blocks to show when overnight foraging trips occurred. Arrows denote the days in which these occurred. 113

Figure 4: The frequency of overnight foraging trips (OFTs) based on days post partum for 23 VHF females which performed OFTs (12 in 2004 and 11 in 2005). A total of 44 and 57 OFTs were observed. 115

Figure 5: The frequency distribution of adult female fur seals arrival times on the colony and departure times when leaving the colony in A) 2004 and B) 2005. 116

Figure 6: Dendrogram showing clustering of 23 individual females fitted with VHF transmitters from both seasons into groups based on year, foraging trip duration, shore bout duration, the proportion of time ashore, and the number of overnight foraging trips performed. 119

Figure 7: Dendrogram showing clustering of 95 individual females from both seasons into 4 groups based on year, foraging trip and shore bout duration. 120

Figure 8: Grouping of 95 females in 2004 and 2005 based on foraging trip duration and each female's deviation from the mean for which they were observed (2004 = 2.74 days, and 2005 = 4.25 days). Each point represents an individual female and they are arranged on the x-axis according to the group they were assigned (3a = 3.25, 3b = 3.5, 3c = 3.75, 4a = 4.25, 4b = 4.5, outliers = 5). Some overlap may occur between females with very similar foraging trip residuals, and as a result there may appear to be fewer than 95 points. 121

Chapter 5: Pup growth patterns in the Kaikoura region and implications of maternal attendance patterns on pup growth and behaviour **133**

Figure 1: The Kaikoura Coast showing the Kaikoura Peninsula and the locations of the Ohau Point and Lynch's Reef seal colonies. **139**

Figure 2: Pup mass based on age (days from median pupping date) for each of four breeding seasons. Weaning weights collected in 2004 are not included in this figure. **146**

Figure 3: Pup mass during different years at: A) birth, approximately B) 56 and C) 116 days of age. P-values for difference between year and gender are displayed, with significant p-values in bold. **151**

Figure 4: Male and Female pup mass at different ages in 2004 and 2005, sample sizes ranged between 22-148 pups in 2004, and 18-54 pups in 2005. Average rates of growth calculated for 40 individuals in 2004 and 25 individuals in 2005 for this time frame are shown along with the p – value for differences between years. **152**

Figure 5: Mass at various ages for pups of known birth date, 40 in 2004 and 52 in 2005. Regression lines of best fit are shown with the regression equations and R² value. **152**

Figure 6: Proportion of time pups spent N – Nursing, P – associating with mother, A – away from mother, each year. Also shown are the proportion (PROP) of days pups were observed with their mother at some time. **153**

Figure 7: Southern Oscillation Index values from 2000 to 2005 (NIWA 2005). Dashed lines indicate approximate pupping times at Ohau Point for the four years of this study. **153**

Figure 8: Adult female mass and condition (M / DSL) in 2003 (n = 17), 2004 (n = 19) and 2005 (n = 14). Significant p – values for between year comparisons are in bold. **155**

Figure 9: Relationship between: A) female mass and pup birth mass (n = 41) and February (56 days) mass (n = 36), and B) female condition and pup birth (n = 41) and February condition (n = 36). A line of best fit is included for all regressions with associated R and p – values. Significant p – values are in bold. **155**

Chapter 6: Common causes of mortality to New Zealand fur seals in the Kaikoura region with special reference to pups and juveniles **170**

Figure 1: Map of the Kaikoura Coastline showing locations of the three main *A. forsteri* breeding colonies, Ohau Point to the North, Lynch's Reef on the Kaikoura Peninsula, and Barney's Rock to the South. Although seals haul-out elsewhere along the coast, most reports are between Clarence (42 km North of Kaikoura), and Oaro/Haumuri Bluff (16 km to the South). **174**

Figure 2: Comparison of the seasonality of the a) most commonly reported incidents relating seals and b) the remaining incident types. As the later incident types are less common, note that the y-axis is displayed on a scale of 10. 178

Figure 3: The number of unexplained deaths reported and confirmed over the years in the Kaikoura region, and the locations where these deaths were sighted. 180

Figure 4: Breakdown of the proportion of explained fatalities in the Kaikoura region. Explained fatalities only make up 17% of the total fatalities reported. 180

Figure 5: A) Blubber depth and B) Estimated State of nutrition of dead individuals based on age group. Blubber depth is known for n = 26 individual post mortems, and the State of Nutrition is known for n = 30 individual post mortems. 184

Figure 6: Estimates of rate of entanglement in the Kaikoura region based on regional counts, and pup-based population estimates for Ohau Point. Note the average number entangled per year is based on the nine years where the database is complete (1996-2004). Also, entanglement rates calculated for years leading up to 1996 and 2005 are underestimates as they are not complete years or did not involve the same effort in reporting entangled animals. 186

Figure 7: The percentage outcome of reported entangled seals in the Kaikoura region over the last decade. 187

Figure 8: The percentage of different types of debris found on fur seals in the Kaikoura region, A) nets, bands and other entanglement hazards, and B) a breakdown of the other hazards which make up 10% of all debris types. 188

Figure 9: Seasonality of road related reports involving seals. 191

Figure 10: The percent of road related incidents on the north and south coasts and the involvement of pups in road related incidents over the years in comparison with the estimate of pup production at Ohau Point. 191

Figure 11: Comparison of body condition between emaciated pups, pups hit by cars and the colony average for that age bracket. Standard errors are included where possible. Individual pups are: #1; male pup ID 4005, #2; male pup unknown, #3; male pup unknown, #4; female pup ID A47. 192

Chapter 7: Ivermectin as a tool to examine the potential for intestinal parasites to affect pup growth in New Zealand fur seals 211

Figure 1: Mass in kilograms of Treatment and Control male and female pups in A) 2004 and B) 2005 from birth to approximately 120 days of age. Error bars show standard errors associated with the measures. 224

List of Tables

Chapter 2: Colony growth and pup condition on the Kaikoura coastline; a comparison with other East Coast colonies **51**

Table 1: Numbers of pups caught in each colony per year. Location abbreviations are: Ohau Point (OP), Lynch's Reef (LR), Horseshoe Bay (HSB), and Te Oka Bay (TOB). **58**

Table 2: Annual rate of increase expressed as the arithmetic mean rate of population increase (r) and, exponential rate of population increase (b) calculated for Ohau Point and Te Oka Bay. Ohau Point was broken into two time periods to show the change in rate of increase during early vs. late phases of colony expansion. **61**

Table 3: The number of male and female pups sampled in February at each location over four consecutive years, and the proportion of male pups to one female pup. Colonies are abbreviated (OP) Ohau Point, (HSB) Horseshoe Bay, and (TOB) Te Oka Bay. The only significant departure from expected is in 2005 at Ohau Point and Te Oka Bay and are shown in bold type. **62**

Table 4: GLM results comparing morphological characteristics and condition indices between years (Y), colonies (C), and sex (S), for 1212 *A. forsteri* pups. Age at time of weighing based on a median pupping date for New Zealand colonies of 16-Dec was included as a covariate. Results of the potential interactions between variables are shown as well. The F- statistic and p- value are provided for all tests carried out, and significant p-values are in bold. The colonies included in the tests were, Ohau Point, Horseshoe Bay and Te Oka Bay. **66**

Chapter 3: Breeding biology of New Zealand fur seals at Ohau Point, Kaikoura **76**

Table 1: Estimated weaning times of pups at Ohau Point colony from 2002 to 2004. They are calculated using the following indices: (PW/AS) Proportion of pre-weaners out of all age/sex categories; and (PW/PE) the proportion of pre-weaners out of estimated number of pups born. **90**

Table 2: Estimated births and lactation durations for Ohau Point colony calculated for 2002 to 2004 breeding seasons. Weaning time was calculated using the PW/AS and PW/PE indices when the indices dropped below 20%. The median of the calculated range for lactation duration is in brackets. In 2004, estimates based on 30 known individuals are shown in brackets for comparison with indices estimates. **90**

Table 3: Ohau Point breeding season compared with other colonies of the same species. OP = Ohau Point, OBI = Open Bay Islands, KI = Kangaroo Island, FG = Fuschia Gully, and TI = Tonga Island. **91**

Chapter 4: Maternal attendance patterns of lactating New Zealand fur seals, *Arctocephalus forsteri*, in Kaikoura **102**

Table 1: Sample sizes of adult females monitored in this study. **107**

Table 2: Raw data for 13 (2004) and 11 (2005) VHF tagged female *A. forsteri* that returned reliable data including the number of: Foraging trips (FTs); Shore bouts (SBs); Overnight foraging trips (OFTs); and Extended foraging trips (EFTs). Also shown are: the proportion of overnight to all foraging trips undertaken for each female (Prop OFT / FT); the proportion of time each female spent ashore; and the mean arrival and departure times for each female. Group mean and standard deviations are calculated for the final four categories and group means are displayed in bold. Standard deviation of arrival and departure times are in minutes. **114**

Table 3: Results of t-tests comparing the proportion of overnight foraging trips (OFT) to all foraging trips (FT) and the proportion of time spent ashore each year. The percentage of females performing overnight foraging trips is also shown. **114**

Table 4: Mean foraging trip (FT) duration and shore bout (SB) duration in days +/- SD, and the mean proportion of time females spent ashore (PROP) in 2004 and 2005 for 54 and 41 females respectively from birth to approximately 125 days post partum. Significant differences were found between years for FT and SB duration as denoted by p-values in bold. **117**

Table 5: Results of backwards discrimination factor analysis for 23 adult female fur seals with VHF transmitters in 2004 and 2005. Significant p-values for the variables used in the analysis are shown in bold. Also in bold is the percentage of females correctly assigned to a strategy. **119**

Table 6 Classification matrix for 23 females categorised by the above model, showing the proportion of females correctly categorised. **119**

Table 7: Results of backwards discrimination factor analysis for 95 adult female fur seals in 2004 and 2005. Significant p-values for the variables used in the analysis are shown in bold. Also in bold is the percentage of females correctly assigned to a strategy. **121**

Table 8: Classification matrix for 95 females categorised by the above model, showing the proportion of females correctly categorised. **121**

Table 9: The proportion of time females spent ashore based on days post-partum. Time blocks were divided into five blocks of 25 days each. Significant p-values from the ANOVA are displayed in bold. Bonferonni corrected p-values required for significance are $p < 0.0009$ for 2004 and $p < 0.0012$ for 2005. **122**

Table 10: Mean shore bout duration, foraging trip duration and proportion of time spent ashore in consecutive years for 19 females. Differences in their

results between years are shown (DIFF) and results of Paired sample t-test are shown with significant p-values in bold. 123

Chapter 5: Pup growth patterns in the Kaikoura region and implications of maternal attendance patterns on pup growth and behaviour 133

Table 1: Mass of pups in kilograms weighed at different times over four seasons. Data are displayed for males (M) and females (F) as well as genders combined (Both). Standard deviations, and sample sizes (N) are also shown. 147

Table 2: Growth of male and female pups based on different periods sampled, approximate ages based on median pupping dates for the year. P- values are shown with significant differences after Bonferroni correction in bold. Bonferroni values for 2002 = 0.0083, 2003 = 0.0056, 2004 = 0.0038, and 2005 = 0.0056. 148

Chapter 6: Common causes of mortality to New Zealand fur seals in the Kaikoura region with special reference to pups and juveniles 170

Table 1: Number of callouts related to seals in the Kaikoura region per financial year from July 1995 to June 2005 and the number of incidents involving seals in the Kaikoura region per calendar year from 1995-2005. *The calendar years of 1995 and 2005 are not complete years. 177

Table 2: Number of dead seals reported by different methods: Average per year based on total number of fatalities recorded in 10 years, Approximate number reported to Department of Conservation staff in a calendar year, and Number sighted during research in approximately 4 month austral summer field seasons. 181

Table 3: Age and Sex classes of dead animals found during searches of the Kaikoura Peninsula, post mortems and seen from the cliffs at Ohau Point. Year 2004 N = 9, is low due to reduced search effort that year. Also, in 2005, the search effort was focused towards Ohau Point rather than the Kaikoura Peninsula. 181

Table 4: Incidental findings related to cause of death are known for n = 46 individuals. Not all underwent necropsy. Sample sizes based on age for this parameter are: 0-50 n = 26; 51-weaning n = 10; 1-5 years n = 4, sub/adult n = 6. For some individuals multiple situations were found, ex: one sub-adult male was emaciated, had GI parasites and lungworm. 184

Table 5: Summary of public related incidents involving seals including seals potentially shot in the last ten years. 189

Table 6: Summary of known dog and seal interactions reported in ten years. 190

Chapter 7: Ivermectin as a tool to examine the potential for intestinal parasites to affect pup growth in New Zealand fur seals 211

Table 1: Raw data showing the number of pairs in which the: treatment (IVO) pup was at least 1 kilo heavier, the control pup was at least 1 kilo heavier, and when both pups of the pair were within 1 kilo of each other. Stars denote the times that correlated with a significant difference between treatments. 221

Table 2: Average mass of treatment and control pups at each weight session for each year. The t-statistic for paired samples is shown along with the corresponding p-value. Significant p-values are in bold, Bonferonni correction p-values for 2004 and 2005 were 0.008, and 0.006, respectively. Stars denote a low sample size for that weight trial. 222

Table 3: Results of Repeated Measures 3-way ANOVA comparing pup mass based on gender, treatment and age. Bold p-values are significant. No interactions between variables were observed. 222

Table 4: Growth rates of male and female treatment and control pups for 2004 and 2005 seasons. Results of a 2-way ANOVA show no significant differences between genders or treatments in either year. 223

Abstract

Colony dynamics, maternal investment, and indicators of health were investigated for the New Zealand fur seal (*Arctocephalus forsteri*) over four austral summers, 2001-2005. Effort was focused at the Ohau Point seal colony, north of Kaikoura. Two colonies at Banks Peninsula were included for comparisons of colony growth and pup condition. A range of other colonies were also included for making comparisons about colony dynamics and health indices. Colony dynamics were investigated through mark-recapture estimates of pup production and daily census of all individuals at the Ohau Point colony. Maternal attendance patterns were observed through behavioural observations of known females (n = 120), the use of VHF radio transmitters (n = 33), and female mass and body condition estimates (n = 51). Maternal investment was also investigated through longitudinal sampling of pup mass and growth rates. Parameters used to indicate colony health were: body condition, growth, presence of parasites, and the levels and common causes of mortality. The influence of parasites on pup growth was tested using treatment of selected pups with Ivermectin anti-helmentic medication, and mortality in the region was investigated through reports of dead individuals, and post mortems of those found fresh.

The Ohau Point colony is in an exponential state of growth, and pup mass and condition was higher and responded to changes in environmental variables differently than at the Banks Peninsula colonies. Lactation lengths were consistently longer at Ohau Point than is typically reported for the species (323-355 days vs. 285 days). Maternal investment strategies were indicative of a close, reliable food source, and showed flexibility between years through extension of foraging trip durations and the increased use of overnight foraging trips. Individual strategies did not significantly influence pup growth. However, increased maternal condition and the ability to respond to inter-annual changes in resource availability resulted in accelerated pup growth even during an El Niño event. The incidence of pups with intestinal parasites was low at Ohau Point, and the average mass of treated and non-treated pups did not differ. Pup mortality in the region was low (3% to 50 days old), however, mortality of older pups was greatly influenced by the proximity of humans, with 2/3 of pup

mortality observed between the age of 50 days and weaning being caused by car collisions.

The results suggest that population dynamics and maternal investment in the region are greatly influenced by local variables, notably the presence of an accessible food source within close proximity to the colony. Various indicators of health reflect a growing colony in good condition, and the presence of a reliable food source may influence the maximum density and carrying capacity the colony is able to sustain. However, some concerns are raised about the influence of human interactions in the region, and how this may affect mortality and colony dynamics in the future. Extra fencing along the Ohau Point colony is recommended to provide added protection from the road. Continued monitoring of mortality and health indices in the region is also recommended for comparison with other colonies as Ohau Point reaches carrying capacity and density-dependent pressures increase.

Chapter 1

General Introduction

Laura J. Boren

Chapter 1: Introduction

Pinnipeds

The pinnipeds are a suborder of carnivores that includes 33 species within three families: the phocids, otariids, and odobenids (Reeves *et al.* 1992). The group is unique in that the members are highly specialised for an aquatic lifestyle, yet are tied to the land for moulting, breeding (in some species), giving birth and rearing offspring (Reeves *et al.* 1992). This spatial separation between foraging and breeding locations is the key characteristic that defines central place foragers (Orians and Pearson 1979). The three main families cope with this division between foraging and breeding locations in different ways (Kovacs and Lavigne 1992).

The family Odobenidae is represented by one species, the walrus, which has characteristics similar to both phocids and otariids, but is more closely related to the otariids. Females of this group nurse their young for up to three years, and feed them both on land and at sea where calves accompany their mothers (Kovacs and Lavigne 1992; Reeves *et al.* 1992). The phocids, or true seals, comprise 19 species, most of which live in high polar latitudes with a few species inhabiting temperate regions and three species of monk seal in the tropics (Reeves *et al.* 1992). The otariids, or eared seals, comprise 13 species that fall into two distinct groups: the fur seals and the sea lions. Within the otariids, the sea lions are represented by two Northern hemisphere species and three Southern hemisphere species. The fur seals comprise eight species, most of which reside in the Southern hemisphere (Reeves *et al.* 1992). The fur seals are typically smaller than the sea lions and have a thick under-fur surrounding their guard hairs that provides extra insulation (Riedman 1990).

There are several morphological and physiological differences between the phocids and the otariids (Riedman 1990). Of most interest to scientists are the physiological differences that shape the unique life histories and maternal strategies of these two families. Phocids, which are generally larger than the otariids and accumulate large fat stores before parturition (Kovacs and Lavigne 1992; Chapters 3 and 4), solve the dilemma of central place foraging by fasting during a shortened lactation period (Kovacs and Lavigne 1992; Boness and Bowen 1996). Otariids, on the other hand, are

typically smaller and exhibit a more protracted lactation duration while alternating between foraging at sea and nursing their young on land (Trillmich 1990; Boness and Bowen 1996). While more is known about the maternal investment strategies of phocids, the knowledge base for otariids is growing, however, the focus until recently has been on the polar species *Arctocephalus gazella*, and *Callorhinus ursinus* (Schulz and Bowen 2004).

Foraging habits and diving capabilities are also variable within these groups. Phocids are the deepest diving pinnipeds, of which the Weddell seal (*Leptonychotes weddelli*: Harcourt *et al.* 2000) and the Southern elephant seals (*Mirounga leonina*: Hindell *et al.* 1991) have been studied in great detail. Within the otariids, sea lions are capable of diving deeper and longer than fur seals, and tend to forage mostly in shallow waters often on benthic prey (Reeves *et al.* 1992; Costa and Gales 2000), whereas fur seals are usually found feeding over the shelf in deeper waters incorporating more mesopelagic prey (Reeves *et al.* 1992; Harcourt *et al.* 1995).

The New Zealand fur seal (*Arctocephalus forsteri*) is one of the smaller species of fur seal, and lives in temperate latitudes around New Zealand and Australia (see section: Distribution). *A. forsteri* shows natal site fidelity, with the majority of animals returning to their birth colony to breed (Bradshaw 1999). Recently more work has been focused on studying *A. forsteri*, investigating their natural history (Miller 1971), history of exploitation (Lalas and Bradshaw 2001), re-colonisation patterns (Bradshaw 1999), and maternal investment strategies (Harcourt *et al.* 1995; 2001; 2002).

New Zealand fur seals

Distribution

Prior to the Polynesian colonisation of New Zealand, New Zealand fur seals bred around both the North and South Islands, and on many offshore and sub-Antarctic islands (Lalas and Bradshaw 2001). With the arrival of the Maori on the mainland of New Zealand, fur seals were harvested for food and gradually exterminated from North to South, confining the breeding range to the south western portion of the South Island by the time of European arrival (Lalas and Bradshaw 2001).

European harvesting of fur seals for their skins began in 1792 in the south-western part of the South Island of New Zealand and continued to spread to offshore temperate and sub-Antarctic islands in an unregulated manner (Lalas and Bradshaw 2001). Populations began to collapse in 1815 when fur seals had been exterminated from many locations including the Anitpodes Islands (Mattlin 1987). The industry was closed in 1894 but reopened in 1946 due to complaints that seals were interfering with the fishing industry (Cawthorn *et al.* 1985). Then in 1978 *A. forsteri* received full protection under the Marine Mammal Protection Act (Cawthorn *et al.* 1985; Mattlin 1987).

Since receiving protection, fur seals have begun to re-colonise areas of their former range and, based on pup counts, census counts, and rates of population increase at several locations, it is suggested that *A. forsteri* numbers are nearing 100,000 (Wilson 1981; Taylor *et al.* 1995; Wickens and York 1997; Goldsworthy *et al.* 1999; Harcourt 2001). Currently, *A. forsteri* breeds on offshore temperate and sub-Antarctic islands, around Stewart Island, the South Island of New Zealand and is currently spreading up the North Island (Crawley and Wilson 1976; Wilson 1981; Cawthorn *et al.* 1985; Mattlin 1987; Dix 1993; Harcourt 2001). In Australia, *A. forsteri* are found in southern and Western Australia and have recently been reported as breeding in eastern Bass Strait and on offshore islands up the east coast of Australia (Gales *et al.* 2000; Arnould *et al.* 2000; Harcourt 2001). Figure 1 shows the distribution of *A. forsteri* around mainland New Zealand in the late 1970's compared with its current distribution.

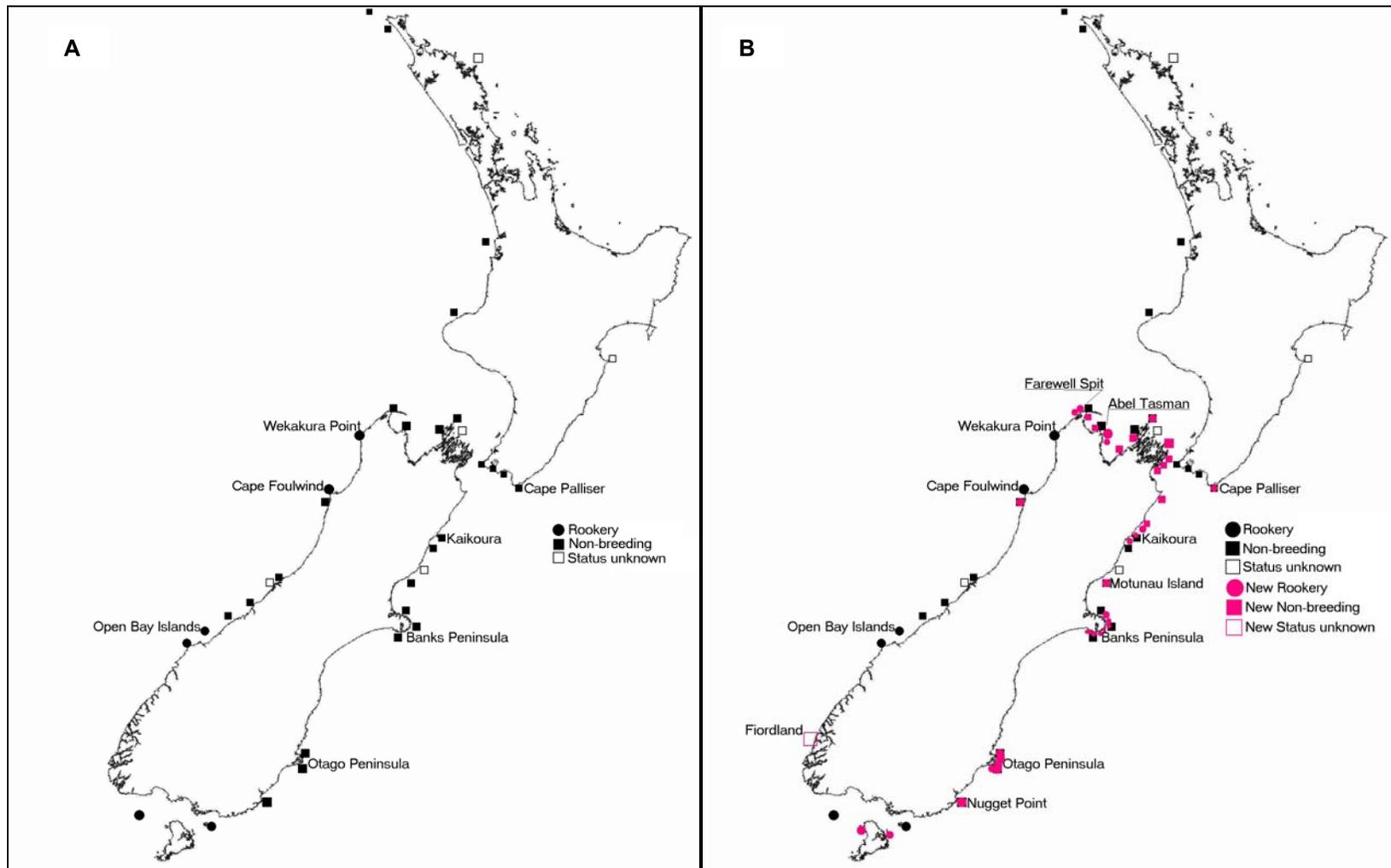


Figure 1: Distribution of *A. forsteri* in A) the late 1970's (from Wilson 1981) and B) with recently established colonies added in colour

Natural history and colony dynamics

The natural history and breeding biology of *A. forsteri* has been described in great detail, with the majority of the work coming from Open Bay Islands off the west coast of the South Island of New Zealand (Miller 1971; Stirling 1970; Crawley and Wilson 1976; Mattlin 1978a) and some information from the Otago Peninsula, on the east coast of the South Island (Lalas and Harcourt 1995). Some Australian comparisons have been provided from studies of fur seals on the South Neptune Islands (Stirling 1971a; b) and more recently the Cape Gantheaume colony on Kangaroo Island, South Australia (Goldsworthy and Shaughnessy 1994).

Male fur seals typically come ashore from September to November to claim territories, while the females begin to haul-out from mid-November to late-December to give birth (Miller 1971; Stirling 1971a; 1971b; Miller 1975; Mattlin 1978a; Goldsworthy and Shaughnessy 1994). Peak breeding occurs within a few weeks of giving birth (Goldsworthy and Shaughnessy 1994; Harcourt 2001). While some adult males may stay at a breeding colony year round (Stirling 1971b), numbers of adult males tend to decrease in the winter after breeding and sub-adult males begin to come ashore at breeding colonies around May (Miller 1971; 1975). Shortly after pupping and mating, the females will begin to alternate between foraging at sea and nursing their pup onshore (Goldsworthy and Shaughnessy 1994). Being a temperate fur seal species, the female will continue the foraging cycle for a lactation period ranging from 7-12 months (Gentry *et al.* 1986). A variety of lactation lengths have been observed in *A. forsteri* from different populations with most colonies weaning their pups between the ages of 8-10 months (Stirling 1970; Mattlin 1978a; Harcourt 2001; Baylis 2003; Haase 2004; K. Barton, pers. comm.), however, a significant number of pups were still suckling between the ages of 10-12 months at New Zealand colonies (Miller 1975; Mattlin 1978a).

Maternal investment

Maternal investment and lactation strategies vary both within and among the different families and species of pinnipeds. At the family level phocids, or true seals, typically have a shorter lactation length than otariids, or eared seals (Kovacs and Lavigne 1992; Boness and Bowen 1996). Female phocids tend to be large and possess an extensive blubber layer for insulation. These large fat reserves enable female phocids to stay

onshore during the entire lactation period while fasting, allowing them to transfer a large amount of nutrients to their offspring in a short time before weaning (Boness and Bowen 1996). Otariids, on the other hand, are typically smaller in size and rely more on their fur than an extensive blubber layer for insulation. Consequently, female otariids are unable to store enough fat to fast during the entire nursing period, and they alternate between foraging at sea and nursing their pup while ashore (Kovacs and Lavigne 1992; Boness and Bowen 1996).

Within the otariids, interspecific differences can be observed in lactation strategies, mostly due to oceanographic patterns and food availability seen loosely along a latitudinal gradient (Trillmich 1990). Sub-polar species, such as the Antarctic fur seal (*A. gazella*) and the Northern fur seal (*C. ursinus*), are exposed to very marked seasonality and, with the quick onset of winter, a decreasing food supply. As a result, lactation lengths for these species are short, around 4 months. At the other extreme, tropical species, such as the Galapagos fur seal (*Arctocephalus galapagoensis*), live in a region of seasonal upwelling, warmer sea temperatures and weak seasonality. This results in an unpredictable food supply, which is worsened in El Niño years. Due to the less predictable food availability in this region, *A. galapagoensis* displays a longer lactation length, typically between 1 and 2 years, but in times of decreased food availability, lactation in this species can be as long as 3 years (Trillmich 1990; Kovacs and Lavigne 1992). Temperate species, of which *A. forsteri* is an example, are intermediate between the two extremes mentioned above. They are exposed to a weaker seasonality than sub-polar species, but forage in more productive waters than *A. galapagoensis*. As a result, temperate species tend to have a lactation period of intermediate duration ranging from 7-12 months (Trillmich 1990), with *A. forsteri* generally in the 8-10 months range (285 days) (Stirling 1970; Miller 1975; Mattlin 1978a; Goldsworthy 1992; Harcourt 2001; Baylis 2003; Schulz and Bowen 2004).

Typically, *A. forsteri* females remain with their pup immediately after birth for up to about two weeks and then begin to alternate between foraging at sea and returning to nurse their young, increasing time spent at sea and decreasing time ashore as lactation progresses (Harcourt 2001). Seasonal differences have been shown in foraging locations, behaviour and diet for *A. forsteri* on the Otago Peninsula (Harcourt and Davis 1997; Harcourt *et al.* 2002) and in sub-Antarctic fur seals, *A. tropicalis*, at

Amsterdam Island (Georges *et al.* 2000). For both species during summer, females forage closer to the colony, spend less time at sea, and target prey species on the continental shelf and/or slope. In winter, the duration of female foraging trips increases, with females foraging further from the colony and spending more time diving and targeting prey in deeper waters (Harcourt and Davis 1997; Georges *et al.* 2000; Harcourt *et al.* 2002). In contrast, no seasonal pattern in foraging behaviour was noted for *A. gazella* or *A. tropicalis* at Macquarie Island (Goldsworthy *et al.* 1997; Goldsworthy 1999) or *A. gazella* at Iles Kerguelen (Lea *et al.* 2002). It is suggested in both cases that this lack of seasonality is related to environmental conditions. At Macquarie Island a rich source of mesopelagic fish is accessible close to the island so females do not need to forage further away in winter (Goldsworthy 1999; Robinson *et al.* 2002). Conversely, Iles Kerguelen, on the Kerguelen Plateau, are located farther from deep waters where the primary prey of *A. gazella* is found, resulting in long foraging trips for the whole of lactation and consistently deeper dives than reported for this species at other locations (Lea *et al.* 2002). Therefore, the location of the food source may result in different foraging strategies within a species and ultimately affect the weaning time of the offspring.

Colony status and health

Reproductive and morphological parameters

Variations in maternal investment strategies may impact the colony in several ways since the resources available, together with female experience, will affect female condition, in turn affecting pup production, growth, condition and survival (Kovacs and Lavigne 1992; Boness and Bowen 1996; Mellish *et al.* 1999). There are a number of ways to assess the general health or status of a colony, but methods are often employed based on a specific question unrelated to colony health (pup condition related to pup density and environmental parameters, Bradshaw *et al.* 2000a), or as the need arises (mass mortality of New Zealand sea lions, Duignan *et al.* 1998). One of the most common ways of assessing the basic status of a colony is to determine its reproductive success by carrying out estimates of pup production (Shaughnessy *et al.* 1994; Lalas and Harcourt 1995; Taylor *et al.* 1995). Estimates of pup production provide useful information on the status of a colony including population decline of endangered species (Steller sea lions, *Eumatopias jubatus*: Sease and Gudmundson 2002, and Hawaiian monk seals, *Monachus schauinslandi*: Baker and Johanos 2004),

level of sustainable fisheries by-catch (New Zealand sea lions, *Phocarctos hookeri*: Breen *et al.* 2003; Breen and Kim 2004), and stage of post-sealing re-colonisation (*A. forsteri*: Bradshaw *et al.* 2000b; Lalas and Bradshaw 2001).

The growth rates of pups can also provide useful information about the colony. Initially, the information can provide a baseline with which to compare future data and survival thresholds for critical stages from birth to nutritional independence (Mattlin 1978a). Growth rates coupled with pup suckling behaviour have been used to study the pups' role in driving nutrient uptake (Chilvers *et al.* 1995). Aspects of maternal attendance have been investigated through pup growth rates, including whether or not mothers show differential allocation between male and female pups (Crawley 1975; Mattlin 1981; Guinet *et al.* 1999). Also of interest are the implications of food availability, distance to foraging grounds, and female foraging efficiency on pup growth (Goldsworthy 1999; Georges and Guinet 2000) and whether or not pup growth can be used as an indicator of food availability (Bester and Van Jaarsveld 1997). More recently growth rates have been used to assess the level of intestinal parasites in New Zealand sea lion pups, *P. hookeri* (A. Castinel, pers. comm.). Also, with further investigation into the onset of diving and foraging behaviour in pups, growth rates have proved beneficial to the understanding of pup development as they near nutritional independence (Baylis 2003).

Pup condition can also be applied in much the same way as pup growth as an indication of female foraging efficiency (Boyd 1999), food availability (Bester and Van Jaarsveld 1997) and colony success (Bradshaw *et al.* 2002). Bradshaw *et al.* (2000a) compared pup condition with pup density in *A. forsteri* colonies at different stages of re-colonisation and found that as density increased in colonies reaching stable states, the condition of pups decreased. Pup condition has been compared between colonies as a potential indicator of food availability (Bradshaw *et al.* 2000a; Boren 2001) and has also been used as an indicator of colony success in modelling suitable fur seal habitats (Bradshaw *et al.* 2002). In addition, pup condition at weaning coupled with first year survivorship is useful for establishing condition thresholds for juvenile survival, with such an approach being utilised successfully in Southern elephant seals, *M. leonina* (McMahon *et al.* 2000), Northern fur seals, *C. ursinus* (Baker and Fowler 1992), Hawaiian monk seals, *M. schauinslandi* (Gillmarten

et al. 1993; Craig and Ragen 1999), and pinnipeds in general (Lee *et al.* 1991). Because of the relationships between pup condition, female condition, female foraging efficiency, and environmental parameters, pup condition may prove to be a useful indicator of colony status, reproductive success, and resource availability (Lee *et al.* 1991; Boyd 1996; Bradshaw *et al.* 2000a; 2002).

Mortality and disease

Morphometric data has proven useful in determining the basic status and relative health of a colony based on indices of condition (Tierney *et al.* 2001). There are a number of indices that take into account various relationships between mass, length and girth of an individual (Tierney *et al.* 2001). These indices can provide useful information on a large number of animals, but are not as accurate in determining parameters such as blubber depth, and are unable to account for gender differences in the utilisation of nutrients (Arnould *et al.* 1996). While animals in good condition are likely to be more resilient to disease (Kuss *et al.* 1990), morphometric parameters are unlikely to be useful in predicting levels of disease in a population.

More thorough investigations including levels and causes of mortality can be employed, along with specifically testing for diseases known to affect the species in question. Accurate records of mortality levels for some marine species are hard to come by, as they are dependent upon the search effort that can be employed in a given area (Estes *et al.* 2003). The search effort can be affected by the habitat of the species in question and the ability to effectively search it on a regular basis, as well as the dispersal or desiccation of carcasses in the marine environment (Estes *et al.* 2003). As a result, mortality is not always monitored on a regular basis. Instead, more detailed studies of the causes of mortality are carried out as the need arises, i.e. mass die offs (Vedros *et al.* 1971; Heide-Jørgenson and Härkönen 1992; Duignan *et al.* 1998; Scholin *et al.* 2000). However, with the increased level of interaction between humans and marine mammals through eco-tourism, captive handling, fisheries interactions, human expansion and development (Gentry and Gentry 1990; Boren 2001) and increased knowledge about the zoonotic (transfer between species) potential of several marine mammal diseases (Smith *et al.* 1978; Geraci 1991; Duignan 2000), it is becoming more important to have baseline information on body condition and

occurrence of disease in marine mammals that are interacting with humans on a consistent or regular basis.

While the most common cause of death to young pinnipeds is starvation (Mattlin 1978b), high levels and/or unusual cases of mortality have been attributed to biotoxins, viral infections, bacterial infections, and parasites (Duignan 2000). Red tides and toxic algal blooms as a result of climate or environmental change have also been implicated in increased mortality of several marine mammal species, including *A. forsteri* along the Kaikoura coast in the summer of 1998 (Chang 1998; Duignan 2000).

A number of viral infections have been reported in various pinniped species including morbillivirus, influenza A, herpesvirus, calicivirus, seal pox, and San Miguel sea lion virus (Smith and Skilling 1979; Duignan 2000). In New Zealand, the status of some of these viruses are unknown (influenza A and calicivirus) and seal pox has never been reported (Duignan 2000). However, the zoonotic potential for some of these viruses is high, and birds have been implicated as a reservoir for transmission of influenza to marine mammals (Geraci *et al.* 1982; Harvell *et al.* 1999). Also, the calicivirus is very contagious and shows no apparent host restrictions (Smith *et al.* 1981). Morbilliviruses, (including phocine distemper virus (PDV) and canine distemper virus (CDV) are responsible for numerous disease outbreaks in cetaceans and pinnipeds, and although reports of PDV were restricted to phocids, there is now evidence that both New Zealand fur seals and sea lions have been exposed to a morbillivirus (Duignan 2000). The population size and range of *A. forsteri* may increase the potential for this species to act as a reservoir for viral diseases and an agent of transfer for disease to other species in New Zealand and Australia (Duignan 2000).

Of the five most prevalent bacterial infections common to marine mammals (*mycobacterium*, *salmonellosis*, *campylobacteriosis*, *brucellosis*, and *leptospirosis*), *brucellosis* and *leptospirosis* were the only two that had not been previously diagnosed in marine mammals in New Zealand (Duignan 2000; Duignan 2003). *Salmonella* and campylobacter were both diagnosed in *P. hookeri* in 1998 and campylobacter was also diagnosed in an *A. forsteri* found stranded in 1998 (Duignan 2000). *Mycobacteria* of the tuberculosis group are a common cause of mortality in

New Zealand pinnipeds including *A. forsteri* (Woods *et al.* 1995; Hunter *et al.* 1998) and the potential for zoonotic infection in humans has been confirmed (Thompson *et al.* 1993). In addition, *brucellosis* has recently been reported in a Hector's dolphin (*Cephalorhynchus hectori*) in New Zealand (P. Duignan pers. comm).

New Zealand marine mammals are reported to be host to numerous parasites (Duignan 2000). Hookworm (*Uncinaria* spp.) has been reported in both *A. forsteri* and *P. hookeri*, and lungworm (*Parafilaroides decorus*) has frequently been found in stranded *A. forsteri* (Duignan 2003). Ivermectin was tested for its effectiveness in reducing the amount of lungworm and heartworm (*Otostrongylus circumlitus*) in harbour seals (*Phoca vitulina*) (Vercruysse *et al.* 2003) and is currently being trialled to determine prevalence of hookworm in wild populations of *P. hookeri* (A. Castinel, pers. comm.). Respiratory mites have also been reported in New Zealand seals, as have 'blubber cysts', the encysted larvae of the cestode, *Phyllobothrium* (Norman 1997). Numerous gastro-intestinal nematodes have been found in New Zealand seals, and heavy burdens can be associated with stomach ulcers (Duignan 2000).

New Zealand fur seals and the Kaikoura region

Kaikoura history

Whalers and sealers first arrived in New Zealand in 1792, however, Kaikoura did not become a well known whaling station until the arrival of Robert Fyffe, who established the first shore based whaling station in Kaikoura in 1842 (Harris 1994). Whaling, an important source of early economic activity had decreased by the mid 1900s, associated with the dramatic decrease in whale stocks, especially the right whale (*Eubalaena australis*).

European settlement in Kaikoura began with whaling and then turned to sheep farming but the sea always remained an important focal point for the community and in 1869 the town became a port of entry for New Zealand (Sherrard 1998). Fishing in the early 1900s was not very profitable and allowed for self-sufficiency, but little export, until the 1960s when the fishermen began to export crayfish to America (Harris 1994).

More recently, sperm whales (*Physeter macrocephalus*) have begun to return to the area, and following the establishment of whale watching in the 1980s, more people

have been coming to see the whales (Harris 1994). With the subsequent re-colonisation of some fur seal breeding colonies in the early 1990s, seals are fast becoming an important target of visitors to the region (Boren 2001) and marine mammal tourism has become a driving force in the development of the Kaikoura community (Horn *et al.* 1998, Simmons and Fairweather 1998).

Kaikoura's appeal to marine mammals

The continental shelf is very narrow off the coast of Kaikoura (Figure 2) and the steep slope forms a system of trenches that commonly produce upwelling of subsurface waters (Garner 1953). Within the trench, mesopelagic fish and squid, including several species of myctophids (lantern fish), migrate vertically in the water column at night (Robertson *et al.* 1978; Würsig *et al.* 1989; Benoit-Bird *et al.* 2004). The head of the Kaikoura Canyon is located around 500 m off the coast and the canyon reaches depths of greater than 1000 m around 1 km off the coast (Benoit-Bird *et al.* 2004). Jaquet *et al.* (2000) suggested that the Kaikoura Canyon provided an adequate food supply to support year-round residency of adult male sperm whales (*P. macrocephalus*). Similarly, dusky dolphins (*Lagenorhynchus obscurus*) are found year-round in Kaikoura, and have been reported to feed on myctophids and squid associated with the deep scattering layer (DSL) (Benoit-Bird *et al.* 2004). In their study, Benoit-Bird *et al.* (2004) used active-acoustic surveys to determine the vertical migration of the DSL, whether *L. obscurus* was foraging in it, and when it was accessible to them. They found that the DSL was within 150 m of the surface from 1900 to 0530 hours, and was within 50 m of the surface between 2300 and 0100 hours. *L. obscurus* was observed foraging at the top of the DSL as long as it was within 130 m of the surface. *A. forsteri* are capable divers and, although they mainly dive at depths between 10 to 70 m, adult females are capable of maximum depths ranging from 106 to 225 m (Harcourt *et al.* 1995; Harcourt and Davis 1997). Even pups aged 6 to 10 months have been reported to dive to depths of up to 44 m (Baylis 2003). Taken at face value, these data suggest that this food source may be accessible to fur seals year round as well.

The diet of *A. forsteri* has been studied on several occasions at a variety of colonies (Street 1964; Carey 1992; Harcourt and Davis 1997; Lake 1997; Harcourt 2001; Harcourt *et al.* 2002; Baylis 2003). While fur seal diet varies between colonies, *A.*

forsteri is consistently reported to primarily eat myctophids, arrow squid, octopus, red cod and, occasionally, hoki. In Kaikoura, the predominant prey species are *Symbolophorus* spp. (myctophid), arrow squid and octopus, and a small amount of hoki (Carey 1992) accessible in the deep scattering layer in the Kaikoura Canyon (Benoit-Bird *et al.* 2004).

Kaikoura's rocky coastal environment also provides the preferred habitat for New Zealand fur seal breeding colonies: a) large rocks and crevices that provide places for pups to hide (Ryan *et al.* 1997; Bradshaw *et al.* 1999), and b) areas of shade, and rock pools that are important for thermoregulation of adult females (Carey 1989) and the development of swimming in pups (Baylis 2003). Other factors that are important for site selection of breeding fur seals are the proximity to a food source as mentioned previously, and the level of human disturbance at a location (Bradshaw *et al.* 1999). The relative importance of these factors remain unknown, but the benefit of a reliable food source such as that found in the Kaikoura Canyon may explain why seals remain in an area of high human disturbance where they are more susceptible to long-term impacts of human development in the region (Boren 2001).

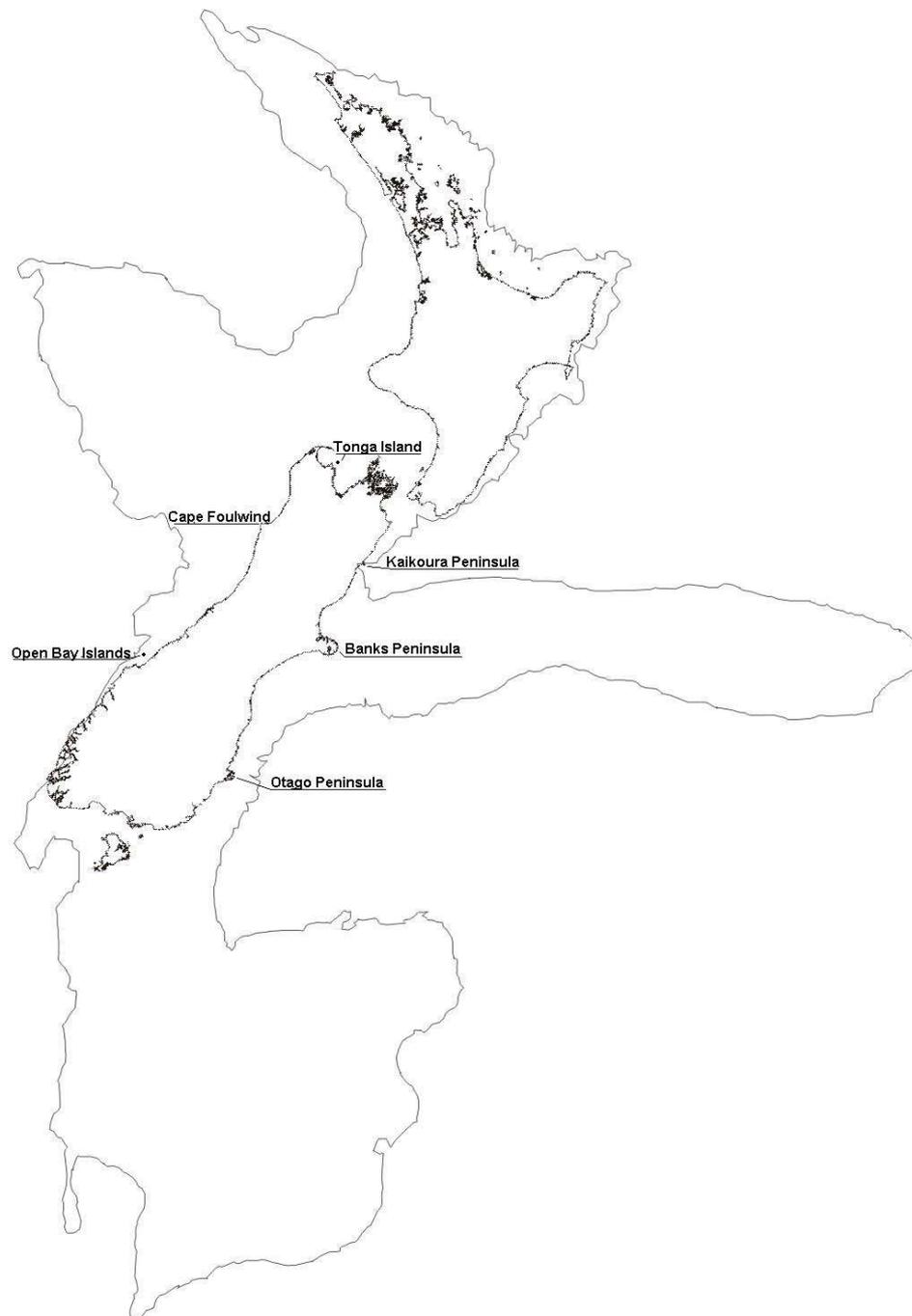


Figure 2: Bathymetry around the coast of New Zealand. The line shown is the 1000 m isobath (from Lalas and Bradshaw 2001). Note how close it is to the shore in Kaikoura, versus the Banks Peninsula, and other areas around New Zealand.

Re-colonisation of fur seals in Kaikoura

In the 1960s and 70s non-breeding fur seals were found to the South, North and on the Kaikoura peninsula in low numbers (Street 1964; Stirling 1970; Miller 1971; Wilson 1981). The Department of Conservation has been monitoring seals in the region for the past few decades, and in 1990 the first births were recorded at Barney's Rock (south coast), Ohau Point (north coast) and on the Kaikoura Peninsula (Figure 3; Report to DOC, Rob Suisted, Nov. 2004). Pupping on Barney's Rock and the Kaikoura Peninsula is limited to about 10 pups per year by the amount of space on the reefs where the breeding seals are found (Bradshaw 1999; Report to DOC, Rob Suisted, Nov. 2004; Chapter 2). Pupping at Ohau Point colony remained under 50 pups per year until 1998 (Bradshaw *et al.* 2000a) when numbers jumped to over 100 pups per year between 1999 and 2001 (Boren 2001) and since then has entered a stage of exponential growth and quadrupled (Chapter 2).

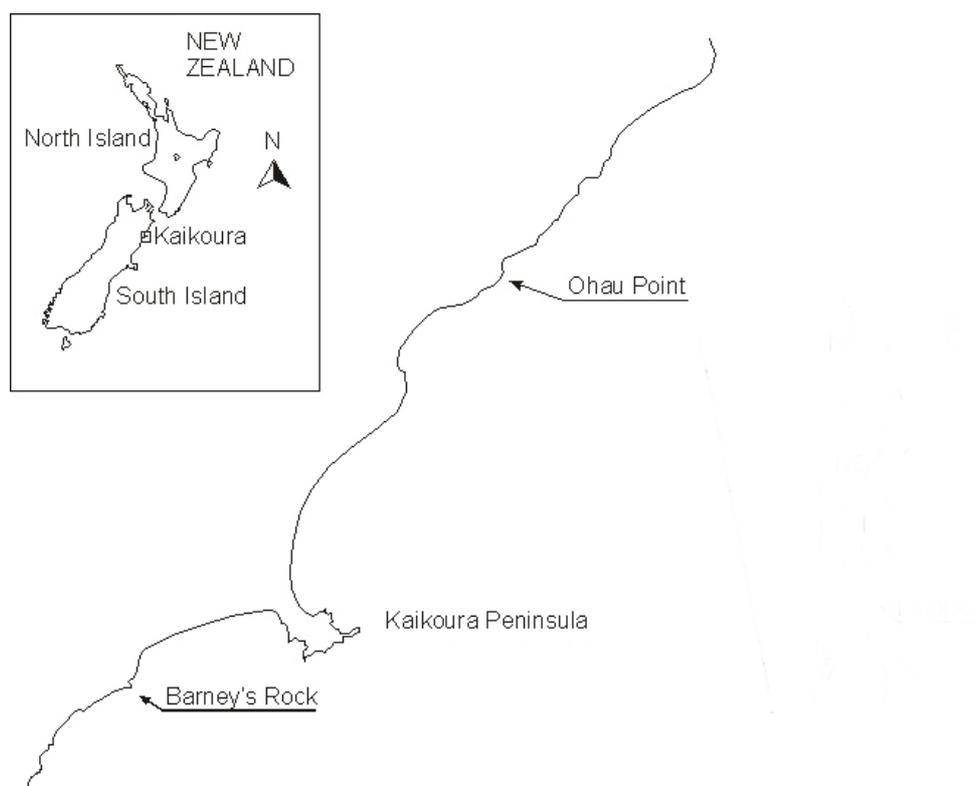


Figure 3: The Kaikoura coast showing the location of the Kaikoura peninsula, Ohau Point and Barney's Rock.

Breeding biology of *A. forsteri* in Kaikoura

The breeding biology of *A. forsteri* in Kaikoura is somewhat different than that reported for other colonies with weaning of pups, arrival of females on colony and pupping all occurring 14-28 days earlier than previously reported (Stirling 1971a; Miller 1975; Mattlin 1978a; Goldsworthy and Shaughnessy 1994; Haase 2004). Although lactation is known to vary within the species between 224-365 days, the most commonly quoted lactation duration for New Zealand fur seals is 285 days and weaning usually occurs around September to October (Stirling 1971; Crawley 1975; Miller 1975; Mattlin 1978a; Goldsworthy 1992; Harcourt *et al.* 1995; Harcourt 2001; Baylis 2003; Schulz and Bowen 2004). It is common in Kaikoura to observe lactation durations longer than 285 days and the implications of these findings will be discussed further in Chapter 3.

Global and local concerns for marine mammals including *A. forsteri*

Tourism

Eco-tourism is a major source of income for the Kaikoura community. As reported by Butcher *et al.* (1998), tourists were spending approximately NZ\$28-36 million (direct spending and flow-on) annually in 1998 with an estimated future increase of NZ\$4.4 million direct spending per year. Visitor numbers by 1998 were estimated at approximately 873,000 tourists per year with an expected increase of 14% per annum (Simmons *et al.* 1998). More recently, the Kaikoura peninsula was named one of the top three visitor destinations in New Zealand, attracting around one million tourists in 2002 (Experience Kaikoura, October 2003). Pinniped-based eco-tourism alone earns an estimated US\$12,590,910 annually in the Southern hemisphere, with New Zealand accounting for US\$1,038,000 (Kirkwood *et al.* 2003). Increasing levels of cetacean and pinniped tourism on a Southern hemisphere and world-wide scale has instigated the need for scientific studies into the impacts of tourism on the target species (Kirkwood *et al.* 2003; Bejder and Samuels 2003). While studies on the impacts of tourism on pinnipeds, especially otariids are few (Boren 2001), three consecutive studies have investigated different aspects of the impacts of tourism on *A. forsteri* in Kaikoura. Barton *et al.* (1998) focused on the impacts of land-based tourism in Kaikoura and found that seals were changing their behaviour in response to tourists and recommended increasing the minimum approach distance for foot traffic from 5

to 10 m. Following this, Boren *et al.* (2002) investigated both land and sea based tourism, including kayaks, motorboats and seal-swimming at a selection of tourist visited and non-visited colonies. The research found that sea-based approaches elicited fewer avoidance responses than land-based approaches and seals with high tourist visitation were showing signs of habituation, but approaches were still causing seals to change their behaviour. New minimum approach distances were recommended and now, regardless of approach type (foot, kayak or boat), one must remain 20 m from the seals and not enter a breeding colony. A follow-up report for Lincoln University looked into the possibility of modelling the impact of tourists on seals at the Kaikoura peninsula, based on the number of seals present (Hughey and Ward 2002; Report prepared for FRST, April 2004). No correlation was found between the number of tourists present and the response of seals, most likely due to the noise inherent in natural behaviour and the potential for habituation at this site. Although we know that tourism is causing seals to modify their behaviour, and that this may affect their ability to conserve energy, we do not know the long-term ramifications of tourist disturbance (Boren 2001).

Fisheries interactions

The interaction between marine mammals and fisheries has been the subject of a long-term worldwide debate and a great amount of research has been directed to settling it (Yodzis 2001; Lavigne 2003). Marine mammals may interact with fisheries in a number of ways typically categorised as either operational or ecological conflicts (Beverton 1985; Lavigne 2003). Both categories involve interactions detrimental to both the marine mammals and the fisheries. For example, under operational interactions, damage to fishing gear or aquaculture facilities (DeMaster *et al.* 1985; Shaughnessy 1985; David and Wickens 2003) and damage to or loss of stock is detrimental to fishermen (DeMaster *et al.* 1985), and often results in the call for a cull (Lavigne 2003). Fishermen are also concerned about the depletion of their stocks through competition with marine mammals (Goldsworthy *et al.* 2003; Ambrose 2004; Kaschner and Pauly 2004), and the potential for transmission of parasites to their stocks (Shaughnessy 1985; Lavigne 2003). On the other hand, marine mammals can be affected through incidental catches or entanglements in fishing gear (Donohue *et al.* 2001; Lavigne 2003; Wilkinson *et al.* 2003; Lewison *et al.* 2004; Page *et al.* 2004),

competition with fisheries for depleting fish stocks and both “organised” (Lavigne 2003; Ambrose 2004) and “non-organised” culling of marine mammals (DeMaster *et al.* 1985). The trophic interactions involved in understanding the effects of competition between marine mammals and fisheries are incredibly complex (Lavigne 2003; Goldsworthy *et al.* 2003) and, as suggested by Bowen (1985), it is very difficult to determine exactly how a decrease or increase in one population will affect the other. For *A. forsteri* in Kaikoura there is a limited amount of dietary overlap with the local fisheries (Carey 1992), however, the concern that seals are competing with local fishers remains (*pers. obs.*). Shootings have been reported to the Department of Conservation on a low level, and entanglement rates for the region are comparable with those reported for other pinniped species around the world, including an *A. forsteri* population in South Australia (Donohue *et al.* 2001; Report to DOC, Rob Suisted, Nov. 2004; Page *et al.* 2004; Chapter 6).

Re-colonisation effects on global and local marine industries

Following the protection of several marine mammal species around the world, we are seeing various trends in re-colonisation. Some species continue to decline in numbers or are only slowly beginning to recover (eg: Steller sea lions, *E. jubatus*: Sease and Gudmundson 2002, Hooker sea lions, *P. hookeri*: Childerhouse and Gales 1998, Hawaiian monk seals, *M. schauinslandi*: Baker and Johanos 2004, and baleen whales, *Mysticetes*: Branch *et al.* 2004). In contrast, other species are entering exponential and mature phases of re-colonisation (*A. forsteri*: Lalas and Bradshaw 2001; Shaughnessy *et al.* 1994; *A. gazella*: Wynen *et al.* 2001 and Harp seals, *Pagophilus groenlandicus*: Ambrose 2004). Along with the increase in marine mammal numbers worldwide, we are also seeing an increase in potential fisheries interactions (Lavigne 2003), and an increase in cetacean and pinniped-based eco-tourism (Bejder and Samuels 2003; Kirkwood *et al.* 2003; Samuels *et al.* 2003). Kaikoura is following a similar pattern with the rest of the world, with the re-colonisation of *A. forsteri* along the coast and marine mammal tourism increasing dramatically in the last decade (Boren 2001).

The re-colonisation of *A. forsteri* in the region plays an important role in both the fishing and tourism industries and raises some concerns for management. With increasing seal numbers there are growing opportunities for expanding pinniped-based

tourism in the region. However, this may affect maternal investment strategies and various colony health parameters including reproductive output, body condition (ability to allocate time appropriately to foraging, nursing and resting) and immune system health (Kuss *et al.* 1990; Ward and Beanland 1996; Constantine 1999; Boren 2001; Creel 2001; Constantine 2004). Another concern with increased human-seal interactions is the increased potential for zoonotic transfer of disease between species (e.g. *Mycobacterium* spp. (tuberculosis) and *Salmonellosis*, Hunter *et al.* 1998; and influenza, Osterhaus *et al.* 2000). A better understanding of the population in question, including their reproductive biology, status, and health, can lead to better management practices in a region where both marine mammal and human activity is increasing.

Thesis Aims

Within New Zealand, little attention has been paid to the maternal behaviour and foraging ecology of fur seals. One key study in the 1990's investigated the at-sea behaviour of fur seals, and this was carried out over five seasons at Fuschia Gully, Otago on a limited number of animals (Harcourt *et al.* 1995; 2001; 2002). The fur seals in the Kaikoura region are unique in that the population is close to a rich food source from the Kaikoura Canyon (Jaquet *et al.* 2000). If fur seals' foraging behaviour depends on site specific factors such as location of feeding grounds (Goldsworthy 1999), then it would be beneficial to know if lactating females are using the Kaikoura Canyon as a food source and, if so, how this affects the growth and weaning of their young. Ohau Point seal colony, the largest in the Kaikoura region, is in a state of growth and is located near an area of increasing human activity. The objectives of this study are to determine colony dynamics and growth of New Zealand fur seals in Kaikoura, maternal attendance patterns of fur seals in the region. Further objectives are to determine the effect of maternal attendance patterns on pup growth and condition in the region, and to provide baseline information on internal parasites, and the mortality of pups at the Ohau Point seal colony. Data collection to achieve these objectives was carried out using a combination of methods over four austral summer seasons (2001/02-2004/05) in Kaikoura. The methods employed include: 1) land-based behavioural data collection, 2) sea-based behaviour of lactating females using radio (VHF) telemetry, 3) collection of morphometric data from mothers and pups, 4) anti-helmenthic medication administered to a sub-set of pups and their growth and

condition monitored, and 5) instances of mortality recorded and post-mortems carried out on freshly dead pups and juveniles.

The main objectives from this thesis can be broken into four main questions:

1. What is the status of New Zealand fur seal breeding colonies in the Kaikoura region and how do they compare with other colonies of the species in New Zealand and Southern Australia?
2. What are the various maternal attendance patterns employed by lactating female fur seals in the region?
3. How might the maternal investment strategies of female New Zealand fur seals affect pup condition and growth in the region?
4. What is the current status of pup health in the region, specifically in terms of internal parasite load, and what are the common causes of mortality?

The thesis will be structured into three main parts: 1) colony dynamics, 2) reproductive behaviour, and 3) health parameters. 'Colony dynamics' will incorporate two chapters. The first chapter will examine the growth of fur seal colonies and the condition of pups in Kaikoura compared with other New Zealand colonies, along the east coast of their range. The next chapter then investigates the breeding biology dynamics of Ohau Point seal colony in Kaikoura.

'Reproductive Behaviour' will also consist of two chapters, looking at biologically and reproductively significant behaviours pertaining to both the mothers and the pups. In Chapter 4 I focus on maternal investment, and investigate female attendance patterns using both behavioural and VHF telemetry data. Chapter 5 will focus on pup growth, nursing times, and activity levels of pups over four breeding seasons.

The 'Health Parameter' section will consist of two chapters, each dealing with a different aspect of colony and/or pup health. Chapter 6 will detail the recorded level of mortality in the region, and examine the common causes of death for pups and juvenile fur seals. Chapter 7 will further investigate the presence of internal parasites by comparing the growth of pups given an anti-helmenthic treatment versus pups that have not received any treatment.

Following these sections, a final 'Discussion' section will revisit the above questions and discuss my findings in terms of the inter-relationships of the reproductive and health parameters on both the species and population levels.

References:

- Ambrose, P. (2004). Canadian harp seal hunt. *Marine Pollution Bulletin* **48**, 1014.
- Arnould, J., Boyd, I. and Speakman, J. (1996). Measuring the body composition of Antarctic fur seals (*Arctocephalus gazella*): validation of hydrogen isotope dilution. *Physiological Zoology* **69**, 93-116.
- Arnould, J. P. Y., Littnan, C., and Lento, G. (2000). First record of New Zealand fur seals (*Arctocephalus forsteri*) breeding in Bass Strait. *Australian Mammalogy* **22**, 57-62.
- Baker, J. and Fowler, C. (1992). Pup weight and survival of northern fur seals *Callorhinus ursinus*. *Journal of Zoology, London* **227**, 231-238.
- Baker, J. D. and Johanos, T. C. (2004). Abundance of the Hawaiian monk seal in the Main Hawaiian Islands. *Biological Conservation* **116**, 103-110.
- Barton, K. J., Booth, K., Ward, J., Simmons, D. and Fairweather, J. (1998). Tourist and New Zealand fur seal interactions along the Kaikoura Coast. Lincoln University Tourism Research and Education Centre Report No. 9, Lincoln, New Zealand.
- Baylis, A. M. (2003). The ontogeny of dive behaviour in New Zealand fur seal pups (*Arctocephalus forsteri*). Postgraduate diploma in Zoology. Department of Zoology, LaTrobe University, Victoria, Australia.
- Bejder, L. and Samuels, A. (2003). Evaluating the effects of nature-based tourism on cetaceans. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 229-256. (CSIRO: Collingwood, VIC, Australia)
- Benoit-Bird, K., Würsig, B. and McFadden, C. (2004). Dusky dolphin (*Lagenorhynchus obscurus*) foraging in two different habitats: active acoustic detection of dolphins and their prey. *Marine Mammal Science* **20**, 215-231.
- Bester, M. and VanJaarsveld, A. (1997). Growth in the subantarctic fur seal *Arctocephalus tropicalis* pups as a possible indicator of offshore food availability. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds M. Hindell and C. Kemper.) pp. 88-91. (Surrey Beatty & Sons, Chipping Norton: Australia)
- Beverton, R. (1985). Analysis of marine mammal-fisheries interactions. In 'Marine Mammals and Fisheries'. (Eds J. Beddington, R. Beverton and D. Lavigne.) pp. 1-33. (George Allen & Unwin Ltd.: London)
- Boness, D. J. and Bowen, W. D. (1996). The evolution of maternal care in pinnipeds. *BioScience* **46**, 645-654.
- Boren, L. J. (2001). Assessing the impact of tourism on New Zealand fur seals (*Arctocephalus forsteri*). MSc. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Boren, L. J., Gemmill, N. J. and Barton, K. J. (2002). Tourist disturbance on New Zealand fur seals, *Arctocephalus forsteri*. *Australian Mammalogy* **24**, 85-96.
- Bowen, W. (1985). Harp seal feeding and interactions with commercial fisheries in the north-west Atlantic. In 'Marine Mammals and Fisheries'. (Eds J. Beddington, R. Beverton and D. Lavigne.) pp. 135-152. (George Allen & Unwin Ltd.: London)

- Boyd, I. (1996). Temporal scales of foraging in a marine predator. *Ecology* **77**, 426-434.
- Boyd, I. (1999). Foraging and provisioning in Antarctic fur seals: interannual variability in time-energy budgets. *Behavioural Ecology* **10**, 198-208.
- Bradshaw, C. J. (1999). Population dynamics and colonisation modelling of New Zealand fur seals. PhD. Department of Zoology, University of Otago, Dunedin, New Zealand.
- Bradshaw, C. J., Thompson, C. M., Davis, L. S. and Lalas, C. (1999). Pup density related to terrestrial habitat use by New Zealand fur seals. *Canadian Journal of Zoology* **77**, 1579-1586.
- Bradshaw, C. J., Davis, L. S., Lalas, C. and Harcourt, R. G. (2000a). Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. *Journal of Zoology, London* **252**, 41-51.
- Bradshaw, C. J., Lalas, C. and Thompson, C. M. (2000b). Clustering of colonies in an expanding population of New Zealand fur seals (*Arctocephalus forsteri*). *Journal of Zoology, London* **250**, 105-112.
- Bradshaw, C. J., Davis, L., Purvis, M., Zhou, Q. and Benwell, G. (2002). Using artificial neural networks to model the suitability of coastline for breeding by New Zealand fur seals (*Arctocephalus forsteri*). *Ecological Modelling* **148**, 111-131.
- Branch, T. A., Matsuoka, K. and Miyashita, T. (2004). Evidence for increases in Antarctic blue whales based on Bayesian modelling. *Marine Mammal Science* **20**, 726-754.
- Breen, P. A. and Kim, S. W. (2004). Modelling the effects of squid fishing on Hooker sea lions. In New Zealand Marine Sciences Society Annual Conference Proceedings. Dunedin, New Zealand.
- Breen, P. A., Hilborn, R., Maunder, M. and Kim, S. (2003). Effects of alternative control rules on the conflict between a fishery and a threatened sea lion (*Phocarctos hookeri*). *Canadian Journal of Fisheries and Aquatic Science* **60**, 527-541.
- Butcher, G., Fairweather, J. and Simmons, D. (1998). The Economic Impact of Tourism on Kaikoura. Lincoln University Report No. 8, Lincoln, New Zealand.
- Carey, P. W. (1989). Behavioural thermoregulation and polygyny in the New Zealand fur seal. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch.
- Carey, P. W. (1992). Fish prey species of the New Zealand fur seal (*Arctocephalus forsteri* Lesson). Department of Conservation No. 115, Wellington, New Zealand. 9.
- Cawthorn, M., Crawley, M. C., Mattlin, R. and Wilson, G. J. (1985). Research on Pinnipeds in New Zealand. Wildlife Research Liaison Group, Wildlife Research Review 7, Wellington, New Zealand.
- Chang, F. (1998). Occurrence of *Gymnodinium*, a toxic dinoflagellate species, off Wairarapa. *Water and Atmosphere* **6**, 4.
- Childerhouse, S. and Gales, N. (1998). Historical and modern distribution and abundance of the New Zealand sea lion, *Phocarctos hookeri*. *New Zealand Journal of Zoology* **25**, 1-16.
- Chilvers, B., Wilson, K. and Hickling, G. (1995). Suckling behaviours and growth rates of New Zealand fur seal, *Arctocephalus forsteri*, at Cape Foulwind, New Zealand. *New Zealand Journal of Zoology* **22**, 263-270.

- Constantine, R. (1999). Effects of tourism on marine mammals in New Zealand. Department of Conservation, Science for Conservation 106, Wellington, New Zealand.
- Constantine, R., Brunton, D. H. and Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation* **117**, 299-307.
- Costa, P. and Gales, N. (2000). Foraging energetics and diving behaviour of lactating New Zealand sea lions, *Phocarctos hookeri*. *Journal of Experimental Biology* **203**, 3655-3665.
- Craig, M. and Ragen, T. (1999). Body size, survival and decline of juvenile Hawaiian monk seals, *Monachus schauinslandi*. *Marine Mammal Science* **15**, 786-809.
- Crawley, M. (1975). Growth of New Zealand fur seal pups. *New Zealand Journal of Marine and Freshwater Research* **9**, 539-545.
- Crawley, M. and Wilson, G. (1976). The natural history and behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Tuatara* **22**, 1-29.
- Creel, S. (2001). Social dominance and stress hormones. *Trends in Ecology and Evolution* **16**, 491-497.
- David, J. and Wickens, P. (2003). Management of Cape fur seals and fisheries in South Africa. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 116-135. (CSIRO: Collingwood, VIC, Australia)
- DeMaster, D., Miller, D., Henderson, J. and Coe, J. (1985). Conflicts between marine mammals and fisheries off the coast of California. In 'Marine Mammals and Fisheries'. (Eds J. Beddington, R. Beverton and D. Lavigne.) pp. 111-118. (George Allen & Unwin Ltd.: London)
- Dix, B. (1993). A new record this century of a breeding colony in the North Island for the New Zealand fur seal *Arctocephalus forsteri*. *Journal of the Royal Society of New Zealand* **23**, 1-4.
- Donohue, M. J., Boland, R. C., Sramek, C. M. and Antonelis, G. A. (2001). Derelict fishing gear in the Northwestern Hawaiian Islands: Diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. *Marine Pollution Bulletin* **42**, 1301-1312.
- Duignan, P. (2003). Disease investigations in stranded marine mammals, 1999-2002. Department of Conservation Department of Conservation Science Internal Series 104, Wellington, New Zealand.
- Duignan, P. (2000). Diseases of cetaceans and pinnipeds. In Marine Wildlife: the Fabian Fay Course for Veterinarians. Post Graduate Foundation in Veterinary Science, University of Sydney, Proceedings 335 Sea World Nara Resort, Gold Coast, Australia. pp. 419-447.
- Duignan, P. J., Hunter, J., Alley, M., Thompson, K., Meers, J., Fenwick, S., Gibbs, N., Gales, N., Childerhouse, S., Garthwaite, I. and Madie, P. (1998). New Zealand sea lion epidemic January-February 1998, preliminary report June 1998.
- Estes, J. A., Hatfield, B. B., Ralls, K. and Ames, J. (2003). Causes of mortality in California sea otters during periods of population growth and decline. *Marine Mammal Science* **19**, 198-216.
- Gales, N., Haberley, B. and Collins, P. (2000). Changes in the abundance of New Zealand fur seals, *Arctocephalus forsteri*, in Western Australia. *Wildlife Research* **27**, 165-168.

- Garner, D. (1953). Physical characteristics of inshore surface waters between Cook Strait and Banks Peninsula, New Zealand. *New Zealand Journal of Science and Technology* **35**, 239-246.
- Gentry, R. and Gentry, E. (1990). Responses of Northern fur seals to quarrying operations. *Marine Mammal Science* **6**, 151-155.
- Gentry, R., Costa, D., Croxall, J., David, J., Davis, R., Kooyman, G., Majluf, P., McCann, T. and Trillmich, F. (1986). Synthesis and conclusions. In 'Fur seals: maternal strategies on land and at sea'. (Eds R. Gentry and G. Kooyman.) pp. 220-264. (Princeton University Press: Princeton, New Jersey).
- Georges, J.-Y. and Guinet, C. (2000). Maternal care in the subantarctic fur seals on Amsterdam Island. *Ecology* **81**, 295-308.
- Georges, J.-Y., Bonadonna, F. and Guinet, C. (2000). Foraging habitat and diving activity of lactating Subantarctic fur seals in relation to sea-surface temperatures at Amsterdam Island. *Marine Ecology Progress Series* **196**, 291-304.
- Geraci, J. (1991). On disease transmission between cetaceans and humans. *Marine Mammal Science* **7**, 191-194.
- Geraci, J. R., St. Aubin, D. J., Barker, I., Webster, R., Hinshaw, V., Bean, W., Ruhnke, H., Prescott, J., Early, G., Baker, A., Madoff, S. and Schooley, R. (1982). Mass Mortality of Harbour seals - Pneumonia associated with Influenza-A virus. *Science* **215**, 1129-1131.
- Gillmartin, W. G., Johanos, T. C. and Eberhardt, L. (1993). Survival rates for the Hawaiian monk seal (*Monachus schauinslandi*). *Marine Mammal Science* **9**, 407-420.
- Goldsworthy, S. (1992). Maternal care in three species of fur seal, *Arctocephalus* spp. at Macquarie Island. Unpublished PhD thesis. Monash University, Melbourne, Australia.
- Goldsworthy, S. (1999). Maternal Attendance behaviour of sympatrically breeding Antarctic and Subantarctic fur seals, *Arctocephalus* spp., at Macquarie Island. *Polar Biology* **21**, 316-325.
- Goldsworthy, S. and Shaughnessy, P. (1994). Breeding biology and haul-out pattern of the New Zealand fur seal, *Arctocephalus forsteri*, at Cape Gantheaume, South Australia. *Wildlife Research* **21**, 365-376.
- Goldsworthy, S., Hindell, M. and Crowley, H. (1997). Diet and diving behaviour of sympatric fur seals *Arctocephalus gazella* and *A. tropicalis* at Macquarie Island. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: status, ecology and medicine'. (Eds M. Hindell and C. Kemper.) pp. 151-163. (Surrey Beatty & Sons, Chipping Norton: Australia).
- Goldsworthy, S., Boness, D. and Fleischer, R. (1999). Mate choice among sympatric fur seals: female preference for conphenotypic males. *Behavioural Ecology and Sociobiology* **45**, 253-267.
- Goldsworthy, S. D., Bulman, C., He, X., Larcome, J. and Littnan, C. (2003). Trophic interactions between marine mammals and Australian fisheries: an ecosystem approach. In 'Marine Mammals: fisheries, tourism and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 62-99. (CSIRO: Collingwood, VIC, Australia)
- Haase, T. (2004). The determinants of weaning in the New Zealand fur seal. Unpublished PhD. Department of Zoology, School of Life Sciences, La Trobe University, Victoria, Australia.
- Harcourt, R. (2001). Advances in New Zealand mammalogy 1990-2000: Pinnipeds. *Journal of the Royal Society of New Zealand* **31**, 135-160.

- Harcourt, R. and Davis, L. (1997). The use of satellite telemetry to determine fur seal foraging areas. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds M. Hindell and C. Kemper.) pp. 137-142. (Surrey Beatty & Sons, Chipping Norton: Australia).
- Harcourt, R. G., Schulman, A. M., Davis, L. S. and Trillmich, F. (1995). Summer foraging behaviour by lactating female New Zealand fur seals (*Arctocephalus forsteri*) off Otago Peninsula, New Zealand. *Canadian Journal of Zoology* **73**, 678-690.
- Harcourt, R., Hindell, M., Bell, D. and Waas, J. (2000). Three-dimensional dive profiles of free-ranging Weddell seals. *Polar Biology* **23**, 479-487.
- Harcourt, R. G., Bradshaw, C. J. and Davis, L. (2001). Summer foraging behaviour of a generalist predator, the New Zealand fur seal (*Arctocephalus forsteri*). *Wildlife Research* **28**, 599-606.
- Harcourt, R. G., Bradshaw, C. J., Dickson, K. and Davis, L. S. (2002). Foraging ecology of a generalist predator, the female New Zealand fur seal. *Marine Ecology Progress Series* **227**, 11-24.
- Harris, J. (1994). 'Tohora: the story of Fyffe House, Kai Koura.' (New Zealand historic places trust: Wellington.)
- Harvell, C., Kim, K., Burkholder, J., Colwell, R. and al., e. (1999). Emerging marine diseases- climate links and anthropogenic factors. *Science* **285**, 1505-1510.
- Heide-Jørgenson, M., and Härkönen, T. (1992). Epizootiology of the seal disease in the Eastern North Sea. *Journal of Applied Ecology* **29**, 99-107.
- Hindell, M., Slip, D. and Burton, H. (1991). The diving behaviour of adult male and female Southern elephant seals, *Mirounga leonina*. *Australian Journal of Zoology* **39**, 595-619.
- Horn, C., Simmons, D. and Fairweather, J. (1998). Evolution and Change in Kaikoura: Responses to Tourism Development. Lincoln University Report No. 6, Lincoln, New Zealand.
- Hughey, K. F. and Ward, J. (2002). Sustainable Management of Natural Assets Used for Tourism in New Zealand. Lincoln University Report 55, Lincoln, New Zealand.
- Hunter, J., Duignan, P. J., Dupont, C., Fray, L., Fenwick, S. and Murray, A. (1998). First report of potentially zoonotic tuberculosis in fur seals in New Zealand. *New Zealand Medical Journal* **111**, 130-131.
- Jaquet, N., Dawson, S. and Slooten, E. (2000). Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: foraging implications. *Canadian Journal of Zoology* **78**, 407-419.
- Kaschner, K. and Pauly, D. (2004). Competition between Marine Mammals and Fisheries: Food for thought. Report to The Humane Society of the United States. Special Report, Philadelphia, Pennsylvania. pp. 28.
- Kirkwood, R., Boren, L., Shaughnessy, P., Szteren, D., Mawson, P., Huckstadt, L., Hofmeyr, G., Oosthuizen, H., Schiavini, A., Campagna, C. and Berris, M. (2003). Pinniped-focused tourism in the Southern hemisphere: a review of the industry. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 257-276. (CSIRO: Collingwood, VIC, Australia)
- Kovacs, K. M. and Lavigne, D. (1992). Maternal investment in otariid seals and walruses. *Canadian Journal of Zoology* **70**, 1953-1964.
- Kuss, F., Graefe, A. and Vaske, J. (1990). Visitor impact management: a review of research. National Parks and Conservation Association Vol. 1, Washington DC.

- Lake, S. (1997). Analysis of the diet of New Zealand fur seals (*Arctocephalus forsteri*) in Tasmania. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: status, ecology and medicine'. (Eds M. Hindell and C. Kemper.) pp. 125-129. (Surrey Beatty & Sons, Chipping Norton: Australia).
- Lalas, C. and Bradshaw, C. J. (2001). Folklore and chimerical numbers: review of a millennium of interaction between fur seals and humans in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research* **35**, 477-497.
- Lalas, C. and Harcourt, R. G. (1995). Pup production of the New Zealand fur seal on Otago Peninsula, New Zealand. *Journal of the Royal Society of New Zealand* **25**, 81-88.
- Lavigne, D. (2003). Marine mammals and fisheries: the role of science in the culling debate. In 'Marine Mammals: fisheries, tourism and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 31-47. (CSIRO publishing: Collingwood, VIC, Australia)
- Lea, M.-A., Hindell, M., Guinet, C. and Goldsworthy, S. (2002). Variability in the diving activity of Antarctic fur seals, *Arctocephalus gazella*, at Iles Kerguelen. *Polar Biology* **25**, 269-279.
- Lee, P., Majluf, P. and Gordon, I. (1991). Growth, weaning and maternal investment from a comparative perspective. *Journal of Zoology, London* **225**, 99-114.
- Lewison, R. L., Crowder, L. B., Read, A. J. and Freeman, S. A. (2004). Understanding impacts of fisheries by-catch on marine megafauna. *Trends in Ecology and Evolution* **19**, 598-604.
- Mattlin, R. (1978a). Population biology, thermoregulation and site preference of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1828) on the Open Bay Islands, New Zealand. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Mattlin, R. (1978b). Pup mortality of the New Zealand fur seal (*Arctocephalus forsteri*). *New Zealand Journal of Ecology* **1**, 138-144.
- Mattlin, R. (1981). Pup growth of the New Zealand fur seal, *Arctocephalus forsteri*, on the Open Bay Islands, New Zealand. *Journal of Zoology, London* **193**, 305-314.
- Mattlin, R. (1987). New Zealand fur seal (*Arctocephalus forsteri*) within the New Zealand region. In 'Status, biology and ecology of fur seals: NOAA Technical Report NMFS 51'. (Eds J. Croxall and R. Gentry.) pp. 49-51. (National Marine Fisheries Service: Cambridge)
- McMahon, C., Burton, H. and Bester, M. (2000). Weaning mass and the future survival of juvenile southern elephant seals, *Mirounga leonina*, at Macquarie Island. *Antarctic Science* **12**, 149-153.
- Mellish, J., Iverson, S. and Bowen, D. (1999). Variation in milk production and lactation performance in grey seals and consequences for pup growth and weaning characteristics. *Physiological and Biochemical Zoology* **72**, 677-690.
- Miller, E. (1971). Social and thermoregulatory behaviour of the New Zealand fur seal. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
- Miller, E. H. (1975). Annual cycle of fur seals, *Arctocephalus forsteri* (Lesson), on the Open Bay Islands, New Zealand. *Pacific Science* **29**, 139-152.
- Norman, R. d. B. (1997). *Tetraphyllidean cysticerci* in the peritoneal cavity of the common dolphin. *Journal of Wildlife Diseases* **33**, 891-895.
- Orians, G. and Pearson, N. (1979). On the theory of central place foraging. In 'Analysis of Ecological Systems'. (Eds D. Horn, E. Stairs and R. Mitchell.) pp. 155-77. (Ohio State University Press: Columbus, Ohio, USA)

- Osterhaus, A., Rimmelzwaan, G., Martina, B., Bestebroer, T. and Fouchier, R. (2000). Influenza B virus in seals. *Science* **288**, 1051-1053
- Page, B., McKenzie, J., McIntosh, R., Baylis, A. M., Morrissey, A., Calvert, N., Haase, T., Berris, M., Dowie, D., Shaughnessy, P. D. and Goldsworthy, S. D. (2004). Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Marine Pollution Bulletin* **49**, 33-42.
- Reeves, R. R., Stewart, B. and Leatherwood, S. (1992). 'The Sierra Club Handbook of Seals and Sirenians.' (Sierra Club Books: San Francisco, California.)
- Riedman, M. (1990). 'The pinnipeds: seals, sea lions and walruses.' (University of California Press Ltd.: Berkely, California).
- Robertson, D., Roberts, P. and Wilson, J. (1978). Mesopelagic faunal transition across the Subtropical Convergence east of New Zealand. *New Zealand Journal of Marine and Freshwater Research* **12**, 295-312.
- Robinson, S., Goldsworthy, S., vandenHoff, J. and Hindell, M. (2002). The foraging ecology of two sympatric fur seal species, *Arctocephalus gazella* and *Arctocephalus tropicalis*, at Macquarie Island during the austral summer. *Marine and Freshwater Research* **53**, 1071-1082.
- Ryan, C., Hickling, G. and Wilson, K. (1997). Breeding habitat preferences of the New Zealand fur seal (*Arctocephalus forsteri*) on Banks Peninsula. *Wildlife Research* **24**, 225-235.
- Samuels, A., Bejder, L., Constantine, R. and Heinrich, S. (2003). Swimming with wild-cetaceans, with a special focus on the Southern hemisphere. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 277-303. (CSIRO: Collingwood, VIC, Australia)
- Scholin, C. A., Gulland, F., Doucette, G. J., Benson, S., Busman, M., Chavez, F. P., Cordaro, J., DeLong, R., Vogelaere, A. D., Harvey, J., Haulena, M., Lefebvre, K., Lipscomb, T., Loscutoff, S., Lowenstine, L. J., Marin III, R., Miller, P. E., McLellan, W. A., Moeller, P. D., Powell, C. L., Rowles, T., Silvagni, P., Silver, M., Spraker, T., Trainer, V. and Van Dolah, F. M. (2000). Mortality of sea lions along the central California coast linked to a toxic diatom bloom. *Nature* **403**, 80-84.
- Schulz, T. and Bowen, W. (2004). Pinniped lactation strategies: evaluation of data on maternal and offspring life history traits. *Marine Mammal Science* **20**, 86-114.
- Sease, J. and Gudmundson, C. (2002). Aerial and land-based surveys of Steller sea lions (*Eumatopias jubatus*) from the Western Stock in Alaska, June and July 2001 and 2002. Report to National Marine Fisheries Service. Alaska. NOAA Technical Memorandum, NMFS-AFSC-131.
- Shaughnessy, P. (1985). Interactions between fisheries and Cape fur seals in southern Africa. In 'Marine Mammals and Fisheries'. (Eds J. Beddington, R. Beverton and D. Lavigne.) pp. 119-134. (George Allen & Unwin Ltd.: London)
- Shaughnessy, P., Gales, N., Dennis, T. and Goldsworthy, S. (1994). Distribution and abundance of New Zealand fur seals, *Arctocephalus forsteri*, in South Australia and Western Australia. *Wildlife Research* **21**, 667-695.
- Sherrard, J. (1998). 'Kaikoura: a history of the district.' (Cadsonbury Publications: Christchurch.)
- Simmons, D. and Fairweather, J. (1998). Towards a Tourism Plan for Kaikoura. Lincoln University Report No. 10, Lincoln, New Zealand.

- Simmons, D., Horn, C. and Fairweather, J. (1998). Summertime visitors to Kaikoura: characteristics, attractions and activities. Lincoln University Report No. 3, Lincoln, New Zealand.
- Smith, A. W. and Skilling, D. E. (1979). Viruses and virus diseases of marine mammals. *Journal of the American Veterinary Medicine Association* **175**, 918-920.
- Smith, A. W., Vedros, N. A., Akers, T. G. and Gilmartin, W. G. (1978). Hazards of disease transfer from marine mammals to land mammals: review and recent findings. *Journal of the American Veterinary Medicine Association* **173**, 1131-1133.
- Stirling, I. (1970). Observations on the behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Journal of Mammalogy* **51**, 766-777.
- Stirling, I. (1971a). Studies on the behaviour of the South Australian fur seal, *Arctocephalus forsteri* (Lesson) II. adult females and pups. *Australian Journal of Zoology* **19**, 267-273.
- Stirling, I. (1971b). Studies on the behaviour of the South Australian fur seal, *Arctocephalus forsteri* (Lesson) I. Annual cycle, postures and calls, and adult males during the breeding season. *Australian Journal of Zoology* **19**, 243-266.
- Street, R. (1964). Feeding habits of the New Zealand fur seal (*Arctocephalus forsteri*). New Zealand Marine Department Fisheries Technical Report No. 9, Wellington, New Zealand. Pp. 20.
- Taylor, R., Barton, K., Wilson, P., Thomas, B. and Karl, B. (1995). Population status and breeding of New Zealand fur seals (*Arctocephalus forsteri*) in the Nelson-northern Marlborough region 1991-94. *New Zealand Journal of Marine and Freshwater Research* **29**, 223-234.
- Thompson, P. J., Cousins, D. V., Gow, B. L., Collins, D. M., Williamson, B. H. and Dagnia, H. T. (1993). Seals, seal trainers and Mycobacterial infection. *American Review of Respiratory Diseases* **147**, 164-167.
- Tierney, M., Hindell, M., Lea, M.-A. and Tollit, D. (2001). A comparison of techniques used to estimate body condition of southern elephant seals (*Mirounga leonina*). *Wildlife Research* **28**, 581-588.
- Trillmich, F. (1990). The behavioural ecology of maternal effort in fur seals and sea lions. *Behaviour* **114**, 4-19.
- Vedros, N. A., Smith, A. W., Schonewald, J., Migaki, G. and Hubbard, R. C. (1971). Leptospirosis epizootic among California sea lions. *Science* **172**, 1250-1251.
- Vercruyse, J., Salomez, A., Ulloa, A., Osterhaus, A., Kuiken, T. and Alvinerie, M. (2003). Efficacy of ivermectin and moxidectin against *Otostrongylus circumlitus* and *Parafilaroides gymnurus* in harbour seals (*Phoca vitulina*). *The Veterinary Record* **152**, 130-134.
- Ward, J. C. and Beanland, R. A. (1996). Biophysical impacts of tourism. Lincoln University Centre for Resource Management Lincoln Environmental Information Paper No. 56, Lincoln.
- Wickens, P. and York, A. E. (1997). Comparative population dynamics of fur seals. *Marine Mammal Science* **13**, 241-292.
- Wilkinson, I., Burgess, J. and Cawthorn, M. (2003). New Zealand sea lions and squid: managing fisheries impacts on a threatened marine mammal. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 192-207. (CSIRA: Collingwood, VIC, Australia)

- Wilson, G. (1981). Distribution and abundance of the New Zealand fur seal, *Arctocephalus forsteri*. Fisheries Research Division No. 20, Wellington, New Zealand.
- Woods, R., Cousins, D. V., Kirkwood, R. and Obendorf, D. L. (1995). Tuberculosis in a wild Australian fur seal (*Arctocephalus pusillus doriferus*) from Tasmania. *Journal of Wildlife Diseases* **31**, 83-86.
- Würsig, B., Würsig, M. and Cipriano, F. (1989). Dolphins in different worlds (social behaviour patterns). *Oceanus* **32**, 71-75.
- Wynen, L., Goldsworthy, S., Guinet, C., Bester, M., Boyd, I., Gjertz, I., Hofmeyr, G., White, R. and Slade, R. (2000). Postsealing genetic variation and population structure of two species of fur seal (*Arctocephalus gazella* and *A. tropicalis*). *Molecular Ecology* **9**, 299-314.
- Yodzis, P. (2001). Must top predators be culled for the sake of fisheries? *Trends in Ecology and Evolution* **16**, 78-83.

Chapter 2
Colony growth and pup condition on the
Kaikoura coastline; a comparison with other
East Coast colonies

Laura J. Boren, Chris G. Muller, and Neil J. Gemmell

Proposed journal for submission: *Journal of Zoology, London*

Chapter 2: Colony growth and pup condition on the Kaikoura coastline; a comparison with other East Coast colonies

Abstract

Since its near extermination due to sealing, the New Zealand fur seal, *Arctocephalus forsteri*, has been re-colonising areas of its former range throughout New Zealand. This study examined fur seal population growth over four breeding seasons spanning 2002-2005 at the Ohau Point (42°15'05"S/173°50'21"E) and Lynch's Reef (42°25'08"S/173°43'51"E) colonies in Kaikoura, and the Horseshoe Bay (43°52'55"S/172°49'30"E) and Te Oka Bay (43°50'50"S/172°46'42"E) colonies on Banks Peninsula. Estimates of pup numbers were made using mark-recapture techniques and condition indices were used to assess the body condition of pups in each colony. We found that the Ohau Point and Te Oka Bay colonies are growing exponentially (32% and 47% per annum respectively), reaching nearly 600 pups at Ohau Point, and 300 pups at Te Oka Bay, while Horseshoe Bay appears stable. Pups born at Ohau Point are consistently heavier and in better condition than their Banks Peninsula counterparts despite the faster rate of growth observed at Te Oka Bay. An El Niño event in 2003 coincided with a drop in mass and condition at the Banks Peninsula colonies but not at the Kaikoura colony. This discrepancy between colonies in response to environmental conditions suggests that colony-specific variables at Kaikoura may provide more favourable conditions for rearing pups than on Banks Peninsula.

Introduction

History of harvesting

Exploitation of pinnipeds for meat, oil, fur, and leather was common practice in the 1700s-1800s around the world (Reeves *et al.* 1992). Southern hemisphere fur seals in particular were subjected to severe hunting pressure with many species nearly driven to extinction (Lento *et al.* 1997; Wynen *et al.* 2000). The New Zealand fur seal, *Arctocephalus forsteri*, was no exception, with subsistence hunting of seals by early Polynesian arrivals to New Zealand (c. 1000 A.D.) followed by hunting for skins by Europeans beginning in 1792 (Lalas and Bradshaw 2001). Reports of sealskin takes for *A. forsteri* at NZ offshore islands exceeded 250,000 skins from Antipodes Island, 193,000 from Macquarie Island, 140,000 from Campbell and 50,000 from Bounty Island (Shaughnessy and Fletcher 1987; Richards 1994; Lalas and Bradshaw 2001). Such intense pressures lead to a collapse of seal numbers and the subsequent closing of the sealing industry in 1894. Eventually *A. forsteri* was fully protected under the Marine Mammals Protection Act of 1978 (Cawthorn *et al.* 1985; Mattlin 1987).

Re-colonisation history

Although some species of pinniped are still culled today (Cape fur seal, *Arctocephalus pusillus*: David and Wickens 2003; Harp seal, *Phoca groenlandica*: Ambrose 2004), many other species have received full protection. Of the protected species, the elephant seals and many of the fur seals have begun to make remarkable recoveries (Reeves *et al.* 1992). Like other fur seal species, since their protection (Wynen *et al.* 2000) *A. forsteri*, has successfully begun to re-colonise areas of their former range (Wilson 1981). Patterns of this re-colonisation have been studied extensively in New Zealand (Wilson 1981; Bradshaw 1999) and Australia (Shaughnessy *et al.* 1994); and New Zealand re-colonisation has occurred in a south to north direction (Lalas and Bradshaw 2001).

The first areas to be re-colonised and reach stable population sizes were offshore islands such as the Snares, which underwent rapid growth in the 1950's and 1960's (Carey 1998). Re-colonisation of Antipode's Island began in the 1950's, however, pups were not observed there until 1985 (Taylor 1992). Re-colonisation continued north to Stewart Island, Fiordland, and south-western areas of the South Island (Wilson 1981; Lalas and Bradshaw 2001). One of the first major breeding colonies re-established on the South Island was at Open Bay Islands on the West Coast, which

reached stable numbers in the mid-1970s (Lalas and Bradshaw 2001). In the late 1970's several colonies were present on the Otago coast and by the early 1980's a few pups were observed on Banks Peninsula (Wilson 1981). Since then population growth has continued and new South Island colonies began increasing in size at rates of 20-30% per annum, eventually advancing to Kaikoura and the Nelson/Marlborough region (Lalas and Harcourt 1995; Taylor *et al.* 1995; Lalas and Murphy 1998; Bradshaw *et al.* 2000a). A reliable estimate of the current total *A. forsteri* population within the New Zealand region is unknown, but a rough estimate of approximately 100,000 individuals has been suggested (Harcourt 2001). The Australian population is estimated to be around 40,000 (Gales *et al.* 2000; Goldsworthy *et al.* 2003), which puts the current population at about 10% of the pre-exploitation (c.1800) estimate of 1.5-2 million (summarised by Lalas and Bradshaw 2001).

In studying the pattern of *A. forsteri* re-colonisation, attempts have been made to determine what is suitable coastline and habitat for fur seals. Both breeding and non-breeding colonies of fur seals are typically found on exposed rocky coasts (Taylor *et al.* 1995; Ryan *et al.* 1997; Bradshaw *et al.* 1999), however, certain factors make some sites preferable for breeding colonies. In general, breeding sites are characterised by large rocks and crevices, which enable pups to hide. Other important factors have been identified such as cooling substrates (e.g. shade and rock pools - Carey 1989), the proximity to food sources, and degree of human disturbance (Bradshaw *et al.* 1999). Taylor *et al.* (1995) also suggested that non-breeding colonies subject to human disturbance are unlikely to become breeding colonies. More recently, modelling using artificial neural networks has further investigated the importance of factors such as prey distribution and abundance, local bathymetry, and coastal substrate in predicting the suitability of coastline for fur seal colonies (Bradshaw *et al.* 2002). The model's predictions overlapped with current distributions, and prey abundance was identified as a key factor in determining site suitability, along with distance to 250 m-, 500 m-, and 1000 m- isobaths. Modelling was also successful in predicting colony performance as indicated by pup condition (Bradshaw *et al.* 2002).

Condition of pups

Condition of individuals can be influenced by a number of environmental variables. In a study of 20 *A. forsteri* colonies around New Zealand, the average number of pups per 100m² in summer was found to explain a significant amount of variation in pup condition and showed a strong negative relationship with pup condition (Bradshaw *et al.* 2000b). The interaction of environmental conditions such as prey abundance and location to a food source and climatic patterns can also impact and even be used to predict pup condition at a colony (Bradshaw *et al.* 2000b; 2002). The behaviour of individuals, such as a female's ability to allocate time between foraging and nursing her pup onshore has also been shown to affect pup condition. Females that make shorter foraging trips and spend more time ashore tend to rear offspring that are in better body condition (Goldsworthy 1999; Haase 2004).

Body condition can be estimated in a number of ways using morphometric measures (Bradshaw *et al.* 2000b), as well as by estimating total body water (TBW) through Hydrogen Isotope Dilution Analysis, and bioelectrical impedance (Arnould *et al.* 1996a; Tierney *et al.* 2001). Although the later methods are more accurate, they are more invasive, expensive, and time consuming, which limits the sample size that can be collected (Tierney *et al.* 2001). However, the morphometric models can still be useful in the field, as they allow fast, simple assessment of the relative condition of a large sample size (Tierney *et al.* 2001). Arnould and Warneke (2002) did find that a body condition index calculated from the residuals of the mass-length relationship was positively correlated with sternal blubber depth in adult *A. pussilus doriferus*. However, when investigating body composition of *A. gazella* pups it was found that male pups directed more of their nutrient intake to lean tissue growth, while female pups developed greater adipose tissue stores, making interpreting mass and condition differences between male and female pups more difficult (Arnould *et al.* 1996b).

Re-colonisation in Kaikoura

Seal surveys along the Kaikoura coast began in the 1950s. Fur seals were first reported in significant numbers, but not breeding, following a survey by Gorman, who sighted a maximum of about 270 animals in 1958 (Street 1964). Gaskin then reported as many as 520 seals on the Kaikoura Peninsula in 1964 (Sorensen 1964). In 1970, work by Stirling reported a maximum of 800 individuals in winter and 200-300 in summer on the Kaikoura Peninsula. Investigation of the distribution and abundance of

A. forsteri around New Zealand provided a lower estimate of seals in the Canterbury-Kaikoura region (300-400), but was important as it confirmed that the Kaikoura colonies were still non-breeding at the time (Wilson 1981). By 1990 the first pups were born in the three current breeding colonies in the Kaikoura region (Kaikoura Peninsula, Barney's Rock and Ohau Point), and population numbers at these colonies have been steadily increasing (Report to DOC, Rob Suisted, Nov 2004).

As fur seal populations increase in distribution and number we can expect to see increasing levels of interaction between seals, their environments, and humans. Of utmost concern are the interactions between seals and fisheries, which include the consumption of target species, the destruction of fishing gear, and the incidental death of seals (Lalas and Bradshaw 2001). There are also more direct interactions between seals and people in the form of tourism activities, which have been increasing within New Zealand (Boren *et al.* 2002). The Kaikoura Peninsula seal colony is now rated as one of the top three tourist visited sites within New Zealand with over 1 million tourists per year (Experience Kaikoura, October 2003). Eco-tourism may affect a population in a number of ways from immediate behavioural changes to decreased body condition and site abandonment (Boren 2001). As interactions between humans and seals increase so does the chance of zoonotic transmission of disease (Lalas and Bradshaw 2001; Introduction). It is important, therefore, that we continue to monitor the re-colonisation of *A. forsteri* around New Zealand, as well as monitor the condition of pups at colonies deemed important for management purposes.

In this chapter we assess (1) the status and rate of growth of the Ohau Point seal colony, in comparison with selected Banks Peninsula colonies, and (2) the condition of pups in Kaikoura and at two colonies from Banks Peninsula over four breeding seasons from 2002-2005. The information gained on current pup production and condition in the region will provide a baseline with which to compare future data as the colonies become more established and reach higher densities. Basic information on the reproductive rates and pup condition can be used as indices of the overall status of each colony, providing a further means to measure the effectiveness of current fur seal population monitoring and sustainable eco-tourism management in a region.

Methods

Study sites

This study was carried out at four colonies on the east coast of the South Island of New Zealand. Two colonies; Ohau Point (OP) ($42^{\circ}15'S/173^{\circ}50'E$), and Lynch's Reef (LR) ($42^{\circ}25'S/173^{\circ}43'E$), are located on the Kaikoura Coast. Ohau Point is located on the mainland, 26 km north of the Kaikoura township, while Lynch's Reef is a small reef off the point of the Kaikoura Peninsula (Figure 1) approximately 5 km from the town centre. Both of these colonies are on exposed rocky coasts with a deep-sea canyon approximately 2 km offshore (Garner 1953; Benoit-Bird *et al.* 2004).

The other colonies; Horseshoe Bay (HSB) ($43^{\circ}52'S/172^{\circ}49'E$), and Te Oka Bay (TOB) ($43^{\circ}50'S/172^{\circ}46'E$), are two of the southern bays located on Banks Peninsula, south-east of Christchurch. These colonies are remote and access is across private farmland, and the colonies are isolated from the land by cliffs 30-100 m high. While the mouths of both bays are exposed to southerly winds, the colonies spread into the more sheltered long narrow bays (Figure 1). The edge of the continental shelf here is located about 100-150 km offshore (Goring and Henry 1998).

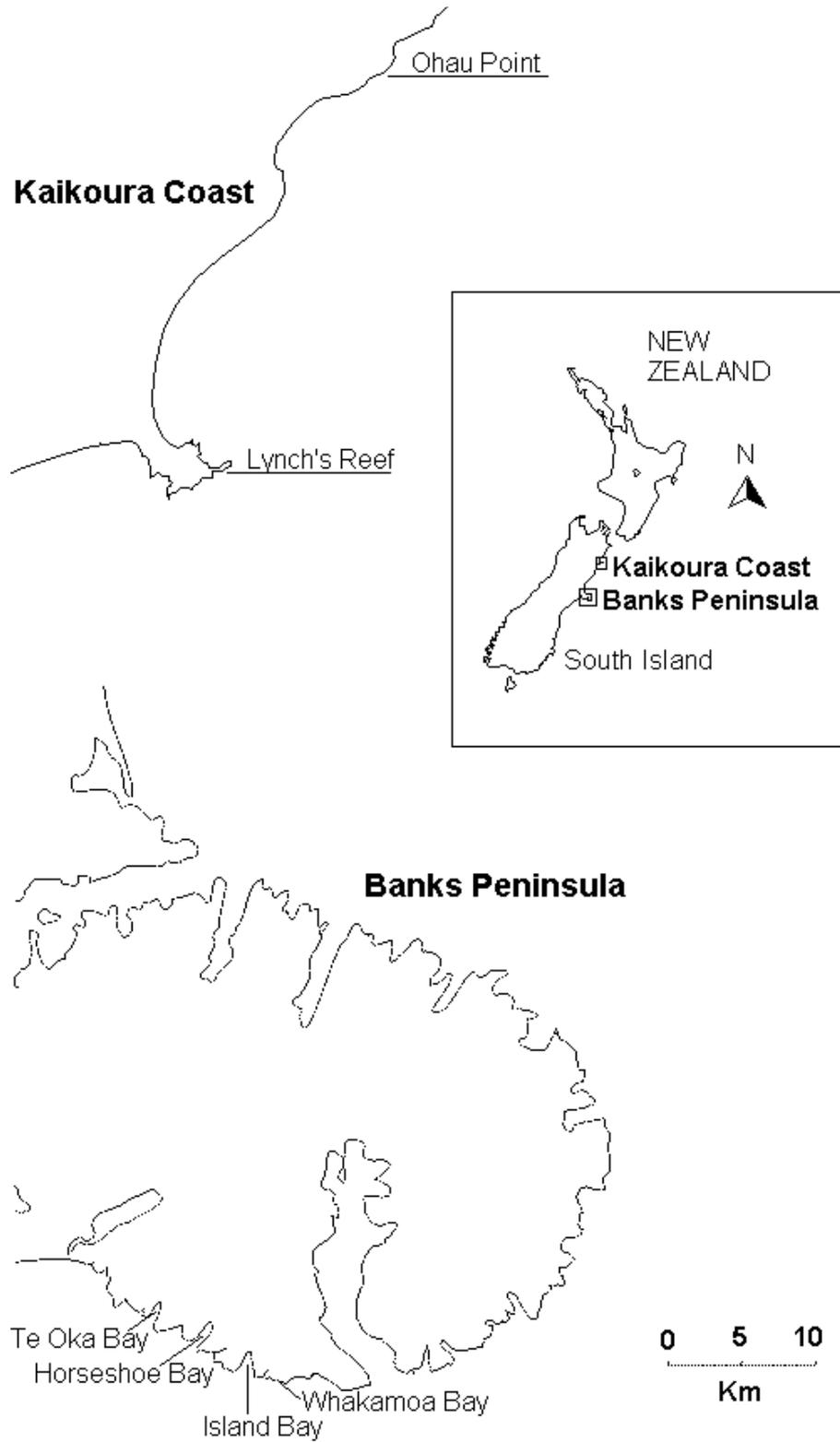


Figure 1: Locations of *A. forsteri* breeding colonies along the Kaikoura coastline and on the southern coastline of Banks Peninsula. Note: Both Banks Peninsula and Kaikoura Coast are on the same scale

Sample sizes and dates

Over the four years of this study, a total of 1212 pups (Table 1) were caught in late January to late February (31-Jan to 27-Feb) for the purposes of estimating pup production and comparing pup mass and condition between the four breeding colonies. A median pupping date of 16-Dec was calculated based on previous median pupping dates reported for New Zealand colonies (Miller 1971; L alas and Harcourt 1995; Barton pers. comm.; current study). This pupping date was used to approximate the age of pups at the time of weighing during this study. Ages ranged between 50 to 77 days old, with a mean and median age of 58 days and a mode of 51 days.

Table 1: Numbers of pups caught in each colony per year. Location abbreviations are: Ohau Point (OP), Lynch's Reef (LR), Horseshoe Bay (HSB), and Te Oka Bay (TOB).

Location	2002	2003	2004	2005
OP	68	112	145	155
LR	8	7		
HSB	71	121	100	101
TOB	50	64	93	117
Totals	197	304	338	373

Pup production estimates

Historical Peterson Estimates (Seber 1982) for pup production estimates at Kaikoura colonies (OP, and LR) were provided by Dr. Corey Bradshaw (1996-1998).

Peterson Estimates (Seber 1982) of pup production using mark-recapture techniques were carried out at Ohau Point and Te Oka Bay in late-January to early-February 2002-2005. These methods allow for an accurate assessment of pup production at boulder beach colonies where pups often hide out of view. Pup counts were also carried out in early February for Lynch's Reef in 2002, and 2003, and at Horseshoe Bay in 2002, 2003, and 2005. The protocol for the mark-recapture experiments involved marking a subset of pups and comparing the number of marked versus unmarked pups sighted on a walk through the colonies on the following day as described by Shaughnessy *et al.* (1994), Bradshaw *et al.* (2000a), and Boren (2001). Walk-throughs were carried out by multiple observers so a range of 2-6 counts were obtained per colony. Walk-throughs involved active searching for pups and took 3-6 hours to complete. Frequent observations at Ohau Point and the very accessible nature of the colony allowed for all areas of the colony to be included in the mark-recapture each year and physical expansion of the colony to be monitored. Trips were only made to the Banks Peninsula colonies once a year and portions of the bays were

difficult to access therefore, expansion of the colony could not be followed as closely it was at Ohau Point. The areas included in the mark-recapture for the Banks Peninsula colonies were potentially underestimated in the 2002 season when the colonies were searched for the first time. In the following seasons when additional pupping areas were discovered, boundaries were set to include what was believed to be as much of the colony as was accessible to researchers, and was the largest continuous area in which pups were observed.

Rate of colony growth for each colony was calculated by regressing the natural log of the Peterson Estimate data against the year. The resultant slope (b) is the exponential rate of population increase (Lalas and Murphy 1998). The average arithmetic rate of increase (r) was calculated using the following equation (Bradshaw *et al.* 2000a):

$$r = 2.71^{b-1}$$

Gender, Morphology, and Condition

During the course of the mark-recapture experiments pups were sexed, weighed, and basic morphometric data (dorsal straight length (DSL) and axillary girth (AG)) were recorded (Bradshaw *et al.* 2000b; Boren 2001).

Sex ratios were compared between colonies and years using Chi-squared tests of independence (Goldsworthy and Shaughnessy 1994).

Two different condition indices were calculated to allow comparison between the methods and more in depth comparison between the colonies. Condition index 1, was the simple calculation of mass (M) divided by DSL (M/DSL), (Pitcher 1986), while condition index 2, was calculated by comparing the observed weight over the expected (Obs M/Exp M), (Bradshaw *et al.* 1999; Boren 2001). Expected weight (M_p) was calculated using the slope (a) and y -intercept (b) derived from the regression between \log_e Mass (kg) and \log_e Length (cm) for all pups as follows:

$$\log_e M_p = a + b * \log_e$$

Morphological characteristics, including mass, dorsal straight length, axillary girth, condition index 1 (M/DSL) and condition index 2 (Obs/Exp), were tested for differences between colony, year, and sex through a General Linear Model (GLM)

using age at time of weighing as a covariate in order to account for sampling on different dates (STATISTICA v.7).

Results

Colony growth and estimates of pup production

Kaikoura Coastline

Pups were first sighted at Kaikoura colonies by the Department of Conservation in 1990 (Figure 2). Progressively more pups were born at Ohau Point until estimates reached almost 50 in 1996 and exceeded 100 in 1998. The colony has continued to expand and reached nearly 600 pups in 2005. Pup production at Lynch's Reef is restricted because of the small area where the colony breeds. As a result the number of pups born has consistently ranged between 8 and 12.

Banks Peninsula

Horseshoe Bay was reported as a breeding colony in the late 1970's (Wilson 1981). Pup production during the present study at Horseshoe Bay was fairly stable in the late 1990's at around 200 pups. There was an apparent drop in February pup numbers in 2002 but was likely to be an underestimate. Due to poor weather conditions, the estimate for 2004 was not able to be completed. The colony began to increase above 200 pups and neared 300 in 2005.

The first report to the Department of Conservation of pupping at Te Oka Bay was in the late 1990's with 3 pups observed in 1997, and approximately 42 pups born in 2001 (C. Challies, pers. comm.). Since 2002 the colony has increased from fewer than 100 to nearly 300 pups born in a season.

General colony growth

There was no significant change in pup numbers over time in Lynch's Reef, and Horseshoe Bay ($r^2 = 0.219$, $p = 0.427$ and $r^2 = 0.001$, $p = 0.945$, respectively), however, Te Oka Bay and Ohau Point both showed significant relationships (Table 2). Ohau Point showed an exponential rate of increase of 32% per annum over 16 years ($r^2 = 0.898$, $p < 0.0001$), with Te Oka Bay increasing at a rate of 47% per annum over five years ($r^2 = 0.910$, $p = 0.046$).

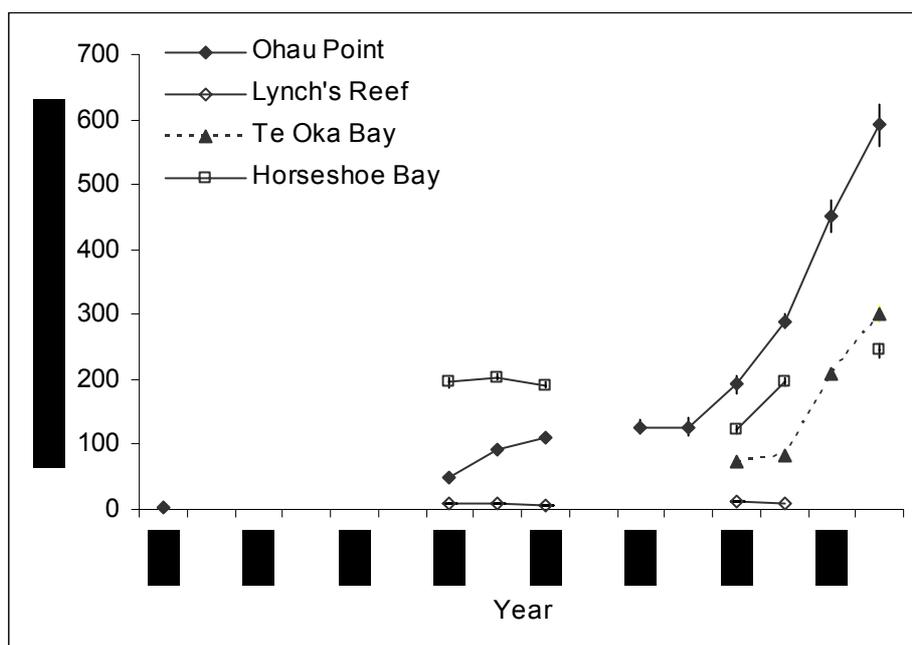


Figure 2: Estimated number of pups in early February at *A. forsteri* colonies between 1990-2005. Historical data sourced from: Kaikoura colonies 1990-1995, from Mike Morrissey, Kaikoura Dept. of Conservation; Kaikoura colonies and HSB 1996-1998, from Dr. Corey Bradshaw; and Ohau Point 2000-2001, from Boren 2001. The line for Horseshoe Bay is not continuous as there is a data point missing for 2004.

Table 2: Annual rate of increase expressed as the arithmetic mean rate of population increase (r) and, exponential rate of population increase (b) calculated for Ohau Point and Te Oka Bay. Ohau Point was broken into two time periods to show the change in rate of increase during early vs. late phases of colony expansion.

	r	b
Ohau 1990-2005	37.4%	31.8%
Te Oka Bay 2002-2005	59.6%	46.9%

Sex ratios

The sex ratio of pups caught at each colony tended towards a 1:1 ratio (Table 3). Chi-squared tests of independence were used to test for deviations from an expected 1:1 ratio within a colony between years and within a year between colonies. The only significant result was in 2005 between colonies ($\chi^2 = 6.2$, $df = 2$, $0.05 < p < 0.025$) where Te Oka Bay was very strongly skewed towards more females, while Ohau Point was skewed towards males, and Horseshoe Bay was weakly skewed towards males.

Table 3: The number of male and female pups sampled in February at each location over four consecutive years, and the proportion of male pups to one female pup. Colonies are abbreviated (OP) Ohau Point, (HSB) Horseshoe Bay, and (TOB) Te Oka Bay. The only significant departure from expected is in 2005 at Ohau Point and Te Oka Bay and are shown in bold type.

	OP		HSB		TOB		Proportion of males to each female		
	m	f	m	f	m	f	OP	HSB	TOB
2002	37	31	31	40	24	26	1.2	0.8	0.9
2003	58	54	55	66	32	32	1.1	0.8	1.0
2004	79	66	49	51	48	45	1.2	1.0	1.1
2005	87	68	55	46	49	68	1.3	1.2	0.7

Morphological Characteristics

Mass

Male pups were consistently heavier than female pups ($F_{1,1188} = 128.02$, $p < 0.0001$, Table 4) at all colonies (Figure 3a). Significant differences between colonies in pup mass were apparent ($F_{1,1188} = 67.48$, $p < 0.0001$, Table 4) with Ohau pups being heavier than Banks Peninsula pups in all years except 2002 (Figure 3a). There were also significant interactions observed between two variables: years and colonies ($F_{5,1188} = 6.87$, $p < 0.0001$, Table 4). Although pups at all colonies were a similar mass in 2002, the masses recorded for the Banks Peninsula colonies were much lower in 2003 (mean: 7.5 kg). Ohau Point pups remained at a similar mass in 2003, but were noticeably heavier in 2004 and 2005.

Dorsal Straight Length

Trends in pup length followed much the same pattern as for mass with male pups being significantly longer than female pups ($F_{1,1188} = 124.75$, $p < 0.0001$, Figure 3b, Table 4). However, the differences between colonies were not as significant as those observed with mass ($F_{1,1188} = 40.12$, $p < 0.0001$). Differences in mean pup length between years were significant for all colonies with most pups being longer in 2004 (74.6 cm vs. 71.1-71.8 cm, $F_{2,1188} = 47.91$, $p < 0.0001$). No interaction was observed between variables: year and colony ($F_{5,1188} = 2.04$, $p < 0.0711$).

Condition Index 1: M/DSL

This condition index indicated males were typically in better condition than females (0.10-0.13 vs. 0.09-0.12 kg/cm, Figure 4a). This was again significantly different for all colonies and years ($F_{1,1188} = 93.65$, $p < 0.0001$, Table 4). Ohau Point pups were on average in better condition (never dropping below 0.115 kg/cm) than pups at any of the other colonies, although Horseshoe Bay and Te Oka Bay male pups showed a high condition index in 2002 (0.13 kg/cm). The differences in condition index among colonies were significant for all years except 2002 ($F_{1,1188} = 63.69$, $p < 0.0001$). Differences in pup condition between years were significant ($F_{2,1188} = 20.15$, $p < 0.0001$) with all pups in 2002 and 2004 typically being in better condition (0.121 and 0.113 kg/cm) than in 2003 and 2005 (0.109, 0.111 kg/cm). This condition index also showed significant interactions between years and colonies ($F_{5,1188} = 9.84$, $p < 0.0001$) with Ohau Point seals in significantly better condition in 2004 than Banks Peninsula pups.

Condition Index 2: Observed / Expected Mass

This condition index showed no difference between the sexes ($F_{1,1188} = 0.069$, $p = 0.793$, Table 4). Ohau Point pups were on average in better condition normally being heavier than expected (Observed Mass/Expected Mass > 1.0) while Banks Peninsula pups were consistently at below expected mass for 2003-2005 (Obs/Exp < 1.0 , Figure 4b). The differences in condition index among colonies were significant for all years except 2002 ($F_{1,1188} = 28.97$, $p < 0.0001$). Differences in pup condition between years were significant ($F_{2,1188} = 82.55$, $p < 0.0001$) with all pups being in poorer condition in 2003. This condition index also showed significant interactions between years and colonies ($F_{5,1188} = 12.20$, $p < 0.0001$) again with Ohau Point pups in significantly better condition in the later years than Banks Peninsula pups.

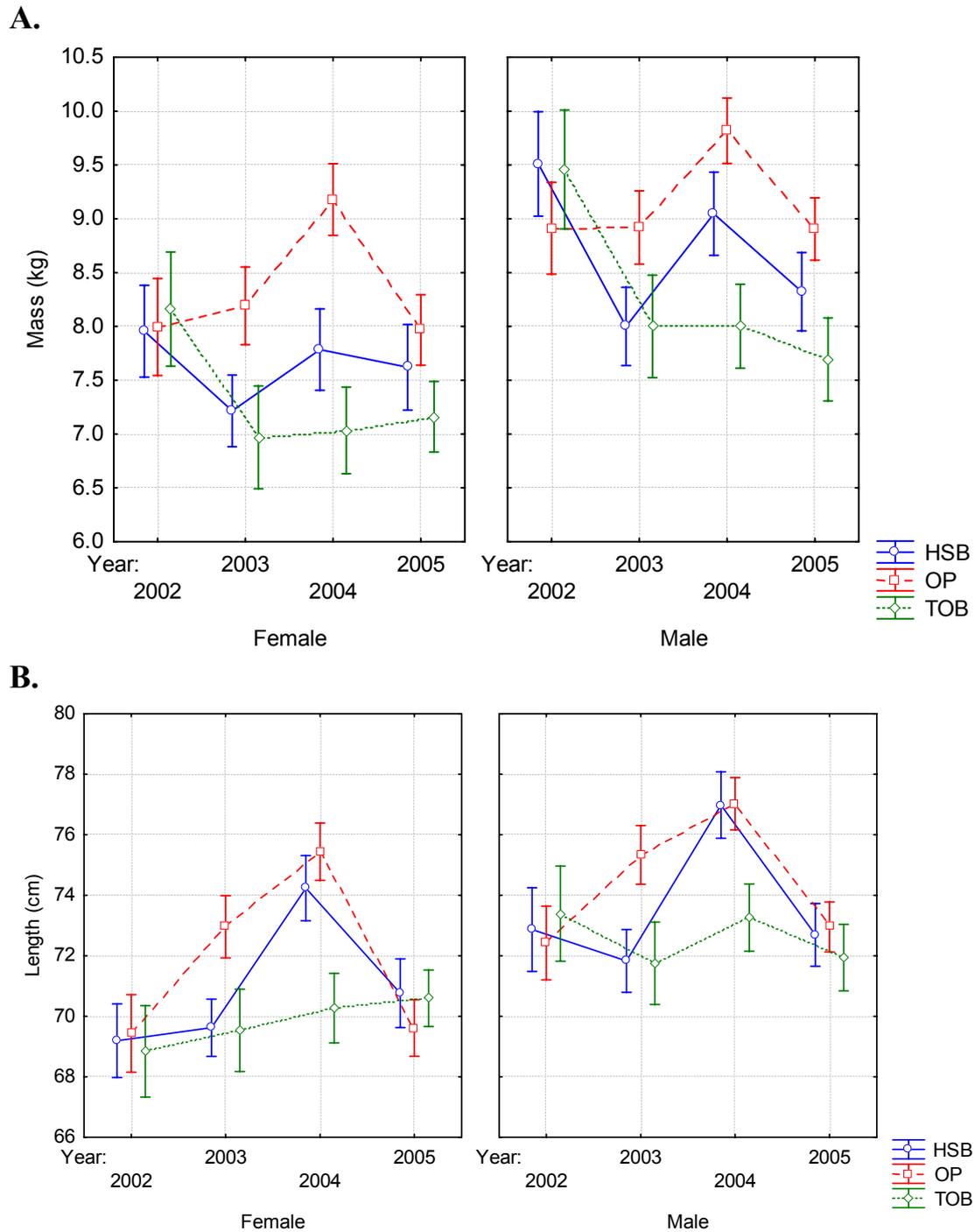


Figure 3: Mean observed A) Mass (kg) and, B) Length (cm), for 612 male (m) and 600 female (f) *A. forsteri* pups in February (approximately 58 days old) at each of the four colonies from 2002-2005. Error bars represent 95% confidence intervals. Note that the y-axes do not start at 0.

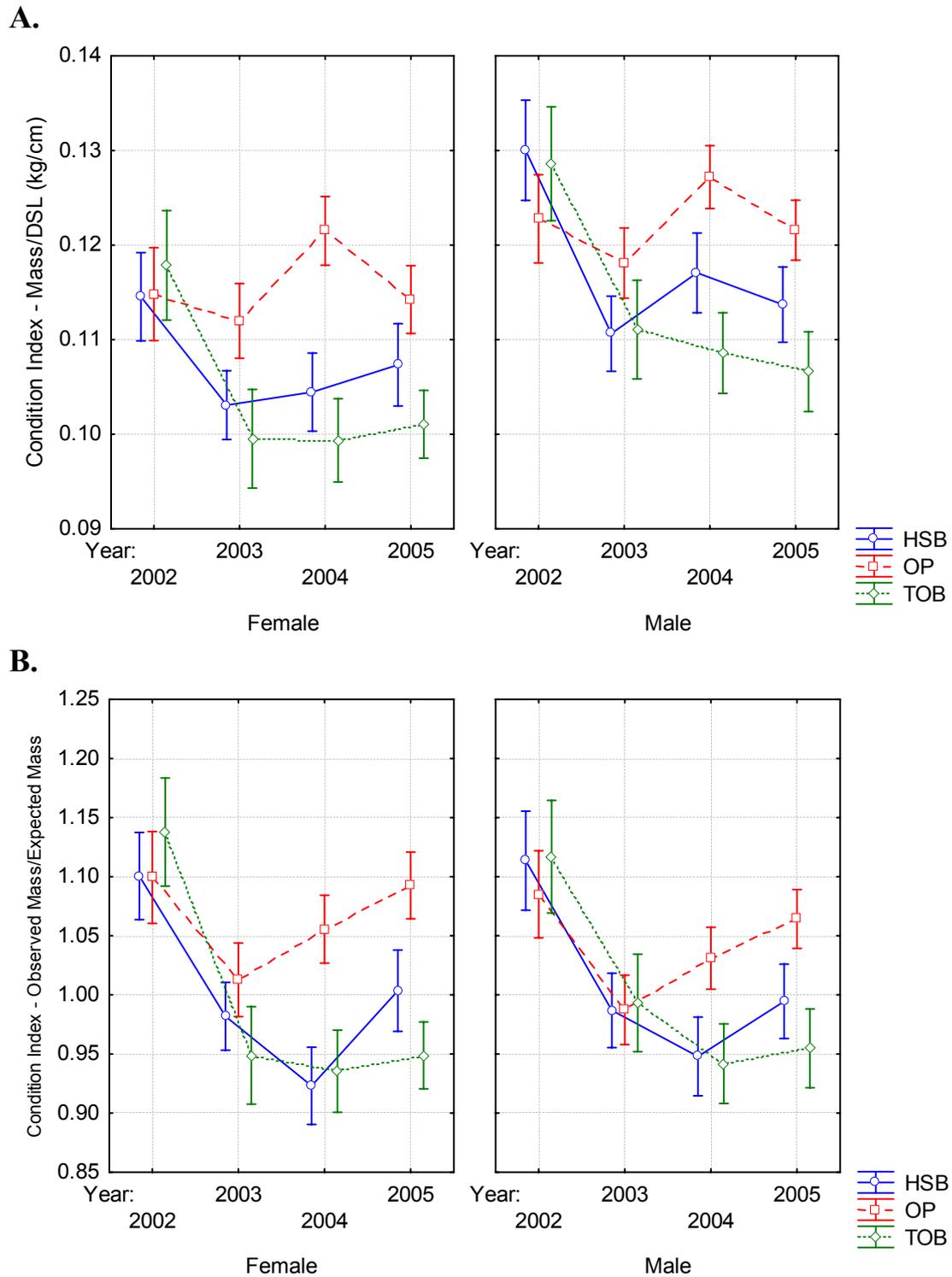


Figure 4: Mean observed A) Condition index 1: M/DSL and, B) Condition index 2: Observed/Expected Mass, for 612 male and 600 female *A. forsteri* pups in February (approximately 58 days old) at each of the four colonies from 2002-2005. Error bars represent 95% confidence intervals. Note that the y-axes do not start at 0.

Table 4: GLM results comparing morphological characteristics and condition indices between years (Y), colonies (C), and sex (S), for 1212 *A. forsteri* pups. Age at time of weighing based on a median pupping date for New Zealand colonies of 16-Dec was included as a covariate. Results of the potential interactions between variables are shown as well. The F- statistic and p- value are provided for all tests carried out, and significant p-values are in bold. The colonies included in the tests were, Ohau Point, Horseshoe Bay and Te Oka Bay.

All Years, 3 Colonies			
		F	P
<u>Mass</u>	Y	1.47	0.228
	C	67.48	< 0.0001
	S	128.02	< 0.0001
	YC	6.87	< 0.0001
	YS	1.62	0.184
	CS	1.00	0.367
	YCS	0.94	0.463
<u>Length</u>	Y	47.95	< 0.0001
	C	40.12	< 0.0001
	S	124.75	< 0.0001
	YC	2.04	0.0711
	YS	1.82	0.143
	CS	0.06	0.942
	YCS	1.35	0.234
<u>Girth</u>	Y	20.83	< 0.0001
	C	34.63	< 0.0001
	S	77.23	< 0.0001
	YC	7.62	< 0.0001
	YS	1.16	0.323
	CS	1.86	0.157
	YCS	1.47	0.186
<u>M/DSL</u>	Y	20.15	< 0.0001
	C	63.39	< 0.0001
	S	93.65	< 0.0001
	YC	9.84	< 0.0001
	YS	1.20	0.307
	CS	1.66	0.190
	YCS	0.75	0.606
<u>Obs/Exp</u>	Y	82.55	< 0.0001
	C	28.97	< 0.0001
	S	0.069	0.793
	YC	12.20	< 0.0001
	YS	0.38	0.768
	CS	2.43	0.089
	YCS	0.47	0.830

Discussion

Colony growth and estimates of pup production

The pup production at Ohau Point and Te Oka Bay *A. forsteri* colonies is increasing rapidly, at a rate of 32% and 47% per annum, respectively, while pup production at Lynch's Reef and Horseshoe Bay colonies appears to be fairly static. The rates of increase in pup production observed for Ohau Point and Te Oka Bay are high in comparison to those reported elsewhere for *A. forsteri*, which are typically in the range between 20-30% per annum (Taylor *et al.* 1995; Lalas and Murphy 1998). In both cases a significant amount of the increase could be related to immigration of adult seals from nearby colonies. This is not surprising given the number of animals tagged at colonies along the West Coast of New Zealand that have been observed breeding at Ohau Point (a minimum of five adult females, most of which were from Cape Foulwind). Also, the unusual high rate of increase observed at Te Oka Bay is likely to be a consequence of the recent establishment of this colony, and the fact that I sampled in the expansion phase.

In 1993, Horseshoe Bay was the only breeding colony known on the southern coastline of Banks Peninsula (Ryan *et al.* 1997). Its lack of significant increase over recent years suggests that the population might have reached carrying capacity (Carey 1998). Female *A. forsteri* display a strong natal philopatry, which impacts on re-colonisation, and Bradshaw *et al.* (2000a) have shown that as established breeding colonies on the Otago Peninsula reached higher densities, new breeders would initiate breeding colonies close to the established colonies. In the last decade, at least three new breeding colonies have been established in the southern bays of Banks Peninsula: Island Bay (43°53'S/172°51'E) and Whakamoia Bay (43°53'S/172°52'E) to the SE of Horseshoe Bay (Boren 2001) and Te Oka Bay to the NW (C. Challies, pers. comm.; Figure 1). It is highly likely therefore, that Horseshoe Bay has supplied the "spill over" to establish new colonies.

Given that fur seal re-colonisation has progressed northwards (Wilson 1981; Lalas and Bradshaw 2001), Ohau Point has only recently been established. The first pups at this colony were sighted in 1990 and the pup production remained below 50 pups until 1997 (Figure 2). The Ohau Point colony features many of the key criteria for a suitable breeding colony; exposed coast, large boulders creating shade and crevices

for pups to hide, and several sheltered rock pools for female thermoregulation and young pups learning to swim (Carey 1989; Ryan *et al.* 1997; Bradshaw *et al.* 1999). Given these ideal conditions, it is unsurprising that this colony exhibits such a rapid increase in pup production. However, it is not surprising that this dramatic increase has continued alongside a rapid increase in human activity in the region based on suggestions that breeding colonies are less likely to establish in areas of high human activity (Taylor *et al.* 1995; Bradshaw *et al.* 1999).

Morphological Characteristics

My results show that male pups were consistently heavier, longer, and for one of the two condition indices (M/DSL) in better relative condition than female pups. This is not surprising given the pronounced sexual dimorphism exhibited in this species with adult males weighing over three times more than an adult female (Reeves *et al.* 1992; Troy *et al.* 1999; Harcourt 2001). However, the study of differential maternal investment in male versus female pups has been the subject of considerable debate for some time (Lunn *et al.* 1993; Chilvers *et al.* 1995; Lunn and Arnould 1997; Guinet *et al.* 1999). It has been suggested and shown in some instances that in order for males to attain their larger sizes they would be typically larger at or near birth (Crawley 1975; Lunn *et al.* 1993; Lea and Hindell 1997; Harcourt 2001); mothers would invest more reserves into rearing male pups (Mattlin 1981; Goldsworthy 1992); and more time, weaning males later than females (Lunn *et al.* 1993; Haase 2004). In the re-evaluation of *A. gazella* data collected over 5 years, Lunn and Arnould (1997) concluded that there were very few differences in maternal investment between the sexes and little cost to females in rearing a son versus a daughter.

While our data does show that males are typically heavier than females, this difference may be related to sex differences in how males versus females utilise nutrients. In a study investigating milk consumption and body condition of 177 *A. gazella* pups, it was found that both sexes consumed the same amount of milk, however, at any given time males were heavier than females (Arnould *et al.* 1996b). This finding was related to body composition, in that female pups had more lipid reserves, while male pups had more lean muscle tissue, accounting for the differences in mass, suggesting that mass alone is not a good indicator of differential maternal investment in the sexes (Arnould *et al.* 1996b). Our data on pup condition used an

index that compared observed to expected weights. This metric showed no difference between the sexes suggesting minimal differential investment between the sexes, this was also the case for a study of pup condition at 20 colonies around New Zealand where significant differences were found between year, season and colony, but not sex (Bradshaw *et al.* 2000b).

A pup's relative body condition is related to its mother's foraging efficiency and as a result may be indirectly influenced by the same parameters that affect her foraging; age, experience, climatic patterns, prey abundance and distribution, and distance to and between foraging locations (Lunn *et al.* 1994). While the relationships between pup condition and some maternal parameters are not always clear, they tend to be accentuated in seasons of low prey abundance, as seen with *A. gazella* in 1990, when pup growth was negatively correlated with mothers' foraging trip duration (Lunn *et al.* 1993). Similarly, reduced pup production, growth and condition have been observed for many species during El Niño years (Trillmich *et al.* 1991) due to the associated environmental and biological changes such as increased sea surface temperatures, decreased upwelling, and decreased food supply (Arntz *et al.* 1991). Bradshaw *et al.* (2000b) observed a decrease in pup condition in *A. forsteri* colonies during the 1998 El Niño event and also found that pup condition varied geographically, and was indicative of proximity of food source. As in the current study they found that pups on the Otago and Kaikoura Peninsulas, where local bathymetry meant closer proximity to a reliable food source, were in better condition than pups on the Banks Peninsula and the West Coast of the South Island (Bradshaw *et al.* 2000b).

Environmental parameters influence maternal investment and subsequently affect pup condition. Consequently, the success of a colony reflected in pup production and condition can potentially be used to indicate food availability and habitat suitability (Bester and Van Jaarsveld 1997; Bradshaw *et al.* 2000b; Bradshaw *et al.* 2002). This study included two El Niño events, the first in 2003 and another in 2005 (NIWA 2005; Chapter 5) and while there was a coincidental decrease in pup condition at all colonies during the 2003 event, the relative drop in pup condition differed significantly between the Kaikoura and Banks Peninsula colonies. There was a dramatic drop in mass and condition among pups at Banks Peninsula colonies, which

was not observed in Ohau Point pups or Lynch's Reef males. In 2004, when the Southern Oscillation Index was near neutral, Ohau Point pups were in significantly better condition and at a much higher mass than their Banks Peninsula counterparts. The two regions differ in that the Kaikoura colonies are close to a deep-sea canyon that may provide a more consistent pelagic food source within 2 km offshore, while for the Banks Peninsula colonies, the 500 m- and 1000 m- isobaths are 100-150 and 150+ km offshore, respectively (Goring and Henry 1998; Introduction Figure 2). This difference may be enough to limit the effects of a mild El Niño along the Kaikoura coast but not for Banks Peninsula (Boren 2001). The adult females of Horseshoe Bay appeared to recover more easily from the period of low food availability than Te Oka Bay females, suggesting a higher proportion of older more experienced foragers at the more established colony (Lunn *et al.* 1994).

Conclusions

In this chapter I have shown that the Horseshoe Bay seal colony, which began breeding in the 1970's has most likely stabilised and is sourcing new breeding colonies, including Te Oka Bay, by a "spill-over" effect (Bradshaw *et al.* 2000b). The Kaikoura breeding colonies are only recently re-established (1990) and among them, Ohau Point, having good habitat, plenty of space available for seals and close access to prey species, has been increasing exponentially.

Sexual differences were detected in mass, length, girth and one condition index within all colonies and years, however, these differences are unable to account for differential nutrient utilisation between the sexes and individual body size. The condition index comparing observed over expected mass, which accounts for individual body size, and is highly correlated with sternal blubber depth did not show any differences between the sexes (Bradshaw *et al.* 2000b; Arnould and Warneke 2002). Use of morphological data allowed the analysis of individual body condition on a large sample size of pups at difficult to access colonies. The most interesting differences evident were those of pup weight and condition between the colonies, and the differences in how colonies responded to years with differing environmental variables. While all pups were in similar condition in 2002, a sustained El Niño event in 2003 coincided with a significant decrease in pup mass and condition at Banks Peninsula colonies, and almost no effect on the Kaikoura colonies. In the following

season of neutral conditions (2004), Ohau Point pups were at high masses and in good condition compared with the Banks Peninsula pups. This suggests that colony-specific differences, for instance an oceanic trench and associated upwelling in Kaikoura, may act as a buffer to El Niño events and the associated environmental and biological changes, and outweigh any potential impacts of human influence in the region including eco-tourism. While the Kaikoura coastline may provide more favourable conditions to rear pups, the increasing seal population in parallel with the increasing human population may cause some concern in the future. Therefore, future monitoring of this colony as it nears its population limit is essential. The following chapters will assess in more detail what makes Kaikoura unique in terms of colony dynamics during the breeding season (Chapter 3), maternal investment strategies (Chapter 4) and how these differences may affect other parameters of pup health (Chapters 5, 6 and 7).

References:

- Ambrose, P. (2004). Canadian harp seal hunt. *Marine Pollution Bulletin* **48**, 1014.
- Arnould, J. and Warneke, R. (2002). Growth and condition in Australian fur seals (*Arctocephalus pusillus doriferus*) (Carnivora : Pinnipedia). *Australian Journal of Zoology* **50**, 53-66.
- Arnould, J., Boyd, I. and Speakman, J. (1996a). Measuring the body composition of Antarctic fur seals (*Arctocephalus gazella*): validation of hydrogen isotope dilution. *Physiological Zoology* **69**, 93-116.
- Arnould, J., Boyd, I. and Socha, D. (1996b). Milk consumption and growth efficiency in Antarctic fur seal (*Arctocephalus gazella*) pups. *Canadian Journal of Zoology* **74**, 254-266.
- Arntz, W., Pearcy, W. and Trillmich, F. (1991). Biological consequences of the 1982-83 El Niño in the Eastern Pacific. In 'Pinnipeds and El Niño, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 22-44. (Springer-Verlag: London)
- Benoit-Bird, K., Würsig, B. and McFadden, C. (2004). Dusky dolphin (*Lagenorhynchus obscurus*) foraging in two different habitats: active acoustic detection of dolphins and their prey. *Marine Mammal Science* **20**, 215-231.
- Bester, M. and VanJaarsveld, A. (1997). Growth in the subantarctic fur seal *Arctocephalus tropicalis* pups as a possible indicator of offshore food availability. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds M. Hindell and C. Kemper.) pp. 88-91. (Surrey Beatty & Sons, Chipping Norton: Australia)
- Boren, L. J. (2001). Assessing the impact of tourism on New Zealand fur seals (*Arctocephalus forsteri*). MSc. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Boren, L. J., Gemmill, N. J. and Barton, K. J. (2002). Tourist disturbance on New Zealand fur seals, *Arctocephalus forsteri*. *Australian Mammalogy* **24**, 85-96.

- Bradshaw, C. J. (1999). Population dynamics and colonisation modelling of New Zealand fur seals. Unpublished PhD Thesis. Department of Zoology, University of Otago, Dunedin, New Zealand.
- Bradshaw, C. J., Thompson, C. M., Davis, L. S. and Lalas, C. (1999). Pup density related to terrestrial habitat use by New Zealand fur seals. *Canadian Journal of Zoology* **77**, 1579-1586.
- Bradshaw, C. J., Lalas, C. and Thompson, C. M. (2000a). Clustering of colonies in an expanding population of New Zealand fur seals (*Arctocephalus forsteri*). *Journal of Zoology, London* **250**, 105-112.
- Bradshaw, C. J., Davis, L. S., Lalas, C. and Harcourt, R. G. (2000b). Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. *Journal of Zoology, London* **252**, 41-51.
- Bradshaw, C. J., Davis, L., Purvis, M., Zhou, Q. and Benwell, G. (2002). Using artificial neural networks to model the suitability of coastline for breeding by New Zealand fur seals (*Arctocephalus forsteri*). *Ecological Modelling* **148**, 111-131.
- Carey, P. W. (1989). Behavioural thermoregulation and polygyny in the New Zealand fur seal. Unpublished PhD Thesis. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Carey, P. W. (1998). New Zealand fur seals (*Arctocephalus forsteri*) at the Snares Islands: a stabilised population? *New Zealand Journal of Marine and Freshwater Research* **32**, 113-118.
- Cawthorn, M., Crawley, M. C., Mattlin, R. and Wilson, G. J. (1985). Research on Pinnipeds in New Zealand. Report to Wildlife Research Liason Group. Wellington. Wildlife Research Research Review 7.
- Chilvers, B., Wilson, K. and Hickling, G. (1995). Suckling behaviours and growth rates of New Zealand fur seal, *Arctocephalus forsteri*, at Cape Foulwind, New Zealand. *New Zealand Journal of Zoology* **22**, 263-270.
- Crawley, M. (1975). Growth of New Zealand fur seal pups. *New Zealand Journal of Marine and Freshwater Research* **9**, 539-545.
- David, J. and Wickens, P. (2003). Management of Cape fur seals and fisheries in South Africa. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 116-135. (CSIRO: Collingwood, VIC, Australia)
- Gales, N., Haberley, B. and Collins, P. (2000). Changes in the abundance of New Zealand fur seals, *Arctocephalus forsteri*, in Western Australia. *Wildlife Research* **27**, 165-168.
- Garner, D. (1953). Physical characteristics of inshore surface waters between Cook Strait and Banks Peninsula, New Zealand. *New Zealand Journal of Science and Technology* **35**, 239-246.
- Goldsworthy, S. and Shaughnessy, P. (1994). Breeding biology and haul-out pattern of the New Zealand fur seal, *Arctocephalus forsteri*, at Cape Gantheaume, South Australia. *Wildlife Research* **21**, 365-376.
- Goldsworthy, S. D. (1992). Maternal care in three species of fur seal, *Arctocephalus* spp. at Macquarie Island. Unpublished PhD Thesis. Monash University, Melbourne, Australia.
- Goldsworthy, S. (1999). Maternal Attendance behaviour of sympatrically breeding Antarctic and Subantarctic fur seals, *Arctocephalus* spp., at Macquarie Island. *Polar Biology* **21**, 316-325.
- Goldsworthy, S. D., Bulman, C., He, X., Larcome, J. and Littnan, C. (2003). Trophic interactions between marine mammals and Australian fisheries: an ecosystem

- approach. In 'Marine Mammals: fisheries, tourism and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 62-99. (CSIRO: Collingwood, VIC, Australia)
- Goring, D. G. and Henry, R. F. (1998). Short period (1-4 h) sea level fluctuations on the Canterbury coast, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **32**, 119-134.
- Guinet, C., Goldsworthy, S. and Robinson, S. (1999). Sex differences in mass loss rate and growth efficiency in Antarctic fur seal (*Arctocephalus gazella*) pups at Macquarie Island. *Behavioural Ecology and Sociobiology* **46**, 157-163.
- Haase, T. (2004). The determinants of weaning in the New Zealand fur seal. Unpublished PhD Thesis. Department of Zoology, School of Life Sciences, La Trobe University, Victoria, Australia.
- Harcourt, R. (2001). Advances in New Zealand mammalogy 1990-2000: Pinnipeds. *Journal of the Royal Society of New Zealand* **31**, 135-160.
- Lalas, C. and Bradshaw, C. J. (2001). Folklore and chimerical numbers: review of a millennium of interaction between fur seals and humans in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research* **35**, 477-497.
- Lalas, C. and Harcourt, R. G. (1995). Pup production of the New Zealand fur seal on Otago Peninsula, New Zealand. *Journal of the Royal Society of New Zealand* **25**, 81-88.
- Lalas, C. and Murphy, B. (1998). Increase in the abundance of New Zealand fur seals at the Catlins, South Island, New Zealand. *Journal of the Royal Society of New Zealand* **28**, 287-294.
- Lea, M.-A. and Hindell, M. (1997). Pup growth and maternal care in New Zealand fur seals, *Arctocephalus forsteri*, at Maatsuyker Island, Tasmania. *Wildlife Research* **24**, 307-318.
- Lento, G., Haddon, M., Chambers, G. and Baker, C. (1997). Genetic variation of Southern hemisphere fur seals (*Arctocephalus* spp.): investigation of population structure and species identity. *The Journal of Heredity* **88**, 202-209.
- Lunn, N. and Arnould, J. (1997). Maternal investment in Antarctic fur seals: Evidence for equality in the sexes? *Behavioural Ecology and Sociobiology* **40**, 351-362.
- Lunn, N., Boyd, I., Barton, T. and Croxall, J. (1993). Factors affecting the growth - rate and mass at weaning of Antarctic fur seals at Bird Island, South Georgia. *Journal of Mammalogy* **74**, 908-919.
- Lunn, N., Boyd, I. and Croxall, J. (1994). Reproductive-performance of female Antarctic fur seals - the influence of age, breeding experience, environmental variation and individual quality. *Journal of Animal Ecology* **63**, 827-840.
- Mattlin, R. (1981). Pup growth of the New Zealand fur seal, *Arctocephalus forsteri*, on the Open Bay Islands, New Zealand. *Journal of Zoology, London* **193**, 305-314.
- Mattlin, R. (1987). New Zealand fur seal (*Arctocephalus forsteri*) within the New Zealand region. In 'Status, biology and ecology of fur seals: NOAA Technical Report NMFS 51'. (Eds J. Croxall and R. Gentry.) pp. 49-51. (National Marine Fisheries Service: Cambridge)
- Miller, E. (1971). Social and thermoregulatory behaviour of the New Zealand fur seal. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
- NIWA (2005) The Climate Update. **74**, pp. 4. Wellington, New Zealand.
- Pitcher, K. W. (1986). Variation in blubber thickness of harbor seals in southern Alaska. *Journal of Wildlife Management* **50**, 463-466.
- Reeves, R. R., Stewart, B. and Leatherwood, S. (1992). 'The Sierra Club Handbook of Seals and Sirenians.' (Sierra Club Books: San Francisco, California.)

- Richards, R. (1994). The upland seal of the Antipodes and Macquarie Islands: a historians's perspective. *Journal of the Royal Society of New Zealand* **24**, 289-295.
- Ryan, C., Hickling, G. and Wilson, K. (1997). Breeding habitat preferences of the New Zealand fur seal (*Arctocephalus forsteri*) on Banks Peninsula. *Wildlife Research* **24**, 225-235.
- Seber, G. (1982). 'The estimation of animal abundance and related parameters.' 2nd edn. (Macmillan:New York.)
- Shaughnessy, P. and Fletcher, L. (1987). Fur seals, *Arctocephalus* spp., at Macquarie Island. In 'Status Biology and Ecology of fur seals: NOAA Technical Report 51'. (Eds J. Croxall and R. Gentry.) pp. 177-188. (National Marine Fisheries Service: Cambridge.)
- Shaughnessy, P., Gales, N., Dennis, T. and Goldsworthy, S. (1994). Distribution and abundance of New Zealand fur seals, *Arctocephalus forsteri*, in South Australia and Western Australia. *Wildlife Research* **21**, 667-695.
- Sorenson, J. New Zealand seals with special reference to the fur seal. New Zealand Marine Department Fisheries Technical Report, Wellington, New Zealand.
- Street, R. (1964). Feeding habits of the New Zealand fur seal (*Arctocephalus forsteri*). New Zealand Marine Department Fisheries Technical Report No. 9, Wellington, New Zealand.
- Taylor, R. (1992). New Zealand fur seals at the Antipodes Islands. *New Zealand Journal of Marine and Freshwater Research* **22**, 107-122.
- Taylor, R., Barton, K., Wilson, P., Thomas, B. and Karl, B. (1995). Population status and breeding of New Zealand fur seals (*Arctocephalus forsteri*) in the Nelson-northern Marlborough region 1991-94. *New Zealand Journal of Marine and Freshwater Research* **29**, 223-234.
- Tierney, M., Hindell, M., Lea, M.-A. and Tollit, D. (2001). A comparison of techniques used to estimate body condition of southern elephant seals (*Mirounga leonina*). *Wildlife Research* **28**, 581-588.
- Trillmich, F., Ono, K., Costa, D., DeLong, R., Feldkamp, S., Francis, J., Gentry, R., Heath, C., LeBoeuf, B., Majluf, P. and York, A. (1991). The effects of El Nino on pinniped populations in the Eastern Pacific. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 247-270. (Springer-Verlag: London)
- Troy, S., Mattlin, R., Shaughnessy, P. and Davie, P. (1999). Morphology, age and survival of adult male New Zealand fur seals, *Arctocephalus forsteri*, in South Australia. *Wildlife Research* **26**, 21-34.
- Wilson, G. (1981). Distribution and abundance of the New Zealand fur seal, *Arctocephalus forsteri*. Fisheries Research Division No. 20, Wellington, New Zealand.
- Wynen, L., Goldsworthy, S., Guinet, C., Bester, M., Boyd, I., Gjertz, I., Hofmeyr, G., White, R. and Slade, R. (2000). Postsealing genetic variation and population structure of two species of fur seal (*Arctocephalus gazella* and *A. tropicalis*). *Molecular Ecology* **9**, 299-314.

Chapter 3
Breeding biology of New Zealand fur seals at
Ohau Point, Kaikoura

Laura J. Boren and Neil J. Gemmell

Proposed journal for submission: *Wildlife Research*

Chapter 3: Breeding biology of New Zealand fur seals at Ohau Point, Kaikoura

Abstract

The breeding biology and colony dynamics of the New Zealand fur seal (*Arctocephalus forsteri*) is well documented. However, colony dynamics and associated breeding biology parameters differ among colonies and understanding why these differences occur may allow for better management of populations through the ability to make decisions based on site-specific parameters. The aim of this study was to quantify site-specific differences in the breeding dynamics of *A. forsteri* at Ohau Point, and discuss possible reasons for the differences observed.

The Ohau Point colony (42°3S, 173°4E), South Island, New Zealand, is located near a deep-sea canyon and pelagic food source, which may affect aspects of the seals' breeding biology. The colony dynamics and breeding biology parameters of *A. forsteri* at Ohau Point, were examined over three austral summers: 2002/3, 2003/4, and 2004/5. Censuses of animals ashore, pupping dates, lactation duration and weaning dates were calculated for all years. In 2003/4, females weaned their pups sooner, began to arrive at the colony earlier, and pupped earlier than the other seasons. Lactation duration ranged from 325-352 days for all seasons, 38-70 days longer than previously reported for the species, leaving adult females with less time to forage between weaning and giving birth to their next pup. This suggests that females have been exposed to poor food availability and will be in a reduced condition for upcoming seasons. Or alternatively, the presence of a near-by reliable food source may allow them to maintain / regain condition quickly in the shortened period between weaning one pup and giving birth to the next, allowing for greater gestational investment.

Introduction

General maternal investment and lactation theory

Pinniped females support the task of nursing the offspring during a lactation period that can last from 4 days up to 2-3 years (Kovacs and Lavigne 1992; Boness and Bowen 1996). Maternal investment and lactation strategies vary between and within the different families of pinnipeds (Phocidae and Otariidae). At the family level, phocids, typically have a shorter lactation period (mean = 25.6 ± 2.3 days) than that observed in otariids, or eared seals (mean = 327.2 ± 30.9 days) (Calculated from reports summarised in Schulz and Bowen 2004).

Female phocids are generally large (range: 50-1000 kg – from Boness and Bowen 1996; Schulz and Bowen 2004) and have massive fat reserves (mean = 34% body fat, calculated from data summarised in Boness and Bowen 1996) so can fast onshore during the entire lactation period. This allows them to transfer a large amount of nutrients to their offspring in a very short time prior to weaning (Kovacs and Lavigne 1992). Otariids, on the other hand, are typically smaller in size (range excluding Steller sea lions: 28-140 kg – from Schulz and Bowen 2004) and rely more on their fur than a blubber layer for insulation (mean 24% body fat, calculated from data summarised in Boness and Bowen 1996). As a result, female otariids are unable to store enough fat to fast during the entire nursing period and therefore alternate between periods foraging at sea and nursing their pup ashore (Kovacs and Lavigne 1992; Boness and Bowen 1996).

Within the otariids, inter-specific differences can be observed in lactation strategies (Trillmich 1990). Most of these differences are the result of variation in environmental parameters influencing food availability (Gentry and Kooyman 1986; Trillmich 1990). Sub-polar species such as the Antarctic fur seal (*Arctocephalus gazella*) and the Northern fur seal (*Callorhinus ursinus*) are exposed to a predictable but very seasonal food supply. As a result, lactation durations for these species are short: 4 months or less (Doidge *et al.* 1986; Gentry and Holt 1986). At the other extreme, tropical species, such as the Galapagos fur seal (*Arctocephalus galapagoensis*), display a longer lactation duration, ranging between 1-3 years (Trillmich 1990; Kovacs and Lavigne 1992). Temperate species, including the New Zealand fur seal (*A. forsteri*), are intermediate between the two extremes. As a result,

temperate species tend to have a lactation period of intermediate duration ranging from 7-12 months (Trillmich 1990), with *A. forsteri* generally in the 8-10 months range (Stirling 1970; Miller 1975; Mattlin 1978; Goldsworthy 1992; Harcourt 2001; Baylis 2003).

Fine scale maternal investment has been described in great detail for many species including: *A. forsteri* (Harcourt and Davis 1997), sub-Antarctic fur seals, *A. tropicalis* (Goldsworthy 1999; Georges *et al.* 2000) and *A. gazella* (Goldsworthy *et al.* 1997; Lea *et al.* 2002). Even within species, variation in female foraging and lactation strategies have been observed and are suggested to result from differing environmental factors such as the location of the food source (Goldsworthy 1992; Harcourt and Davis 1997; Goldsworthy *et al.* 1997; Goldsworthy 1999; Harcourt *et al.* 2002; Georges *et al.* 2000; Lea *et al.* 2002).

New Zealand fur seal Range

A. forsteri is currently re-colonising areas of its former range and can be found on much of the New Zealand coastline and southern parts of Australia (Harcourt 2001). Within mainland New Zealand *A. forsteri* breeds around the South Island, Stewart Island and is beginning to re-colonise southern parts of the North Island (Wilson 1981; Mattlin 1987; Dix 1993; Harcourt 2001). *A. forsteri* can also be found breeding on many of the sub-Antarctic islands (Wilson 1974; Crawley and Wilson 1976). Within Australia, *A. forsteri* can be found around much of the southern coast and is beginning to re-colonise areas in the eastern Bass Strait and islands along the east coast of Australia (Shaughnessy *et al.* 1994; Gales *et al.* 2000; Arnould *et al.* 2000; Goldsworthy *et al.* 2003)

New Zealand fur seal breeding cycle

The natural history and breeding biology of the New Zealand fur seal has been described in great detail (Stirling 1970; 1971; Crawley and Wilson 1976; Goldsworthy and Shaughnessy 1994). The majority of the data come from studies undertaken on the Open Bay Islands, off the west coast of the South Island of New Zealand (Miller 1971; Stirling 1971; Crawley and Wilson 1976; Mattlin 1978), while some information comes from the Otago Peninsula, on the east coast of the South Island (Lalas and Harcourt 1995). An Australian comparison is provided by the Cape

Gantheaume colony on Kangaroo Island, South Australia, which has also been studied intensively (Goldsworthy and Shaughnessy 1994).

The generalised fur seal breeding season begins when males come ashore and claim territories from September-November. Females arrive later, hauling out from mid-November to late-December to give birth (Miller 1971; Miller 1975; Mattlin 1978; Goldsworthy and Shaughnessy 1994). Shortly after giving birth, the females will copulate (generally within 7 to 10 days post partum) and then begin to alternate between foraging at sea and nursing their pup onshore (Goldsworthy and Shaughnessy 1994). In this temperate fur seal species, the female will continue the foraging cycle for a lactation period of approximately 285 days (Goldsworthy 1992; Schulz and Bowen 2004). Among colonies of *A. forsteri*, the major differences seen in the breeding biology is in the timing of weaning, female arrival and pupping (Miller 1971; Goldsworthy and Shaughnessy 1994; Lalas and Harcourt 1995).

Ohau Point, Kaikoura

The Ohau Point seal colony, located north of the Kaikoura township, began pupping in 1990 and is currently in a stage of exponential growth (Chapter 2). This colony is unique relative to its location and interaction with human activities (Barton *et al.* 1998; Chapters 1 and 2). The Kaikoura Canyon provides a pelagic food source as close as 2 km from shore (Jaquet *et al.* 2000). This rich food source supports a variety of marine life, including many marine mammals (e.g. dusky dolphins, sperm whales etc.), and its proximity to Kaikoura has enabled the township to develop a marine tourism industry (Simmons *et al.* 1998; Boren 2001). In order to investigate more complex questions pertaining to *A. forsteri* in the Kaikoura region, it is a necessary prerequisite to understand the re-colonisation and breeding biology of the colony in question and how site-specific variables are related.

In this chapter the breeding biology of the New Zealand fur seal at Ohau Point, Kaikoura is documented. The main objectives were to: (1) determine when the majority of females arrived onshore and when the majority of pupping took place, and (2) calculate the mean pupping dates and the duration of the female lactation period for the colony.

Methods

Site Description

The Ohau Point seal colony (42°15'S, 173°50'E), is located 26 km north of the Kaikoura township. It is the largest breeding colony in the Kaikoura region (estimated 1000-3000 seals during the course of the study – Chapter 6). The colony extends for approximately 0.75-1 km immediately alongside highway SH1. At the southern edge of the colony, a lookout platform was built for safe seal viewing at what was once a non-breeding portion of the colony. For a range of study purposes the colony was divided into five main sectors (Figure 1). Sectors C to S are the most established parts of the colony, while breeding has only recently begun to extend from S to L and from C to N. While L is the closest breeding area to the lookout it is not fully visible from the lookout. The north edge of N tends to be used by males and immature seals and is not currently a breeding area.

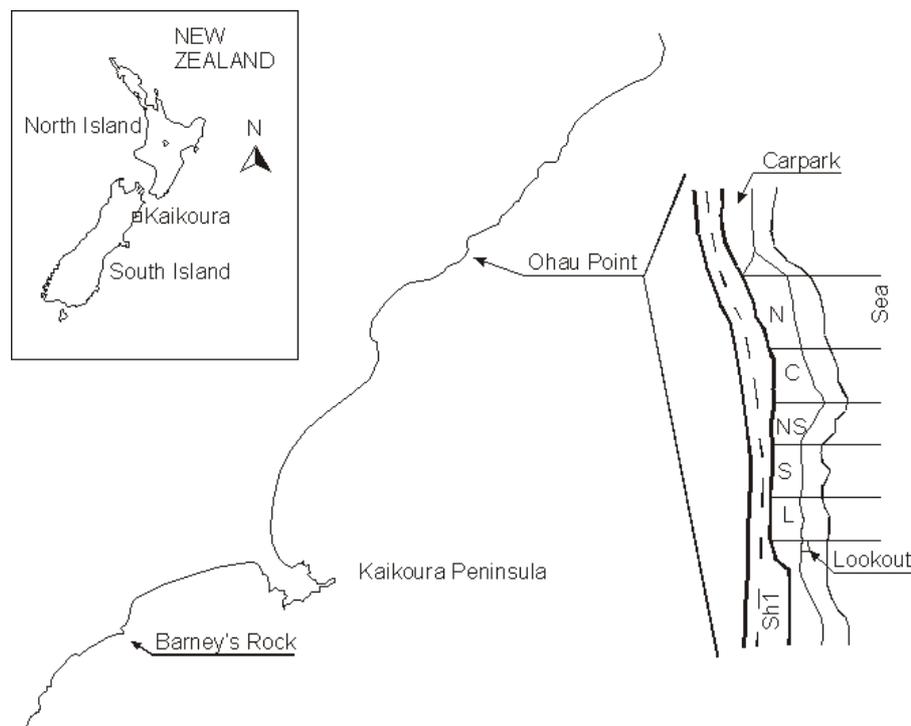


Figure 1: Map of the Kaikoura coastline on the eastern coast of the South Island of New Zealand, showing the location of Ohau Point seal colony. The colony is divided into sectors: N, C, NS, S, and L for the purposes of this study.

Census counts

Observations were made from late October to mid-December in 2002, and 2004. In 2003 census counts ceased at the beginning of December due to the commencement of several concurrent projects at the colony. Census counts were carried out one to three times a day; weather permitting, at 1000, 1200 and 1600 hours. The colony was broken into three major areas for the census: N, C, and 'South' included sectors NS, and S. Sector L was not included in this count since large portions of it are obscured from view by vegetation. For each census, seals in the area were counted and classified as: males, adult females, pre-weaners, and newborns. The numbers of any tagged pups were also recorded. Definitions for the age/sex groups are similar to those used by Goldsworthy and Shaughnessy (1994). However, "male" in the current census included both territorial and non-territorial males. Also, pups under 1 year of age were divided into two categories for our census. "Pre-weaners" around 300 days old can be differentiated from "newborn" pups by their size and lack of natal pelage or coat. The numbers of seals visible during a census is not the total population estimate as many may be obscured by the terrain, one section of the colony was not included in the census, and census data did not extend into January.

Birth/copulation observation

In between census counts the colony was observed for the presence of newborn pups, copulations, and births. For any newly born pup, we recorded the presence, length and condition of the umbilicus, presence of blood, presence and condition of the placenta and any other relevant details. This information was used to infer birth dates for the pups concerned and to determine mean and median pupping dates for the colony (Goldsworthy and Shaughnessy 1994; Lalas and Harcourt 1995; Haase 2004).

Sightings of known females and pups

During the 2003/4 and 2004/5 field seasons the presence of known animals were recorded on a daily basis. These included animals that could be recognised by tags or by unique flipper scars, amputations, entanglements and facial wounds. From November to December, weather permitting, the colony was scanned one to three times a day for the presence of approximately 80-120 known females. Female presence was recorded along with whether or not she had a pup. This provided

information on female fecundity, when specific individuals gave birth, and individual pups' weaning dates.

Estimation of Weaning Dates

Weaning was examined on a colony level for all three years and at an individual level for 2004. There is a limited amount of work detailing the timing and processes involved in weaning for temperate species of fur seals (Haase 2004). Weaning has typically been estimated based on when the majority of pups have left the colony through visual counts (Miller 1975; Mattlin 1978; Goldsworthy 1992) or through sightings of known mother/pup pairs in later lactation ($n = 16$, Goldsworthy 1992). The most recent and in depth study investigating the timing and determinants of weaning followed a large number of known individuals (n range per year for three years = 152-177) through behavioural observation and was based at a colony where a greater number of individuals were tagged and visibility is better (Haase 2004; Chapter 4). Due to these colony differences the use of identical methods to determine the time of weaning at Ohau Point was not possible.

In order to approximate weaning times for Ohau Point in all seasons, two indices were calculated that allowed comparison between the number and proportion of pre-weaners present in relation to other groups and the rest of the colony. These indices were: the proportion of pre-weaners out of all age/sex categories (PW/AS); and the proportion of pre-weaners on the colony out of the estimated number of pups born for that year calculated from the mark-recapture Peterson Estimate (PW/PE) (Chapter 2). The criteria set to estimate colony weaning in this study were when: i) approximately 80% of pups born had weaned, and ii) pre-weaners made up less than 20% of all animals on the colony. Estimated weaning ages for pups were calculated using the median pupping date for the year, and the median weaning date estimated from the indices used in this study. Mean weaning age for the colony over three seasons was calculated using the median weaning ages derived from the indices each year and is displayed \pm standard error.

In 2004, weaning age was calculated for 30 identifiable pre-weaners still on the colony during the observation period. The median pupping date (5/Dec/2003, See Table 2) was used as a birth-date for pups whose actual birth-date was unknown (11 of 30). For individuals, weaning was defined as the last date they were observed on

the colony. Weaning age was calculated in two ways, first by averaging the weaning age calculated for each of the 30 pups, and for comparison with Haase (2004) the difference between the median pupping date for the colony (5-Dec-2003) and the median weaning date calculated for these individuals. The information for these 30 individuals should provide a closer comparison for the methods used by Haase (2004).

Estimated weaning ages from this study were compared with those reported for other colonies and for *A. forsteri* in general, using a 2-sample t-test with unequal variances (Dytham 1999).

Results

Numbers of seals ashore

The number of seals sighted ashore in the sectors censused varied among years but tended to follow the same broad trends. Males steadily increased in number over the course of the season, initially arriving in October. Over 30 males were visible per day in late October and increased to 70-100 in late November and December. Female numbers were moderate in November (30-60), then decreased before pupping began (20-40), followed by an increase to over 100. Pre-weaners decreased over the study period from 40-100 visible per day in late October/early November to below 20 by late November/early December. The number of newborns ranged from 1 in mid-late November to 40 in mid-December.

Proportion of seals in each age/sex category

In 2002 (Figure 2a), males made up 40-52% of the population from 6/Dec to 21/Dec, decreased slightly, and then began to increase again in mid-December. In 2003, males made up 40-50% of the colony from 31/Oct to 21/Nov, peaked on 22/Nov (60.3%), and decreased afterwards. In 2004, males made up 15-40% of the colony from 1/Nov to 17/Nov, peaked on 26/Nov (47.3%), and decreased afterwards.

Females peaked in number on 9/Dec/2002 (50.3%) (Figure 2b). In 2003, adult females peaked in number on 14/Nov (43.7%), while in 2004 they peaked on 6/Dec (59.3%) although an initial peak prior to pupping was seen on 13/Nov.

The first newborns sighted in 2002 were born on 26/Nov (Figure 2c). In 2003 the first newborn was sighted on 13/Nov (0.23%) and more newborns were sighted on a regular basis by 22/Nov (2.21%). In the final season the first newborn was sighted on 17/Nov.

In 2002 pre-weaners still accounted for half of the population early in November then began to decrease steadily (Figure 2d). They dropped below 20% on 25/Nov and below 10% on 6/Dec. In the following year, pre-weaners made up approximately 23% of the colony on 6/Nov, however, decreased below 20% on 8/Nov, and below 10% on 19/Nov. In 2004, pre-weaners still made up approximately 20% of the colony on the 17/Nov, and dropped below 10% after 22/Nov.

Comparison between seasons

Male numbers were at their highest from late-November to mid-December in all seasons. However, their peak in relation to the peak in female numbers did vary; in the first two seasons males peaked about one week after the female peak, and in the third season, about two weeks before the female peak. The female peak occurred almost one month earlier in the last two seasons (14/Nov/03 and 13/Nov/04 vs. 9/Dec/02). Weaning took place approximately two weeks earlier in the 2003 and 2004 seasons (4/Nov/03 and 11/Nov/04 vs. 25/Nov/02). Similarly first births were observed 10-14 days earlier in the last two seasons (13/Nov/03 and 17/Nov/03 vs. 26/Nov/02).

Weaning times

Weaning times for all seasons can be compared using different indices (Table 1).

PW/AS: In the 2002 field season, the numbers of pre-weaners decreased between 19-25/Nov/02 although some individuals (n=10) were still present in the colony until 17/Dec/02. In 2003, the number of pre-weaners appeared to decrease markedly between 31/Oct/03 and 8/Nov/03, although some individuals were still on colony around 19 November. In 2004, the number of pre-weaners decreased between 19-30/Nov/04.

PW/PE: The proportion of pre-weaners left on the colony out of the total born decreased below 20% on 25/Nov/02 and below 10% on 17/Dec/02. The proportion left on colony in 2003 dropped below 20% from 31/Oct/03 and below 10% 19/Nov/03. In 2004 pre-weaners decreased below 20% on 4/Nov/04 and below 10% on 15/Nov/04 (Table 1).

Births

In 2002, the first birth was observed on 26/Nov/02 (Table 2) and a median pupping date of the 16th of December was estimated. In order to calculate weaning age for pups weaning in 2002, we need to know the peak pupping date for 2001. As data is not available from 2001, the range of known pupping dates for the colony in 2002-2004 (5-16/Dec) was used to estimate this since pupping is thought to remain similar between years (Stirling 1971; Miller 1971; Mattlin 1978).

Weaning Age

Based on the range of median birth dates for 2001 and a weaning date of 25/Nov for pups weaned in 2002 a median weaning age of 352 days (range 346-357 days) was calculated (Table 2). For pups weaning in 2003, weaning age was calculated using the median pupping date 16/Dec/02 and a weaning range of 31/Oct - 8/Nov/03, giving a median weaning age of 325 days (range 321-329 days). For pups weaning in 2004, a median weaning age of 343 days (range 336-351 days) was calculated using the median pupping date of 5/Dec/03 and weaning range 4-19/Nov/04. As a comparison, in 2004 a minimum of 30 out of 107 (28.0%) pups tagged in the previous season were still on the colony on 11th of October (311 days of age based on median pupping date 2003). Weaning age was calculated for each of these individuals in two ways. An average weaning age of 339 ± 4 days (range 304-394 days) was calculated based on individual birth and weaning dates, while a weaning age of 343 days was calculated based on a median pupping date of 5/Dec/03 and a median weaning date of 11/Nov/04. This estimate is similar to that calculated using the indices for that year. Figure 3 shows the decline of the maximum number of pre-weaners sighted ashore during censuses for each of the three years. The decrease in the number of pre-weaners over time was significant in all years (2002: $R^2 = 0.886$, $p < 0.0001$; 2003: $R^2 = 0.440$, $p < 0.0001$; 2004: $R^2 = 0.750$, $p < 0.0001$). Although this does not show a median weaning date it does support the longer time to weaning in 2003, when all pups were predicted to have left the colony by 28/Dec, versus 25/Dec in 2002, and 11/Dec in 2004.

Colony Comparison

The peak in both male and female numbers was earlier (late-November) at Ohau Point than elsewhere (Table 3). The median pupping date was similar to Tonga Island, but a

bit earlier than reported for other colonies. Weaning usually occurred in November, which is later than typically reported for other colonies of that species, and accounting for median birth date, weaning age was found to be significantly different at Ohau Point (mean = 340 ± 9 days) than for other studied NZ fur seal colonies (mean = 294 ± 6 days, [$t = 2.75$, $df = 5$, $p = 0.006$]). This late weaning and reasonably early pupping suggests that females who give birth 2 years in a row have a maximum of 8-44 days to regain condition before giving birth to their next pup. Although there was not enough data for statistical comparison, females that weaned late were not less likely to pup in the following season. One female in particular nursed two pups for nearly one year (Dec/03 to Dec/04), and still gave birth to a new pup in Dec 2004.

Discussion

Breeding biology

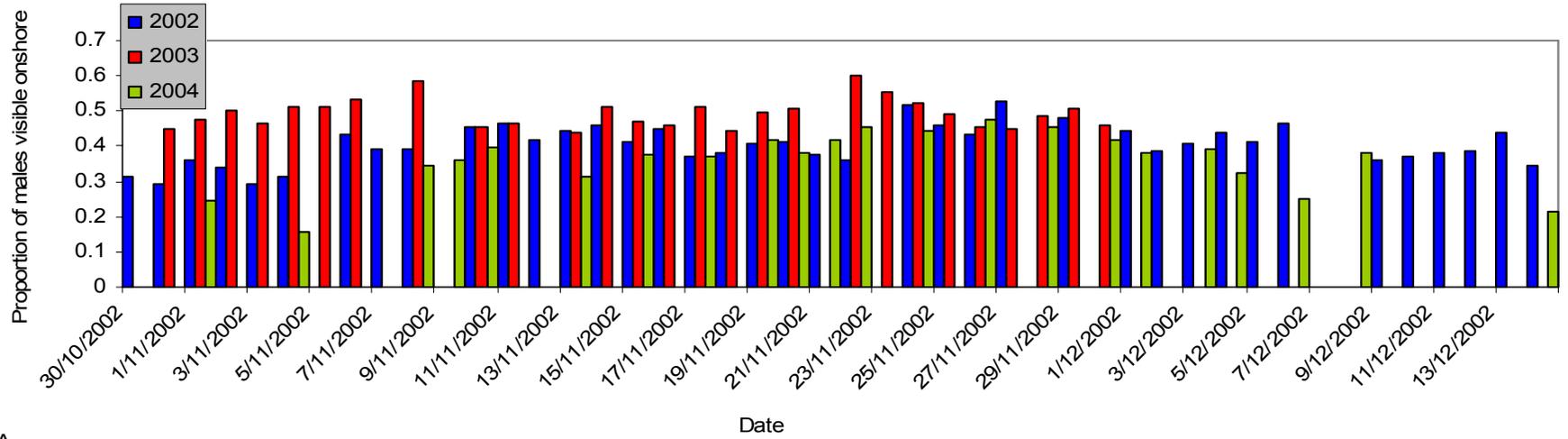
We compared key breeding biology events in three successive seasons and showed that: the weaning of pups, arrival of females to the colony and pupping all occurred two to four weeks earlier in the second and third seasons. While lactation duration and weaning time is known to vary in response to food availability (Gentry *et al.* 1986), it is unusual for the timing of pupping to vary greatly between seasons (Miller 1971; Stirling 1971). However, fluctuations in environmental parameters may affect many aspects of breeding biology in pinnipeds (Trillmich *et al.* 1991; Lunn *et al.* 1994; Boyd 1996).

Lactation duration / Weaning age

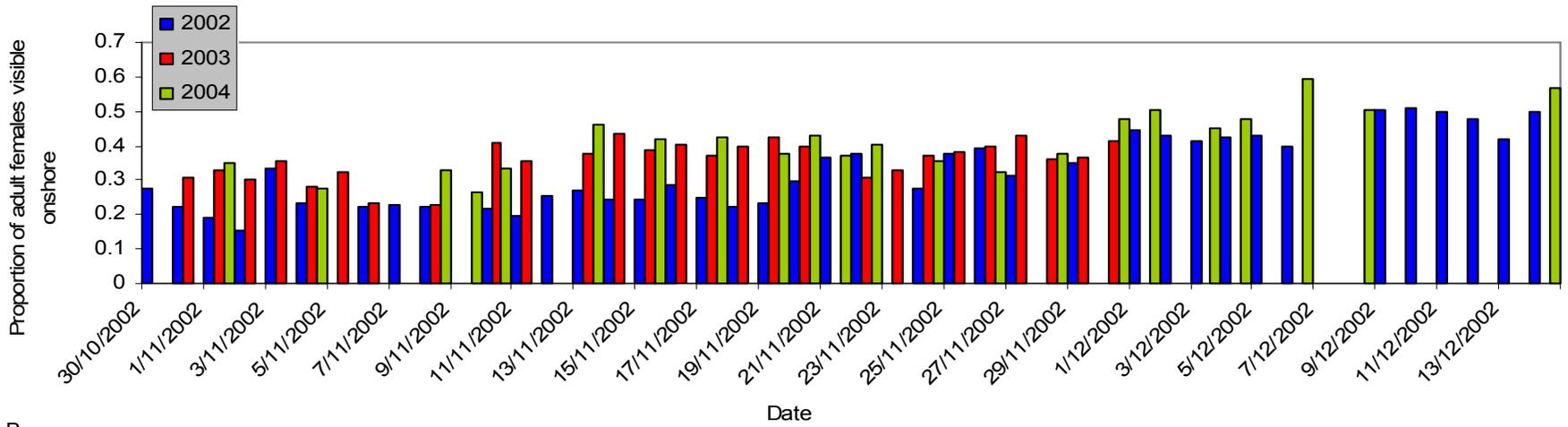
Gaining accurate estimates of weaning age in pinnipeds can be difficult. In the current study, with poor visibility in sections of the colony, and a small number of identifiable individuals, two indices were used to help calculate an estimated weaning age for pups in three seasons. The estimate based on the number of pups born in that cohort (PW/PE) does not take into account mortality of pups, and is also likely to underestimate the proportion of pre-weaners on the colony due to the reliability of re-sighting pups in irregular terrain. The comparison of pre-weaners to all age/sex categories is likely to be more accurate assuming that all age/sex categories are equally undercounted during the census. This may not be directly comparable to studies carried out at other colonies, which followed marked individuals for the last several months of weaning and could calculate a median weaning date/age (Goldsworthy 1992; Haase 2004). However, in October 2004, when data collection

leading up to the breeding season began at Ohau Point, several known pups were still observed at the colony and associating with their mothers. For 30 of these known individuals weaning ages were able to be calculated in ways similar to Haase 2004, and the weaning age calculated (mean – 339, median – 343) was similar to that calculated using the PW/PE and PW/AS indices for all years in the current study (median 343, range 336-351, Tables 1 and 2). Based on this, the indices used for estimating a median weaning date/age may provide a useful indication of the timing of weaning for pups at the Ohau Point colony. Since observations at Ohau did not begin as early as those at Kangaroo Island (July/August – Goldsworthy 1992; Haase 2004) this information may be biased towards pups that wean late. However, information from census counts in the decline of pre-weaners on the colony showed that as many as 98 pre-weaners (out of estimated 450 born) were visible within the census areas on 1-Nov (Figure 3), which is likely to be an underestimate of the true number of pre-weaners present. These results also predicted that all pups should be weaned by approximately 11-28th of Dec, as much as one month later than suggested by census counts at Kangaroo Island (10-11th November, Goldsworthy 1992).

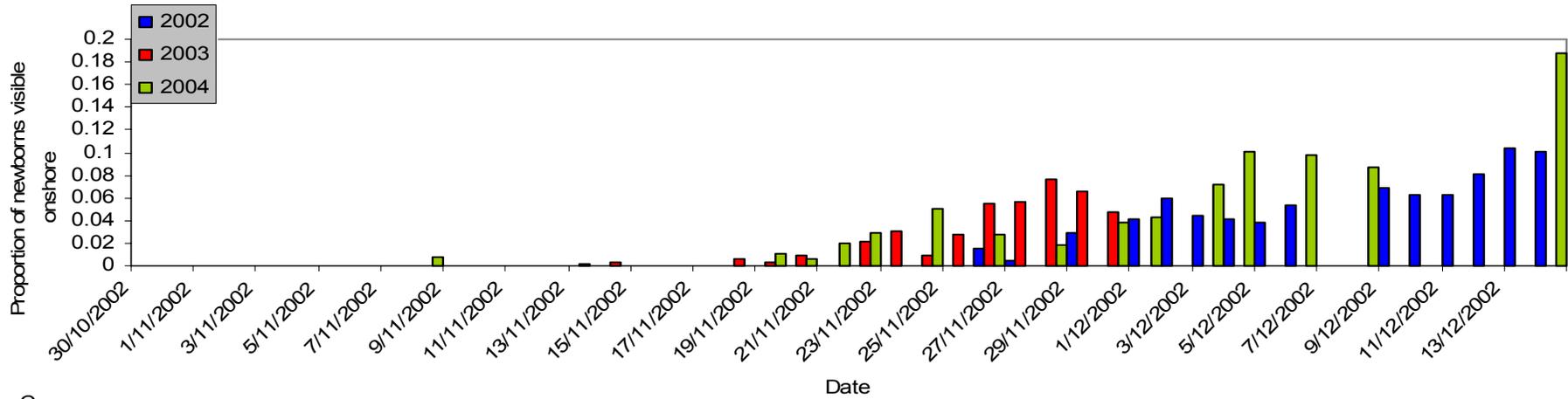
Over our three field seasons, mean female lactation durations were 321-357 days leaving females with only 8-44 days to regain condition between weaning their previous pup and parturition. Although lactation is known to vary within the species and individuals between 238-365 days, the most commonly quoted median lactation duration for New Zealand fur seals is approximately 294 ± 6 days, and weaning usually occurs around September to October (Stirling 1971; Miller 1975; Mattlin 1978; Goldsworthy 1992; Harcourt *et al.* 1995; Harcourt 2001; Baylis 2003; Schulz and Bowen 2004; Haase 2004). Few studies have investigated the time of weaning in detail, the most in depth being a recent study on the *A. forsteri* pups at Kangaroo Island (Haase 2004). This work showed that pups weaned one week earlier each year (in 2001, 02 and 03) at approximately 301, 297 and 291 days of age. This difference was found to be significant and was suggested to be a result of females' ability to adapt to small scale inter-annual variations in environmental conditions (Haase 2004).



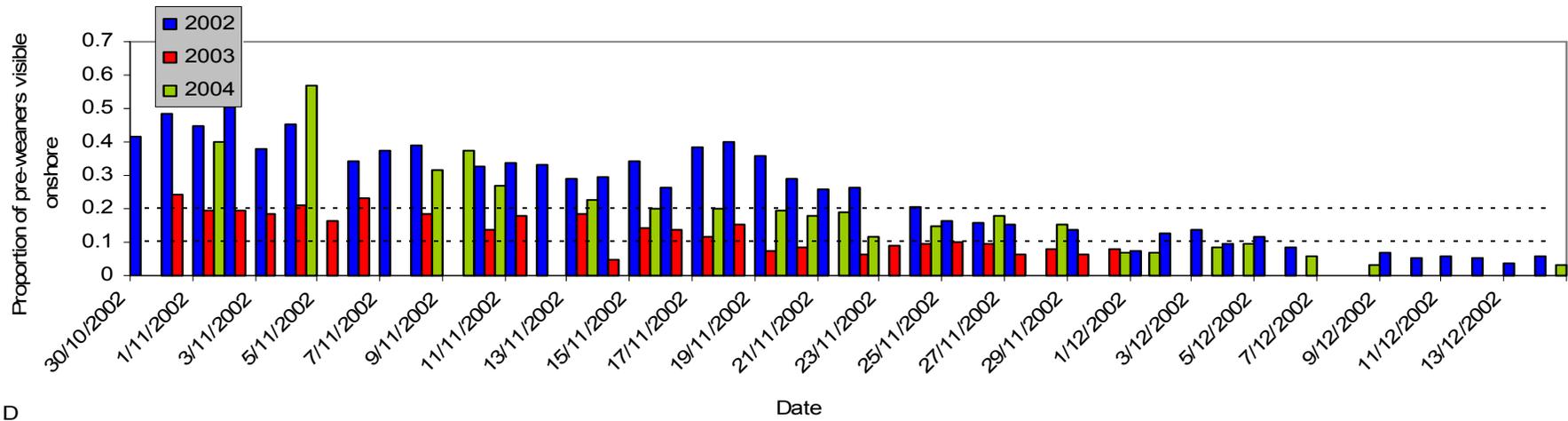
A



B



C



D

Figure 2: Percentage of seals ashore each year at Ohau Point colony by age/sex category: A) Males, B) Adult females, C) Newborns, and D) Pre-weaners during the breeding season. Note that the y-axis scale for newborns is different than for the other age/sex categories. Also, for reference to the proportion of pre-weaners ashore, lines demarcating 10% and 20% of all age/sex categories are shown.

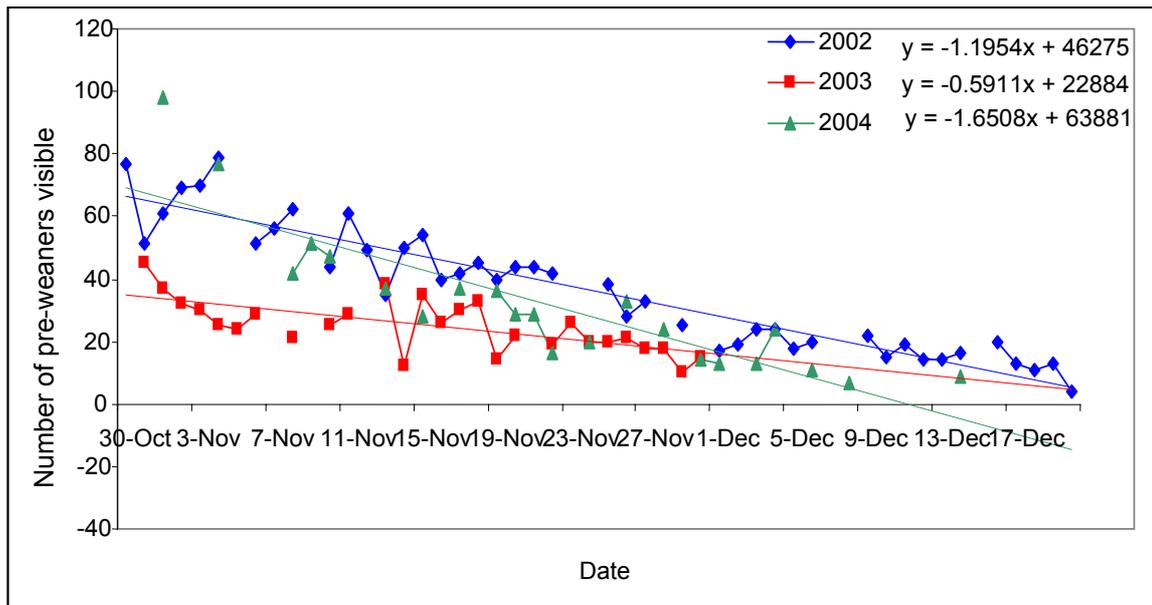


Figure 3: The decline in maximum number of pre-weaners seen ashore within the census areas from 30-Oct to approximately 20-Dec over three breeding seasons. For each year the regression models displayed were found to be significant for $x = \text{day}$, when 30 Oct = day 1 ($p < 0.0001$).

Table 1: Estimated weaning times of pups at Ohau Point colony from 2002 to 2004. They are calculated using the following indices: (PW/AS) Proportion of pre-weaners out of all age/sex categories; and (PW/PE) the proportion of pre-weaners out of estimated number of pups born.

Weaning times	Pups born in 2001 = 192		Pups born in 2002 = 290		Pups born in 2003 = 450	
	Wean year 2002		Wean year 2003		Wean year 2004	
Index	<20%	<10%	<20%	<10%	<20%	<10%
PW/AS	25-Nov 16.4%	6-Dec 8.3%	8-Nov 18.4%	19-Nov 7.5%	19-Nov 19.6%	30-Nov 6.6%
PW/PE	25-Nov 19.7%	17-Dec 6.7%	31-Oct 15.5%	19-Nov 4.8%	4-Nov 17.1%	15-Nov 8.4%

Table 2: Estimated births and lactation durations for Ohau Point colony calculated for 2002 to 2004 breeding seasons. Weaning time was calculated using the PW/AS and PW/PE indices when the indices dropped below 20%. The median of the calculated range for lactation duration is in brackets. In 2004, estimates based on 30 known individuals are shown in brackets for comparison with indices estimates.

Births	2002 Season	2003 Season	2004 Season
1 st Live Birth	26-Nov	13-Nov	17-Nov
Last Birth	/	29-Dec	29-Dec
Median pupping date	16-Dec-2002	5-Dec	7-Dec
Peak pupping date	/	3-Dec	4-Dec
Pre-weaners' estimated birth date	~5-16-Dec-2001	16-Dec-2002	5-Dec-2003
Estimated weaning time (indices dropping below 20%)	25 th Nov 2002	31 st Oct- 8 th Nov 2003 (median 4-Nov)	4-19 th Nov 2004 (median 11-Nov)
Lactation duration (in 2004 based on 30 known individuals)	346-357 days (352)	321-329 days (325)	336-351 days (343) (mean – 339, median – 343)

Table 3: Ohau Point breeding season compared with other colonies of the same species. OP = Ohau Point, OBI = Open Bay Islands, KI = Kangaroo Island, FG = Fuschia Gully, and TI = Tonga Island.

Colony	OP	OBI	KI	FG	TI
♂ peak	Late-Nov	Mid-Dec	Mid-Dec	/	/
♀ peak	Late-Nov	Mid-Dec	Mid-Dec	/	/
(M)edian/(P)eak Pupping Date	M: 5- 16Dec P: 3-4-Dec	M: 9-16 Dec	M: 21-Dec	M: 24 Dec	P: 5-6 Dec
Weaning	4-25 Nov	Early Oct	Mid-Oct	/	July/Aug
Lactation Duration	340 +/-9 days	300 days	285, 291- 301 days	/	238-269 days
References	1	2,3,4,5	6,7, 11	8	9,10

References: 1 – current study, 2 – Stirling 1970, 3 – Miller 1971, 4 - Crawley and Wilson 1975, 5 – Mattlin 1978, 6 – Goldsworthy and Shaughnessy 1994, 7 - Haase 2004, 8 – Lalas and Harcourt 1995, 9 – Taylor *et al.* 1995, 10 – K. Barton, Pers. Comm., Goldsworthy 1992.

Within site variation

As well as a long lactation duration, differences in the length of lactation varied between years (Table 2). Also, the timing of female arrivals and the beginning of the pupping season was variable (Table 3). It is likely that intraspecific variation in lactation strategies between years at a colony may be a result of changes in environmental variables and/or fluctuations in prey availability between years (Guinet *et al.* 2001; Lea *et al.* 2002; Haase 2004). While intraspecific variation in lactation strategies at different locations may be related to a wider range of environmental variables, such as sea surface temperatures, the presence and characteristics of local upwellings, weather patterns (El Niño), and habitat type (shallow or oceanic) (Gentry *et al.* 1986; Trillmich *et al.* 1991; Guinet *et al.* 2001; Lea *et al.* 2002; Beauplet *et al.* 2004), ultimately these all impact seals by affecting food availability.

Decreases in food availability can affect both female and pup condition and often result in females spending more time at sea (Gentry *et al.* 1986; Trillmich *et al.* 1991). Adult female *Zalophus californianus* were reported as spending significantly more time at sea, on longer trips to sea during the 1983 El Niño event, which was also associated with a decrease in squid, mackerel and anchovy landings (Heath *et al.* 1991). These extended maternal foraging trips result in pups fasting for longer periods of time, and the decreased transfer of nutrients leads to poor pup growth rates. Tropical and temperate species have the ability to respond to this nutrient shortage by delaying weaning sometimes into a second or third year to improve the pups' chances of survival (Trillmich *et al.* 1991).

In order to ensure their offspring wean at an adequate weight, *A. forsteri* females' have flexibility within their oestrous cycle to postpone weaning (Haase 2004). Flexibility in female attendance patterns as a result of changing environmental variables and/or decreased food availability have commonly been reported for some of the more tropical species (*A. galapagoensis*: Trillmich 1986; *A. australis* and *Otaria flavescens*: Majluf 1991) but has also been reported for temperate (*Zalophus californianus*: Ono *et al.* 1987; Heath *et al.* 1991; *A. tropicalis*: Beauplet *et al.* 2004; *A. forsteri*: Haase 2004) and polar species (*Callorhinus ursinus*: DeLong and Antonelis 1991).

Reported biological consequences of an El Niño have included increased Sea Surface Temperatures (SSTs), reduced upwelling and primary productivity, and often a decrease in the primary prey of pinnipeds (Arntz *et al.* 1991). These factors in turn affect lactating females' attendance patterns, foraging activity, energetics and mother/pup behaviours (Ono *et al.* 1987; Heath *et al.* 1991; Costa *et al.* 1991).

During the current study a strong El Niño event occurred from 2001 to 2003, which may be responsible for the delayed weaning age observed for pups weaning in 2002. Pups weaned in 2003 were weaned in the shortest time frame, and despite poor conditions at birth, weaned during a neutral phase in the ENSO cycle. In the final season, pups were initially born during this neutral phase, had a mild season, and then weaned during another El Niño event (NIWA 2005; Chapter 5).

Colony comparisons

The peak of male vs. female numbers is fairly similar between sites (Table 3). Despite males initially arriving earlier, their peak in numbers is likely to coincide with the increase in female numbers for the purpose of mating after the females have given birth (Crawley and Wilson 1976). The major differences observed between sites were the earlier female peak and pupping times, and the consistently later weaning and consequently longer lactation at Ohau Point compared with other colonies.

Based on our knowledge of maternal investment theory, if the consistently long lactation duration we observed at Ohau Point was related to a poor food source, one

would expect to see associated modifications signalling this problem, such as: decreased pup growth, poor pup condition, increased rates of starvation, and decreased rates of pup production (Trillmich *et al.* 1991, Chambellant *et al.* 2003, Hindell *et al.* 2003). However, at Ohau Point, the colony is expanding and increasingly more pups are born each year (Chapter 2). Pups appear to be in good condition, reaching 9 kg, the threshold to nutritional independence (Mattlin 1978), by 1.5-2.5 months of age and reaching weaning weight, 12-14 kg, (Mattlin 1978; Lee *et al.* 1991; Haase 2004; Chapter 5) by the age of 4-6 months (Chapter 5). Also, growth rates for *A. forsteri* pups at Ohau Point are some of the highest reported for the species even in years of increased sea surface temperatures (SST's) (ranges 45 g/day – 130 g/day, Chapter 5). Therefore, it is unlikely that the extended lactation duration observed at Ohau Point is a result of a decrease in food availability.

Gentry *et al.* (1986) suggested that food available on a sustained basis (e.g. reduced seasonality) could lead to an extended pupping season and a longer lactation duration, as seen in tropical and temperate species. They also concluded that predictability of the food source was more important in shaping maternal strategies than seasonality itself. So, in the presence of a highly predictable and sustained food source, a species with a flexible lactation duration could extend lactation and wean pups at an increased mass with reduced cost to the female. Therefore, it is possible that the presence of the Kaikoura Canyon could provide a predictable and sustained food source for fur seals in the Kaikoura region, whereby females remain in good condition throughout the season and nurse their offspring longer to a heavier weight with minimal cost.

The head of the Kaikoura Canyon is located around 500 m off the coast and the canyon reaches depths of greater than 1000 m around 1 km off the coast (Benoit-Bird *et al.* 2004). Jaquet *et al.* (2000) suggested that the Kaikoura Canyon provided an adequate food supply to support year-round residency of adult male sperm whales (*Physeter macrocephalus*). Dusky dolphins (*Lagenorhynchus obscurus*) are also found year-round in Kaikoura, and have been reported to feed on myctophids and squid, associated with the deep scattering layer (DSL), that rise vertically in the water column at night (Benoit-Bird *et al.* 2004). In Kaikoura, the predominant prey species of *A. forsteri* are: *Symbolophorus* spp. (myctophid), arrow squid and octopus, and a very small amount of hoki (Carey 1992) similar to the diet of *L. obscurus*, and accessible close to shore.

The foraging pattern of a lactating *A. forsteri* usually starts with short trips to sea to sites close to the colony. As lactation progresses, the female will forage further away from the colony, and spend more time at sea (Harcourt *et al.* 2002). The duration of time a female spends at sea will vary with proximity and quality of a food source and foraging efficiency. Therefore, foraging trip duration can be used as an indicator of foraging success (McCafferty *et al.* 1998; Boyd 1999). Seasonal changes in foraging have been shown in *A. forsteri* females, foraging up to 100 km further in winter than in summer on trips up to 11 days in duration (Harcourt and Davis 1997). *A. tropicalis* and *A. gazella*, from Amsterdam Island and Iles Kerguelen, were reported to travel over 500 km on a single summer foraging trip lasting on average 11 days (Georges and Guinet 2000; Georges *et al.* 2000, Bonadonna *et al.* 2000), while a later study on *A. tropicalis* at Amsterdam Island showed females foraging as far as 1800 km on trips that averaged 29 days in duration in winter (Beauplet *et al.* 2004). This colony is likely to be at carrying capacity and the results of the study suggested that the food source was depleted later in lactation forcing females to forage farther away for longer periods (Beauplet *et al.* 2004).

Conversely, the populations of *A. gazella* and *A. tropicalis* breeding on sub-Antarctic Macquarie Island (54°S, 159°E) are located close to a pelagic food source where the shelf break to deep sea occurs within 3 km of North Head. Both species predominantly fed on the pelagic myctophids, *Electrona subaspersa* and *Gymnoscopelus* spp. (Goldsworthy *et al.* 1997), and alternated between overnight foraging trips (OFTs) and extended foraging trips (EFTs) (Goldsworthy 1999). Both species also typically foraged in the same locations: 10 km from the island on OFTs and 30-60 km from the island on EFTs (Robinson *et al.* 2002). Goldsworthy (1999) suggested that females alternated between OFTs and EFTs to optimise their foraging efficiency with regard to nutrient transfer to their pups. Extended foraging trips are potentially better for the female as they allow her to build up more energy reserves feeding in an area of high prey density while limiting commuting, whereas, the shorter fasting periods between nursing bouts associated with OFTs would likely be better for the pup (Goldsworthy 1999; Robinson *et al.* 2002). Radio telemetry and behavioural data from Ohau Point has shown females are likely to be making

overnight foraging trips, which could be indicative of their utilising a close food source such as the Kaikoura Canyon (Chapter 4).

Conclusions

The present study shows that Ohau Point fur seals are exhibiting a significantly longer lactation period than for other colonies of *A. forsteri*. Chapter 2 also shows that the colony is in a state of exponential growth and animals are in consistently better condition than *A. forsteri* pups at other colonies. Several factors including oceanographic conditions and food availability may cause the breeding biology of a species to vary between sites, influencing in return its population dynamics as a whole. Given that *Arctocephalinae* are known to be flexible in foraging and maternal attendance behaviours, and that weaning dates for temperate and tropical species can be flexible as well, it is possible that *A. forsteri* females at Ohau Point nurse their pups longer because of a close, predictable and sustained food source from the Kaikoura Canyon. The data presented here provide a baseline for a unique colony of *A. forsteri*, located near a booming tourist town. These data help to provide a better understanding of the breeding biology of this colony, which will be vital to the future management of this colony when attempting to answer site-specific questions, in this case relating to fisheries and tourist interactions with fur seals. The following chapters continue to investigate reproductive behaviour and pup health in the Kaikoura region through maternal investment and pup growth.

References:

- Arnould, J. P. Y., Littnan, C., and Lento, G. (2000). First record of New Zealand fur seals (*Arctocephalus forsteri*) breeding in Bass Strait. *Australian Mammalogy* **22**, 57-62.
- Arntz, W., Pearcy, W. and Trillmich, F. (1991). Biological consequences of the 1982-83 El Nino in the Eastern Pacific. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 22-44. (Springer-Verlag: London).
- Barton, K. J., Booth, K., Ward, J., Simmons, D. and Fairweather, J. (1998). Tourist and New Zealand fur seal interactions along the Kaikoura Coast. Lincoln University Tourism Research and Education Centre Report No. 9, Lincoln, New Zealand.
- Baylis, A. M. M. (2003). The ontogeny of dive behaviour in New Zealand fur seal pups (*Arctocephalus forsteri*). Postgraduate diploma in Zoology Thesis. Department of Zoology, LaTrobe University, Victoria, Australia.
- Beauplet, G., Dubroca, L., Guinet, C., Cherel, Y., Dabin, W., Gagne, C., and Hindell, M. (2004). Foraging ecology of subantarctic fur seals (*Arctocephalus tropicalis*) breeding on Amsterdam Island: seasonal changes in relation to maternal characteristics and pup growth. *Marine Ecology Progress Series* **273**, 211-225.
- Benoit-Bird, K. J., Würsig, B., and McFadden, C. J. (2004). Dusky Dolphin (*Lagenorhynchus obscurus*) foraging in two different habitats: active acoustic detection of dolphins and their prey. *Marine Mammal Science* **20**, 215-231.
- Bonadonna, F., Lea, M. A., and Guinet, C. (2000). Foraging routes of Antarctic fur seals (*Arctocephalus gazella*) investigated by the concurrent use of satellite tracking and time-depth recorders. *Polar Biology* **23**, 149-159.
- Boness, D. J., and Bowen, W. D. (1996). The evolution of maternal care in pinnipeds. *BioScience* **46**, 645-654.
- Boren, L. J. (2001). Assessing the impacts of tourism on New Zealand fur seals (*Arctocephalus forsteri*). Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
- Boyd, I. (1996). Temporal scales of foraging in a marine predator. *Ecology* **77**, 426-434.
- Boyd, I. (1999). Foraging and provisioning in Antarctic fur seals: interannual variability in time-energy budgets. *Behavioural Ecology* **10**, 198-208.
- Carey, P. W. (1992). Fish prey species of the New Zealand fur seal (*Arctocephalus forsteri* Lesson). Report to Department of Conservation. Science and Research Internal Report, No. 115, Wellington, New Zealand.
- Chambellant, M., Beauplet, G., Guinet, C. and Georges, J. (2003). Long-term evaluation of pup growth and preweaning survival rates in subAntarctic fur seals, *Arctocephalus tropicalis*, on Amsterdam Island. *Canadian Journal of Zoology* **81**, 1222-1232.
- Costa, D., Antonelis, G. and DeLong, R. (1991). Effects of El Nino on the energetics of the California sea lion. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 156-166. (Springer-Verlag: London).
- Crawley, M. C., and Wilson, G. J. (1976). The natural history and behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Tuatara* **22**, 1-29.
- DeLong, R. and Antonelis, G. (1991). Impact of the 1982-1983 El Nino on the Northern fur seal population at San Miguel Island, California. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 75-83. (Springer-Verlag: London.)

- Dix, B. (1993). A new record this century of a breeding colony in the North Island for New Zealand fur seals (*Arctocephalus forsteri*). *Journal of the Royal Society of New Zealand* **23**, 1-4.
- Doidge, D. W., McCann, T. S., and Croxall, J. P. (1986). Attendance behaviour of Antarctic fur seals. In 'Fur seals: maternal strategies on land and sea'. (Eds. R. L. Gentry and G. L. Kooyman) pp. 102-114. (Princeton University Press: Princeton, New Jersey.)
- Dytham, C. (1999). 'Choosing and using statistics, a biologist's guide.' 1st. (Blackwell Science Ltd.: Oxford.)
- Gales, N. J., Haberley, B., and Collins, P. (2000). Changes in the abundance of New Zealand fur seals, *Arctocephalus forsteri*, in Western Australia. *Wildlife Research* **27**, 165-168.
- Gentry, R. and Holt, J. (1986). Attendance behaviour of Northern fur seals. In 'Fur seals: maternal strategies on land and at sea'. (Eds R. Gentry and G. Kooyman.) pp. 41-60. (Princeton University Press: Princeton, New Jersey)
- Gentry, R. L. and Kooyman, G. L. (1986). Introduction. In 'Fur seals: maternal strategies on land and sea'. (Eds. R. L. Gentry and G. L. Kooyman) pp. 3-27. (Princeton University Press: Princeton, New Jersey.)
- Gentry, R. L., Costa, D. P., Croxall, J. P., David, J. H. M., Davis, R. W., Kooyman, G.L., Majluf, P., McCann, T.S. and Trillmich, F. (1986). Synthesis and conclusions. In 'Fur seals: maternal strategies on land and sea'. (Eds. R. L. Gentry and G. L. Kooyman) pp. 220-264. (Princeton University Press: Princeton, New Jersey).
- Georges, J.-Y. and Guinet, C. (2000). Maternal care in the subantarctic fur seals on Amsterdam Island. *Ecology* **81**, 295-308.
- Georges, J. Y., Bonadonna, F., and Guinet, C. (2000). Foraging habitat and diving activity of lactating subantarctic fur seals in relation to sea-surface temperatures at Amsterdam Island. *Marine Ecology Progress Series* **196**, 291-304.
- Goldsworthy, S. D. (1992). Maternal care in three species of fur seal, *Arctocephalus* spp. at Macquarie Island. Unpublished PhD Thesis. Monash University, Melbourne, Australia.
- Goldsworthy, S. (1999). Maternal attendance behaviour of sympatrically breeding Antarctic and subantarctic fur seals, *Arctocephalus* spp., at Macquarie Island. *Polar Biology* **21**, 316-325.
- Goldsworthy, S. D., and Shaughnessy, P. D. (1994). Breeding biology and haul-out pattern of the New Zealand fur seal (*Arctocephalus forsteri*) at Cape Gantheaume, South Australia. *Wildlife Research* **21**, 365-376
- Goldsworthy, S. D., Hindell, M.A., and Crowley, H.M. (1997). Diet and diving behaviour of sympatric fur seals *Arctocephalus gazella* and *A. tropicalis* at Macquarie Island. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds. M. Hindell and C. Kemper). pp. 151-163. (Surrey and Beatty and Sons, Chipping Norton: Australia).
- Goldsworthy, S. D., Bulman, C., He, X., Larcome, J. and Littnan, C. (2003). Trophic interactions between marine mammals and Australian fisheries: an ecosystem approach. In 'Marine Mammals: fisheries, tourism and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 62-99. (CSIRO: Collingwood, VIC, Australia)
- Guinet, C., Dubroca, L., Lea, M. A., Goldsworthy, S., Cherel, Y., Duhamel, G., Bonadonna, F., and Donnay, J. P. (2001). Spatial distribution of foraging in Antarctic fur seals, *Arctocephalus gazella*, in relation to oceanographic variables:

- a scale dependant approach using geographic information systems. *Marine Ecology Progress Series* **219**, 261-264.
- Haase, T. (2004). The determinants of weaning in the New Zealand fur seal. Unpublished PhD. Department of Zoology, School of Life Sciences, La Trobe University, Victoria, Australia.
- Harcourt, R. G. (2001). Advances in New Zealand mammalogy 1990-2000: Pinnipeds. *Journal of the Royal Society of New Zealand*. **31**, 135-160.
- Harcourt, R. and Davis, L. (1997). The use of satellite telemetry to determine fur seal foraging areas. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds. M. Hindell and C. Kemper). pp. 137-142. (Surrey and Beatty and Sons,+ Chipping Norton: Australia).
- Harcourt, R. G., Schulman, A. M., Davis, L. S., and Trillmich, F. (1995). Summer foraging by lactating female New Zealand fur seals (*Arctocephalus forsteri*) off Otago Peninsula, New Zealand. *Canadian Journal of Zoology* **73**, 678-690.
- Harcourt, R. G., Bradshaw, C. J. A., Dickson, K. and Davis, L. S. (2002). Foraging ecology of a generalist predator, the female New Zealand fur seal. *Marine Ecology Progress Series* **227**, 11-24.
- Heath, C., Ono, K., Boness, D. and Francis, J. (1991). The influence of El Nino on female attendance patterns in the California sea lion. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 138-145. (Springer-Verlag: London)
- Hindell, M., Bradshaw, C. J., Harcourt, R. and Guinet, C. (2003). Ecosystem monitoring: are seals a potential tool for monitoring change in marine ecosystems? In 'Marine mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 330-343. (CSIRO: Collingwood, Victoria, Australia).
- Jaquet, N., Dawson, S., and Slooten, E. (2000). Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: foraging implications. *Canadian Journal of Zoology* **78**, 407-419.
- Kovacs, K. M., and Lavigne, D.M. (1992). Maternal investment in otariid seals and walruses. *Canadian Journal of Zoology* **70**, 1953-1964.
- Lalas, C. and Harcourt, R. (1995). Pup production of the New Zealand fur seal on Otago Peninsula, New Zealand. *Journal of the Royal Society of New Zealand* **25**, 81-88.
- Lea, M. A., Hindell, M., Guinet, C., and Goldsworthy, S. (2002). Variability in the diving activity of Antarctic fur seals, *Arctocephalus gazella*, at Iles Kerguelen. *Polar Biology* **25**, 269-279.
- Lee, P., Majluf, P. and Gordon, I. (1991). Growth, weaning and maternal investment from a comparative perspective. *Journal of Zoology, London* **225**, 99-114.
- Lunn, N., Boyd, I. and Croxall, J. (1994). Reproductive-performance of female Antarctic fur seals - the influence of age, breeding experience, environmental variation and individual quality. *Journal of Animal Ecology* **63**, 827-840.
- Majluf, P. (1991). El Nino effects on pinnipeds in Peru. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 55-65. (Springer-Verlag: London).
- Mattlin, R. H. (1978). Population biology, thermoregulation and site preference of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1828) on the Open Bay Islands, New Zealand. Unpublished PhD thesis, University of Canterbury, Christchurch, New Zealand.
- Mattlin, R. (1987). New Zealand fur seal (*Arctocephalus forsteri*) within the New Zealand region. In 'Status, biology and ecology of fur seals: NOAA Technical

- Report NMFS 51'. (Eds J. Croxall and R. Gentry.) pp. 49-51. (National Marine Fisheries Service: Cambridge)
- McCafferty, D., Boyd, I., Walker, T. and Taylor, R. (1998). Foraging responses of Antarctic fur seals to changes in the marine environment. *Marine Ecology Progress Series* **166**, 285-299.
- Miller, E. (1971). Social and thermoregulatory behaviour of the New Zealand fur seal. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
- Miller, E. H. (1975). Annual cycle of fur seals, *Arctocephalus forsteri* (Lesson), on the Open Bay Islands, New Zealand. *Pacific Science* **29**, 139-152.
- NIWA (2005) The Climate Update. **74**, pp. 4. Wellington, New Zealand.
- Ono, K., Boness, D. J. and Oftedal, O. (1987). The effect of a natural environmental disturbance on maternal investment and pup behaviour in the California sea lion. *Behavioural Ecology and Sociobiology* **21**, 109-118.
- Robinson, S. A., Goldsworthy, S. D., van den Hoff, J., and Hindell, M.A. (2002). The foraging ecology of two sympatric fur seal species, *Arctocephalus gazella* and *Arctocephalus tropicalis*, at Macquarie Island during the Austral summer. *Marine and Freshwater Research* **53**, 1071-1082.
- Schulz, T. and Bowen, W. (2004). Pinniped lactation strategies: evaluation of data on maternal and offspring life history traits. *Marine Mammal Science* **20**, 86-114.
- Shaughnessy, P. D., Gales, N. J., Dennis, T. E., and Goldsworthy, S. D. (1994). Distribution and abundance of the New Zealand fur seal *Arctocephalus forsteri* in South Australia and Western Australia. *Wildlife Research* **21**, 667-695.
- Simmons, D., Horn, C. and Fairweather, J. (1998). Summertime visitors to Kaikoura: characteristics, attractions and activities. Report to Lincoln University. Tourism Research and Education Centre Report, Report No. 3, Lincoln, New Zealand.
- Stirling, I. (1970). Observations on the behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Journal of Mammalogy* **51**, 766-777.
- Stirling, I. (1971). Studies on the behaviour of the South Australian fur seal, *Arctocephalus forsteri* (Lesson) II. Adult females and pups. *Australian Journal of Zoology* **19**, 267-273.
- Taylor, R., Barton, K., Wilson, P., Thomas, B. and Karl, B. (1995). Population status and breeding of New Zealand fur seals (*Arctocephalus forsteri*) in the Nelson-northern Marlborough region 1991-94. *New Zealand Journal of Marine and Freshwater Research* **29**, 223-234.
- Trillmich, F. (1986) Attendance behaviour of Galapagos fur seals. In 'Fur seals: maternal strategies on land and sea'. (Eds. R. L. Gentry and G. L. Kooyman). pp. 168-185. (Princeton University Press: Princeton, New Jersey).
- Trillmich, F. (1990). The behavioural ecology of the maternal effort in fur seals and sea lions. *Behaviour* **114**, 4-20.
- Trillmich, F., Ono, K. A., Costa, D. P., DeLong, R.L., Feldkamp, S.D., Francis, J.M., Gentry, R.L., Heath, C.B., LeBoeuf, B.J., Majluf, P., and York, A.E., (1991). The effects of El Niño on pinniped populations in the Eastern Pacific. In 'Pinnipeds and El Niño: Responses to Environmental Stress'. (Eds. F. Trillmich and K. A. Ono). pp. 247-270. (Springer-Verlag: London).
- Wilson, G. J. (1974). Distribution, abundance and population characteristics of the New Zealand fur seal (*Arctocphalus forsteri*). Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
- Wilson, G. (1981). Distribution and abundance of the New Zealand fur seal, *Arctocephalus forsteri*. Report to Fisheries Research Division. Occasional Publication, No. 20, Wellington, New Zealand.

Intermission 1

In Chapter 2: Colony Growth and pup condition, we saw that the Ohau Point seal colony in Kaikoura is in an exponential state of growth (Figure 3). It was also apparent that pups at Ohau Point were in consistently good condition (Figure 4) and that when compared with colonies on Banks Peninsula, there was a significant interaction between variables colonies and years when analysing pup mass. This suggests that some local parameters may cause the colonies to respond to environmental changes in different ways. Given the oceanographic features surrounding the colonies in question, it is possible that fur seal females in Kaikoura are able to forage between 2-20 km away (Benoit-Bird *et al.* 2004) while females at the Southern Banks Peninsula colonies may have to travel as far as 100 km to forage (Goring and Henry 1998).

Interestingly, Chapter 3: Breeding Biology, shows that contradictory to the expected, in the face of a reliable food source, lactation lengths at Ohau Point were significantly longer than for *A. forsteri* at other colonies (Table 4). This may normally be inferred as reduced food availability (Gentry *et al.* 1986). However, could it be possible that the proximity of such a reliable food source reduces the potential costs of lactation and foraging to a point that females can invest more into the survival of their offspring with little cost to themselves? More work is required to further investigate the relationship between possible foraging locations and lactation duration at Ohau Point. In the following section I will investigate the local maternal foraging strategies and their impacts on pup growth rates.

Firstly, I will look at the female foraging strategies utilised in the Kaikoura region (Chapter 4: Maternal attendance), if they are indicative of where the females might be foraging, and how disturbance in the colony could affect maternal attendance patterns. Then, Chapter 5: Pup growth, will go further to investigate the growth patterns of pups in Kaikoura, and the relationship maternal parameters such as mass, condition and foraging strategies have on pup growth.

Chapter 4
Maternal attendance patterns of lactating New Zealand fur seals, *Arctocephalus forsteri*, in Kaikoura, and the impact of disturbance on attendance patterns

Laura J. Boren, Chris G. Muller, Sacha Dowell, Abigail Caudron, and Neil J. Gemmell

Chapter 4: Maternal attendance patterns of lactating New Zealand fur seals, *Arctocephalus forsteri*, in Kaikoura

Abstract

Maternal attendance patterns vary markedly among pinnipeds. Although much work has focused on the highly-constrained maternal investment patterns of polar otariids, recent studies have shown temperate species to exhibit more flexible patterns. To this end, the maternal attendance patterns of *Arctocephalus forsteri* at Ohau Point, Kaikoura were investigated over two austral summers; 2004 and 2005, using radio telemetry and behavioural methods. Nineteen and 14 females were fitted with radio transmitters in the two seasons, and behavioural data were collected on 54 and 41 identifiable females, respectively. Attendance patterns were categorised based on year, foraging trip duration, shore bout duration, and the proportion of time spent ashore, and additionally on the number of overnight foraging trips performed for the 23 VHF females for which these data were available. Foraging trip duration was significantly longer in 2005 (mean: 4.25 vs. 2.74 days), an El Niño year. Most females performed some overnight foraging trips (92% and 100% of VHF females) in contrast with other colonies of the same species, and in 2005 the relative proportion of overnight foraging trips increased, indicating greater utilisation of a nearby food source. VHF females were classified into 3 groups with 2 outliers, while four groups were defined in the analysis of all females. However, while year and foraging trip duration were most important in categorising 95 females' attendance patterns, overnight foraging trips were the most important feature in defining patterns observed in VHF females. Suggesting that for the Kaikoura region, behavioural data alone are not adequate in defining maternal attendance patterns, as overnight foraging trips play an important role in maternal provisioning.

Introduction

Maternal attendance theory

Provisioning of young is one of the most energetically costly exercises in parental care and various strategies have been observed for rearing young under different circumstances in a number of species (Clutton-Brock 1991). Pinnipeds are a unique group of animals in that foraging and rearing locations are spatially separated between water and land (Kovacs and Lavigne 1992). As a result, two main maternal strategies have evolved to cope with this situation, and although it was previously believed that each family developed a unique strategy, maternal strategies in pinnipeds are now believed to be more closely related to maternal size than to phylogeny (Boness and Bowen 1996).

For example, the larger phocids employ a fasting strategy, whereby they store up a large amount of fat reserves before coming ashore to give birth and then remain ashore with their offspring throughout a short lactation period (4-50 days, Kovacs and Lavigne 1992). In contrast, the otariids (seals and sea lions) and some smaller phocids including the harbour seal (*Phoca vitulina*), utilise a foraging cycle strategy although this typically only occurs later in lactation for phocids (Boness and Bowen 1996). This involves alternating between trips to sea to feed and bouts ashore to nurse young with the length of lactation ranging from 4 to 36 months between species (Kovacs and Lavigne 1992). This situation of central place foraging, where the female has to return to her young on a regular basis is commonly observed in mammals and birds. To optimise foraging success a female will need to maximise energy gain for the distance they travel to a feeding site (Orians and Pearson 1979) often by staying longer at a more distant site (Robinson *et al.* 2002).

Within otariids differing maternal investment strategies have developed among species since different species are exposed to different foraging conditions (Gentry *et al.* 1986). For example, the subpolar fur seal species, *Arctocephalus gazella* and *Callorhinus ursinus*, are restricted to a short lactation period when their food source is highly abundant during the polar summers (Trillmich 1990). On the other hand, tropical species populate areas of weak seasonality and thus their food source is less predictable (Trillmich 1990). Temperate species are intermediate and show a much weaker relationship between maternal strategy and latitude (Trillmich 1990).

The strategies employed for rearing young incorporate a host of traits and can be described in several ways including and not limited to: energy expenditure, nutrient transfer, differential allocation between the sexes, and the number of offspring produced (Kovacs and Lavigne 1992). Some of the traits are fixed and vary little between species and years. These traits relate more to a female's total lifetime output and appear to be set by genetic or physiological constraints (e.g. % fat in females milk, Gentry *et al.* 1986). More flexible traits are those that are under behavioural control and allow a female to make adjustments to a set of environmental variables in the short term (e.g. altering attendance behaviour in response to poor vs. abundant resources, Gentry *et al.* 1986).

As more knowledge is gained on the maternal attendance patterns of temperate species it is increasingly apparent that local environmental variables have a strong influence on shaping these patterns (Trillmich 1990; Robinson *et al.* 2002). For example, a significant amount of intra-specific variation has been observed within (Harcourt *et al.* 2001; Beauplet *et al.* 2004) and between years (McCafferty *et al.* 1998; Boyd 1999; Lea *et al.* 2002) suggesting that females are able to adapt their maternal strategies to the local environment and changes in food availability. Examples of adaptability within a year include female fur seals foraging further from the colony in winter due to depletion of a summer food source (Beauplet *et al.* 2004) or a shift in primary prey species (Harcourt *et al.* 2001). Between-year differences have been observed in foraging trip duration, shore bout duration, and dive activity in response to a variable food source often brought on by environmental changes (Boyd 1999). The most common response in times of poor food availability is to increase time spent at sea, decrease time ashore and increase dive effort while at sea (Gentry *et al.* 1986; Ono *et al.* 1987; Boyd 1999). In temperate and tropical species, females not only have the ability to adjust their foraging strategies and dive activity while at sea, but also have the ability to extend the lactation period in times of food shortages (Trillmich *et al.* 1991; Chapter 3).

Most work on maternal investment in *A. forsteri* has been carried out on the Otago Peninsula (45°S/170°E), South Island, New Zealand (Harcourt *et al.* 1995; 2001; 2002) and at Kangaroo Island (36°04'S/137°28'E), South Australia (Goldsworthy

1992; Haase 2004). The primary foraging locations for these colonies are approximately 70+ km away near the 500 and 1000 m iso-baths (Page, unpub. data; Harcourt *et al.* 1995). In contrast, the *A. forsteri* colonies of the Kaikoura coast are located as close as 1-2 km to the 1000 m isobath (Benoit-Bird *et al.* 2004). Given that fur seal maternal attendance patterns vary greatly between species, and potentially within species as well, it is important to understand what variables shape these differences and how. If maternal attendance patterns in the Kaikoura region vary from patterns observed by other *A. forsteri*, and these differences are shaped by the local bathymetry and resource availability then this may influence how the Kaikoura population responds to other regional factors including the increase in human activity. Since *A. forsteri* in the region are common targets of eco-tourism ventures then it is beneficial to understand the variables shaping the behaviour of the colony and thus how they will respond to human influence in the region, and how best to manage it for the future.

The goals of this chapter were to determine if adult female *A. forsteri* used distinct attendance patterns in the Kaikoura region and to what extent the local environment may shape their patterns.

Methods

Site description

This study was conducted at Ohau Point seal colony, 25 km north of Kaikoura township ($42^{\circ}15'S/173^{\circ}50'E$), on the east coast of the South Island, New Zealand. The colony is approximately 1 km long, adjacent to State Highway 1, and is primarily made up of large boulders and caves (Figure 1). The Kaikoura Canyon lies approximately 2 km offshore, providing a nearby access to a pelagic food source (Chapters 2 and 3). Ohau Point was only recently re-colonised (Chapter 1) and has expanded from 100 to nearly 600 pup births a year since 2000 (Chapter 2). While the seal colony is expanding, the town of Kaikoura is growing with an increasing eco-tourism industry, and New Zealand fur seals are one of the primary targets of eco-tourism operations in the Kaikoura region (Boren 2001). There is a lookout positioned at the south end of the Ohau Point colony, and a car-park at the north end, across from the access to the Ohau stream walkway. Many tourists pull over and view the seals, and increasingly more are walking the length of the colony on the road and entering the colony (pers. obs.). This study was carried out over two austral summers, 2003/04 and 2004/05. As the majority of the observations were carried out in the new year the two seasons will be referred to as 2004 and 2005, respectively.

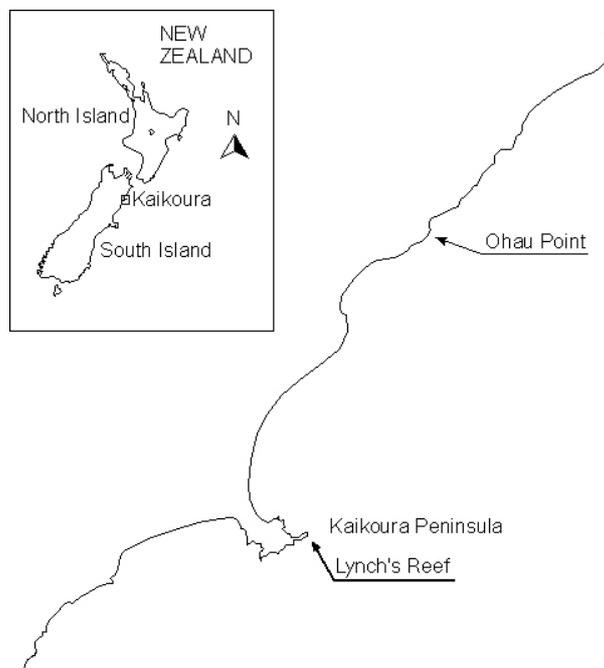


Figure 1: The Kaikoura coast showing the location of Lynch's Reef on the Kaikoura Peninsula and the Ohau Point breeding colony to the North.

Sample sizes and identification of breeding age females

Females were monitored using both radio telemetry and behavioural methods, which are described in the following sections. This study required the ability to individually identify a sample of breeding-age females. Female sightings from 2004 and 2005, and preliminary sighting data from 2003 provided reproductive information on 55 identifiable females and a colony fecundity rate (Goldsworthy and Shaughnessy 1994) of approximately 62%. Based on this rate and estimates of pup production (Chapter 2), Ohau Point supported approximately 687-764 breeding aged females in 2004 and 900-1006 in 2005. Approximately 5.2-7.7% (53) of all females on the colony were tagged. These females had a range of tag types (Allflex and Zeetag), shapes (cattle, sheep and button), and colours (red, orange, yellow, white, and green). Photo identification of females with unique flipper scalloping, flipper ribs, and scars increased the identifiable proportion of females on the colony to 10.5-23% (80-210). Photos were collected on a digital Nikon coolpix 3500 camera, through a spotting scope (20-60x) and stored in SuperJPG (Midnight Blue Software Inc.), which allows photos to be annotated and keyed for fast searching (Harting *et al.* 2004). Due to the terrain of the colony, however, not all identifiable females could be reliably sighted. Therefore, although up to 210 females can be identified, sample sizes of females with usable data were significantly lower (Table 1).

Table 1: Sample sizes of adult females monitored in this study.

	Sighting categories (No. of sightings)	Frequency of Sightings	Females (n)	Sightings / fem	Useable Beh (n)	VHF deployed / useable (total n / useable n)	Females in consecutive years / useable (total n / useable n)
2004	20+	539	22	24.50	54	19 / 13	43 / 19
	10-19	470	30	15.67			
	5-9	65	9	7.22			
	<5	9	7	1.29			
	Total	1083	68	15.93			
2005	20+	412	16	26.10	41	14 / 11	
	10-19	375	28	13.70			
	5-9	145	21	6.90			
	<5	106	51	2.10			
	Total	1038	116	8.95			

VHF radio telemetry and marking of caught females

A total of 33 adult females were fitted for radio telemetry monitoring (19 in 2004, and 14 in 2005). Females were caught early in December of the previous year shortly after pupping, when they were more likely to stay near their pup (Crawley and Wilson 1976). Adult females were chosen based on their position in the colony, to minimise disturbance. They were also selected if they were associating with a pup or had enlarged teats, to minimise the chance of catching a pregnant female. Females were caught using a modified hoop-net, with a removable handle (Robinson *et al.* 2002). Once in the net the handle was removed and the female was carried to a safe place to work and placed onto the restraining board for handling. The hoop-net had a nose-hole, which allowed breathing to be monitored throughout handling. The VHF unit (Sirtrack New Zealand) (attached to a piece of neoprene and then a piece of mesh using araldite two-part epoxy) was then attached to the female's back, midline and posterior to the shoulder blades using a Devcon five-minute setting two-part epoxy (Stokes and Boersma 1999; Müller 2004). Females were also marked for future identification in one of three ways. The majority of females were flipper tagged, using white Allflex sheep-tags with four digit numbers. A small proportion of females caught had been tagged in previous studies and had lost both tags. In this situation numbered caps (L. Chilvers pers. comm.) were applied anterior to the VHF unit. Caps of 2-4 cm in diameter were made of a dark plastic mesh material, and an identification number was applied using a syringe filled with a two-part epoxy mixed with a coloured enamel paint. The cap was fixed to the fur on the individuals' backs, posterior to the shoulder blades, using a 90 second setting Araldite 2-part epoxy. One female received a hair-cut (Mattlin 1978) anterior to her VHF due to a slightly longer handling time than the other females. Measurements and genetic samples were collected for concurrent studies before the female was released. Handling time averaged 23 minutes (range: 12-35 minutes).

VHF units (Sirtrack, NZ) operated on the frequency of 160 MHz, and were monitored from a remote station on the cliff above the colony using an omni-directional antenna (Sirtrack, NZ) and ATS (Advanced Telemetry Systems) receiver R2100, and data logger D5041. The data logger was programmed to scan the assigned frequencies every thirty minutes and record presence or absence of signal. Not all VHF females returned reliable data, four VHF tags came off early, four females were not picked up

on a regular basis most likely due to terrain, two VHF tags did not return any data and were presumed faulty and one female was never re-sighted with a pup.

Behavioural sampling of maternal attendance

Tags or scars could be used to identify approximately 70 females in 2004 and approximately 120 females in 2005. Although more females were in the photo ID database, not all were reliably identified between multiple observers. The colony was searched twice a day weather permitting from the clifftop using binoculars (8 x 40) and a spotting scope (20-60 x). If a female was present she was recorded along with whether or not she was with her pup and nursing. It was possible that a female could be at the colony but out of site during these colony checks. To correct for this, a subset of known females in an area where detailed pup behaviour was being recorded (See Chapter 5), were searched for once an hour to ensure a correct sighting. Once all data were compiled some females were not sighted frequently enough to reliably assess their attendance patterns, and these were left out of the final analysis. To be included in the final analysis females had to be in one of the two categories of most frequent sightings from Table 1, and those that were not sighted as often, were only used for the time frame where their sightings were more reliable. Useful data were collected on 54 females in 2004 and 41 females in 2005. Out of 43 females seen in consecutive years, 19 were reliably sighted to provide a comparison between years (Table 1).

Data analysis

Telemetry data were initially analysed separately from the behavioural data to assess the frequency of arrival and departure times of females, and the presence of overnight foraging trips. The frequency distributions of arrival and departure times were compared using a t-test for each year (Dytham 1999). The proportion of overnight foraging trips (OFT's) to all foraging trips (FT's), and the proportion of time spent ashore for VHF females was compared between years using a t-test. To test for a relationship between the number of OFTs performed and the proportion of time spent ashore a linear regression was performed between these two variables as per Goldsworthy (1999).

To assess maternal attendance patterns, data from all females (telemetry and behaviour) were used, and the duration of foraging trips, and shore bouts were calculated as was the proportion of time each female spent ashore. Foraging trip duration was the time spent at sea based on sighting and telemetry data, and shore bout duration was the time spent ashore. Proportion of time ashore was calculated as total time ashore out of total observation time. Where telemetry data was available, the time an individual was last picked up on the colony was used as a departure time, and the first sighting back on the colony was used as an arrival time. For animals where only behaviour was available, arrival and departure was calculated based on sightings as described by Lea and Hindell (1997) and Haase (2004). Initially these three variables were tested between years using a t-test to determine if the data from both years could be pooled. As differences between the years were detected (see Results: Maternal attendance patterns- seasonal differences) year was included as a factor in the following analysis. Females were categorised into groups based on year and the three variables described above, using a cluster analysis with Euclidean distances and a weighted pair group average amalgamation rule (STATISTICA v. 7). The grouped data were then tested for importance of factors in determining groups using a backwards discriminant function analysis and the accuracy in categorising females was tested with a jack-knife classification matrix (Lea *et al.* 2002; Baylis 2003; Haase 2004).

Differences in the proportion of time spent ashore based on days post partum (dpp) was analysed using a 1-way ANOVA for the following time blocks: 1-25, 26-50, 51-75, 76-100 and 101-125 dpp each year. To account for lack of independence between the time blocks a Bonferonni correction was applied to the p-value. Nineteen females were reliably sighted during both seasons, and their foraging trip duration, shore bout duration and proportion of time ashore were compared between years using a paired sample t-test (Dytham 1999).

Results

VHF results

A total of 24 females returned reliable data from VHF transmitters over the two seasons (Figures 2 and 3). Information was collected on 177 shore bouts (SBs) and

157 foraging trips (FTs) in 2004, followed by 146 SBs and 134 FTs in 2005. In both years overnight foraging trips (OFTs; defined as night-time absences of 6 hours or more) were observed (44 in 2004 and 57 in 2005). All females except one in 2004 performed OFTs, and their frequency ranged from 0-6 in 2004 to 1-17 in 2005 (Table 2, Figures 2 and 3). Mean OFT duration was 14.5 hours in 2004 and 13.1 hours in 2005. OFTs occurred between 27-99 days post partum (dpp) in 2004, and 24-110 dpp in 2005, with 90% of OFTs happening over 41 days in 2004 (27-68 dpp) and 57 days in 2005 (32-89 dpp) (Figure 4). Only eight OFTs in either year took place after 80 dpp, and median and peak dpp for OFTs to occur were 63 and 44, and 67 and 40 for 2004 and 2005, respectively (Figure 4). While the occurrence of OFTs appeared higher in the second season, so did the relative proportion of overnight foraging trips undertaken (0.29 in 2004 vs. 0.42 in 2005) calculated by: # OFTs / # FTs. This apparent increase in importance of OFTs in the second season was found to be significant ($t = -1.89$, $df = 16$, $p = 0.03$, Table 3). There was a slight increase in the proportion of time females spent ashore in the second season, however, this result was not significant ($t = -1.32$, $df = 15$, $p = 0.10$, Table 3). The proportion of time females spent ashore was significantly related to the proportion of OFTs to all FTs performed ($r^2 = 0.3664$, $df, 23$, $p = 0.0017$).

In both years the mean time that females arrived on the colony was late morning (1120 and 1058 hours, respectively) and the mean time females departed for foraging was usually late afternoon (1606 and 1628 hours, respectively; Table 2). In both seasons the frequency of arrival times were spread throughout the day, while departure times were more tightly clumped around 1500-1800 hours (Figure 5). In both seasons the distribution of arrival and departure times were significantly different ($p < 0.0001$ for both seasons).

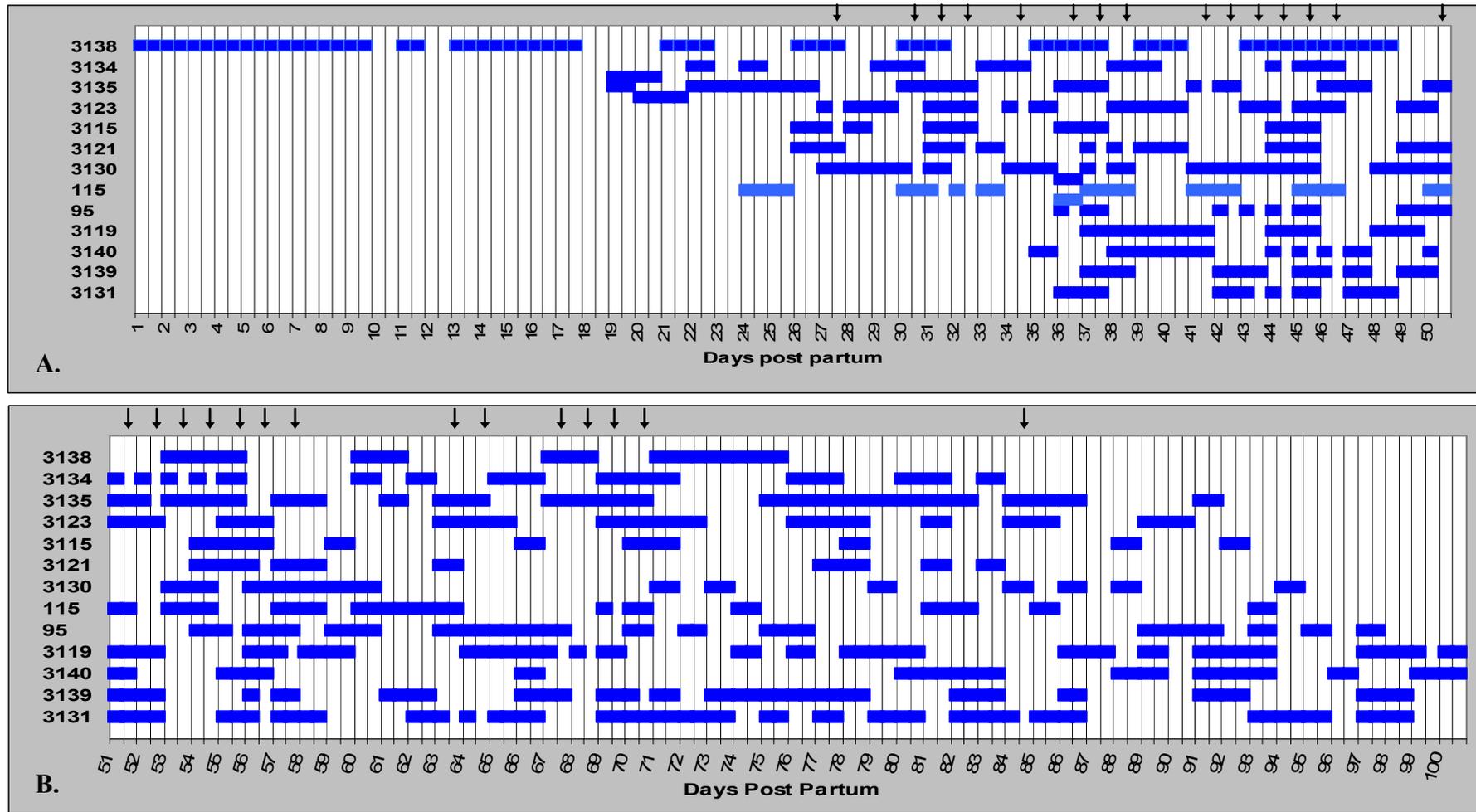


Figure 2: The presence and absence of 13 females fitted with VHF transmitters in 2004 for A) 0-50 days post partum, and B) 51-100 days post partum. Blue bars denote when the female is present on the colony. Each day is divided into two time blocks to show when overnight foraging trips occurred. Arrows denote the days in which these occurred.

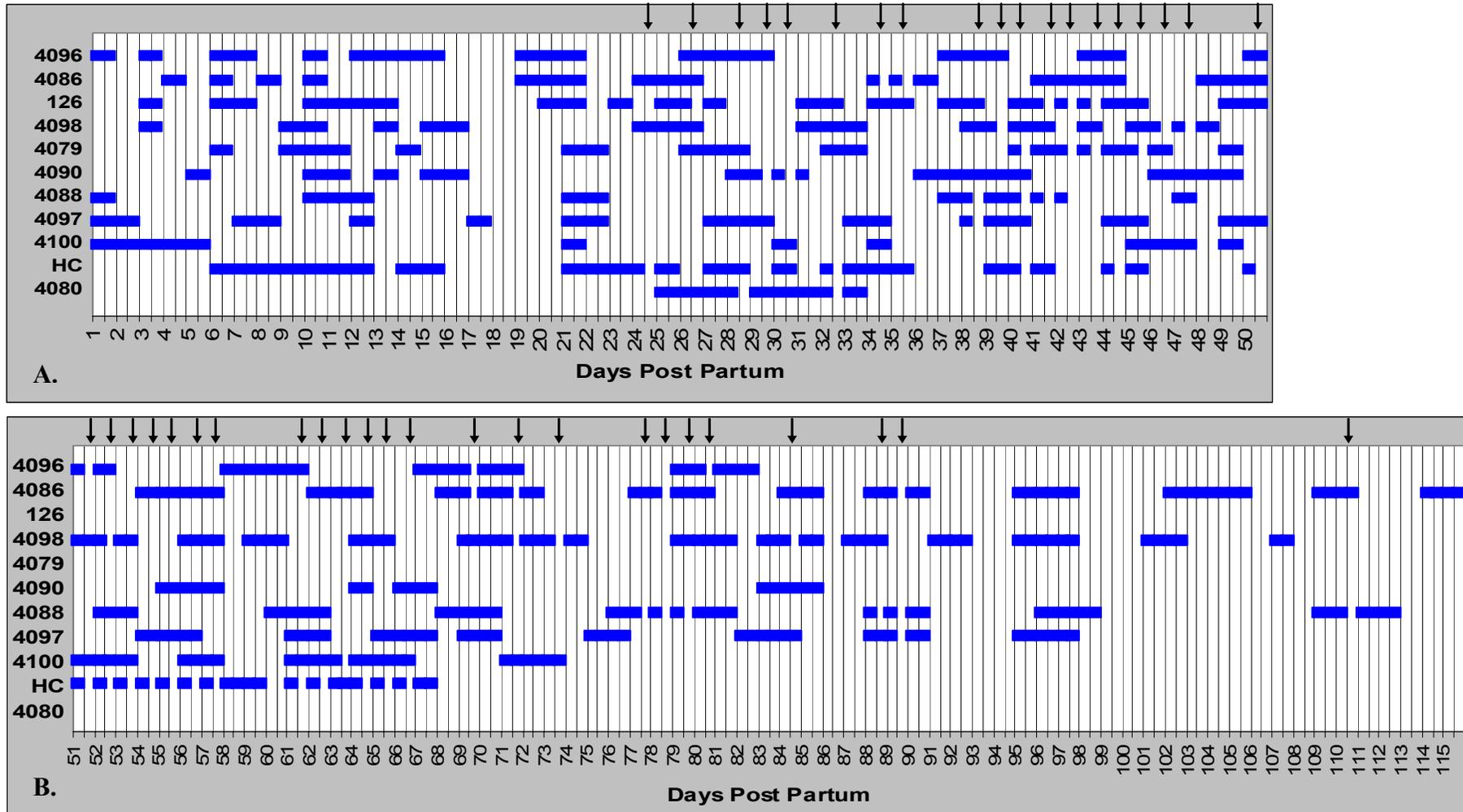


Figure 3: The presence and absence of 11 females fitted with VHF transmitters in 2005 for A) 0-50 days post partum, and B) 51-115 days post partum. Blue bars denote when the female is present on the colony. Each day is divided into two time blocks to show when overnight foraging trips occurred. Arrows denote the days in which these occurred.

Table 2: Raw data for 13 (2004) and 11 (2005) VHF tagged female *A. forsteri* that returned reliable data including the number of: Foraging trips (FTs); Shore bouts (SBs); Overnight foraging trips (OFTs); and Extended foraging trips (EFTs). Also shown are: the proportion of overnight to all foraging trips undertaken for each female (Prop OFT / FT); the proportion of time each female spent ashore; and the mean arrival and departure times for each female. Group mean and standard deviations are calculated for the final four categories and group means are displayed in bold. Standard deviation of arrival and departure times are in minutes.

	Female ID	# FTs	# SBs	# OFTs	# EFTs	Prop OFT / FT	Prop time ashore	Mean OFT duration (hours)	Mean Arrival time (24 hour time)	Mean Departure time (24 hour time)
2004	3119	16	18	4	12	0.25	0.46	16.4	1050	1439
	3130	8	9	2	6	0.25	0.60	15.5	1133	1678
	115	15	16	3	12	0.20	0.44	22.2	1269	1671
	3131	20	22	6	14	0.30	0.47	18.8	1105	1555
	3115	5	6	1	4	0.20	0.34	21.5	1267	1600
	95	13	14	5	8	0.38	0.47	15.2	1157	1758
	3118	11	13	0	11	0.00	0.42	0	1338	1546
	3121	9	10	4	5	0.44	0.48	14.5	1050	1840
	3123	12	15	4	9	0.31	0.52	14.0	779	1621
	3139	11	13	4	7	0.36	0.56	14.1	931	1550
	3140	7	8	4	3	0.57	0.53	17.8	1038	1600
	3134	19	21	5	14	0.26	0.40	15.8	1329	1655
	3135	11	12	2	9	0.18	0.52	17.3	1067	1458
	total / mean	157	177	44	114	0.29	0.48	14.5	1120	1606
SD					0.14	0.07	6.64	160.29	111.25	
2005	4080	3	4	2	1	0.67	0.78	13.5	1000	1675
	HC	24	25	17	7	0.71	0.66	13	860	1884
	4100	5	6	1	4	0.20	0.59	18.5	1233	1467
	4097	14	15	2	12	0.14	0.46	10.0	1186	1573
	4088	16	19	9	8	0.53	0.42	10.6	941	1735
	4090	9	10	2	7	0.22	0.34	12.8	1256	1340
	4079	6	7	4	2	0.67	0.57	14.3	1043	1567
	4098	22	22	7	15	0.32	0.52	15.2	1091	1732
	126	7	8	4	3	0.57	0.57	16.8	1013	1713
	4086	19	20	6	13	0.32	0.49	10.7	979	1660
	4096	9	10	3	6	0.33	0.44	9.3	1040	1560
	total / mean	134	146	57	78	0.42	0.53	13.1	1058	1628
SD					0.21	0.12	2.91	123.40	147.83	

Table 3: Results of t-tests comparing the proportion of overnight foraging trips (OFT) to all foraging trips (FT) and the proportion of time spent ashore each year. The percentage of females performing overnight foraging trips is also shown.

	Percentage of Females doing OFTs	Proportion of OFT / All FT	Proportion of time ashore
2004	92%	0.29	0.48
2005	100%	0.42	0.53
t-statistic		-1.89	-1.32
p-value		P = 0.03	P = 0.10

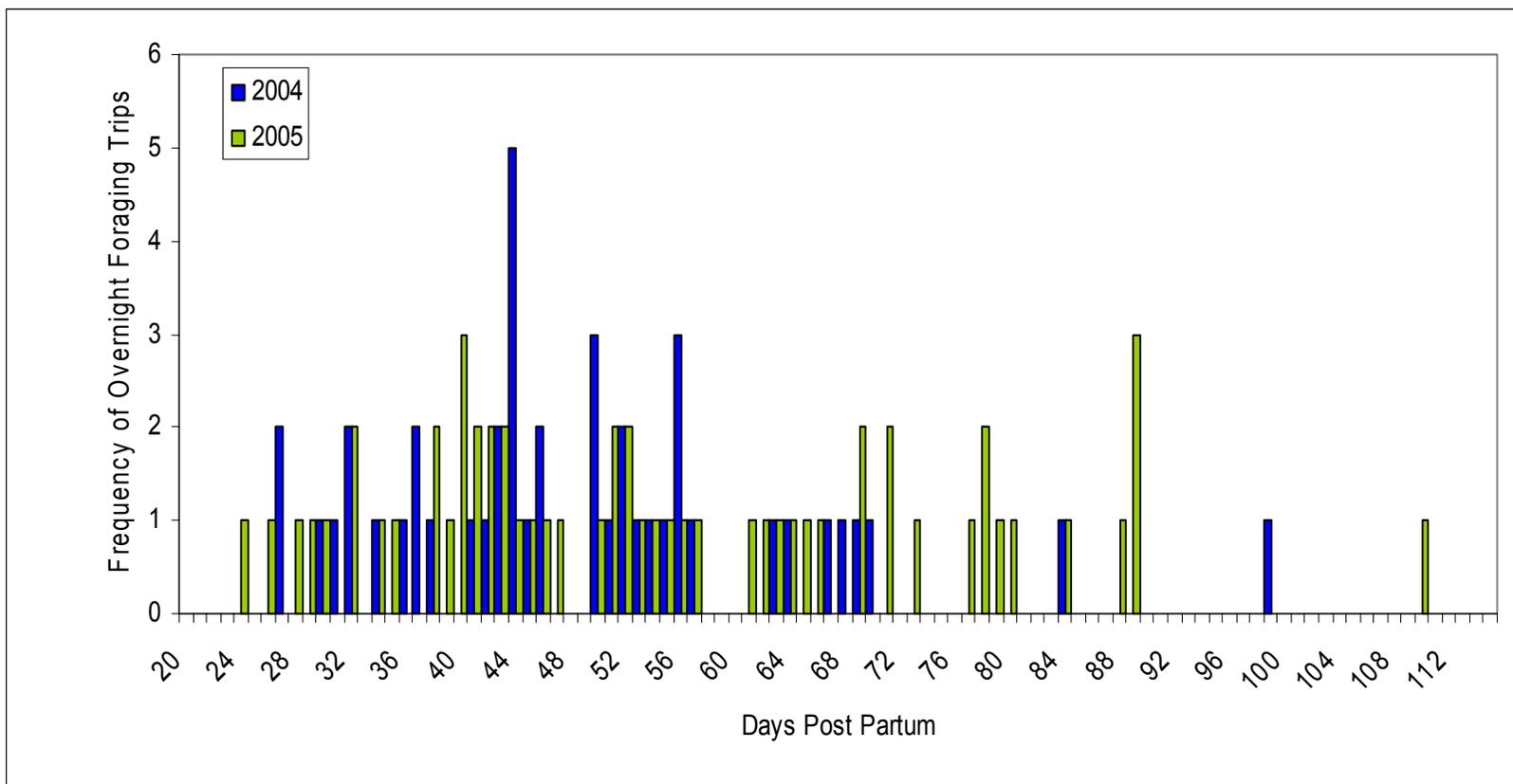


Figure 4: The frequency of overnight foraging trips (OFTs) based on days post partum for 23 VHF females which performed OFTs (12 in 2004 and 11 in 2005). A total of 44 and 57 OFTs were observed.

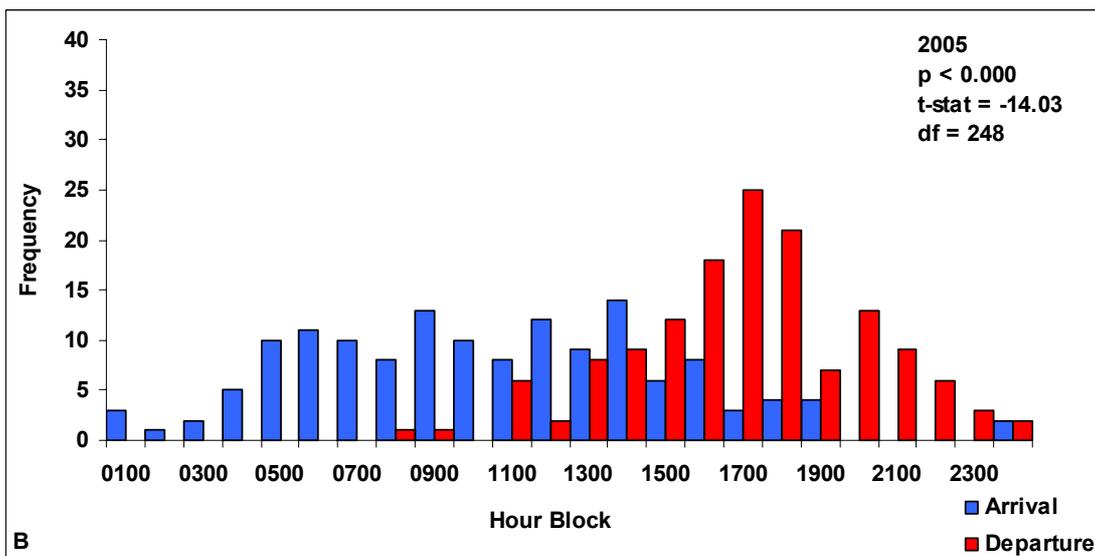
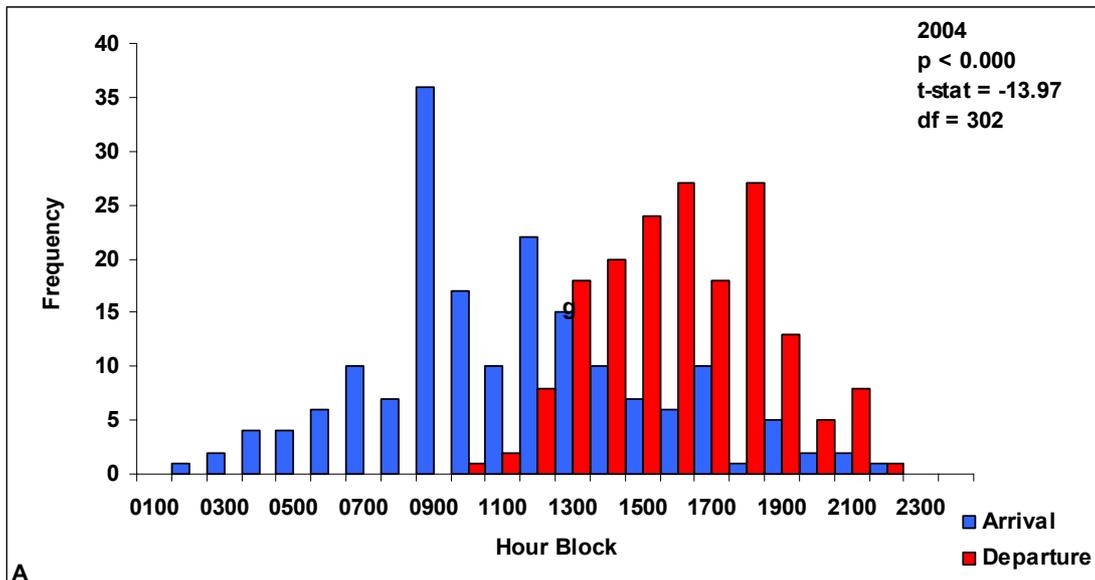


Figure 5: The frequency distribution of adult female fur seals arrival times on the colony and departure times when leaving the colony in A) 2004 and B) 2005.

Do females at Ohau Point show distinct maternal attendance patterns?

Seasonal differences

Before categorising maternal attendance patterns, the behaviours used to classify the different patterns were compared between years. Foraging trip (FT) duration, shore bout (SB) duration and the proportion of time spent ashore (PROP) for 54 females in 2004 and 41 females in 2005 were compared. Foraging trip duration was found to be significantly longer in 2005 (4.25 ± 1.39 d vs. 2.74 ± 0.50 d, $p < 0.0001$, Table 4). Shore bout duration was slightly longer in 2005 ($p = 0.04$), while there was no difference between the proportion of time spent ashore each year ($p = 0.85$). Because of the significant difference in foraging trip duration between years, the year needed to be taken into account when looking for distinct attendance patterns.

Table 4: Mean foraging trip (FT) duration and shore bout (SB) duration in days +/- SD, and the mean proportion of time females spent ashore (PROP) in 2004 and 2005 for 54 and 41 females respectively from birth to approximately 125 days post partum. Significant differences were found between years for FT and SB duration as denoted by p-values in bold.

	FT (days)	SB (days)	PROP
2004	2.74 +/- 0.50	1.75 +/- 0.44	0.35 +/- 0.12
2005	4.25 +/- 1.39	2.03 +/- 0.72	0.35 +/- 0.11
t - statistic	6.49	2.08	0.19
p - value	<0.0001	0.04	0.85

Grouping of females

Before categorising all females together, the 23 females that performed OFTs were categorised on their own, and then with the remaining females making up the 95 individuals for which behavioural and/or VHF data were available over the 2 years of this study. This was done to see how much the OFTs influenced the females' groupings since behavioural data alone cannot pick up when OFTs occur. Cluster analysis using the variables 1) Number of OFTs, 2) FT duration, 3) SB duration, and 4) Proportion of time ashore and year as a predicting factor gave the resulting groups as shown in Figure 6. The 23 females with VHF transmitters were grouped into 3 main groups of 11, 7, and 3 individuals with 2 distinctly different individuals as outliers (Group 4). A backwards discriminant factor analysis (DFA) of the 23 VHF females showed that year was less important in differentiating the females ($p =$

0.138), but that the number of OFTs performed was the most significant contributor to the groupings ($p < 0.0001$, Table 5) followed by shore bout duration ($p = 0.002$), foraging trip duration ($p = 0.004$) and finally proportion of time ashore ($p = 0.008$). The model also successfully categorised 95.65% of the females (Table 6).

Comparing the categorisation of the VHF females between Figure 6 (23 VHF females only) and Figure 7 (95 females without OFTs included in analysis), 16 out of 23 (69.5%) females were grouped similarly in both analyses. A subsequent backwards discriminant factor analysis (DFA) of all 95 females, showed that year ($p = 0.0001$) and foraging trip duration (FT) ($p = 0.0001$) and to a lesser extent shore bout (SB) duration ($p = 0.0191$), were found to be important in defining female attendance patterns (Table 7). The classification matrix showed that 87% of females were correctly assigned using this model, with all females in groups 1-3 being correctly assigned (Table 8). As an alternate way of assessing the importance of foraging trip duration on the grouping of females, the individual females were plotted based on their residual foraging trip duration from each year's mean (2.74 days for 2004 and 4.75 for 2005) and according to the group they were assigned (Figure 8). This figure shows that females in G1 typically performed foraging trips of greater duration than the mean for their year, G2 females performed trips much shorter than the mean, G3 females performed trips around the mean, or slightly shorter, and G4 females were spread evenly around the mean. Despite this general clumping based on foraging trip duration, it is apparent from this figure that foraging trip duration alone cannot adequately categorise female behaviour and that other factors contribute in shaping these patterns. However, while the behavioural data was useful in increasing the sample size of females in this study and accurately categorised around 70% of the VHF females without the inclusion of OFTs in the analysis, it is clear that in this region, OFTs do play an important role in shaping maternal attendance patterns, and behavioural data alone is not sufficient.

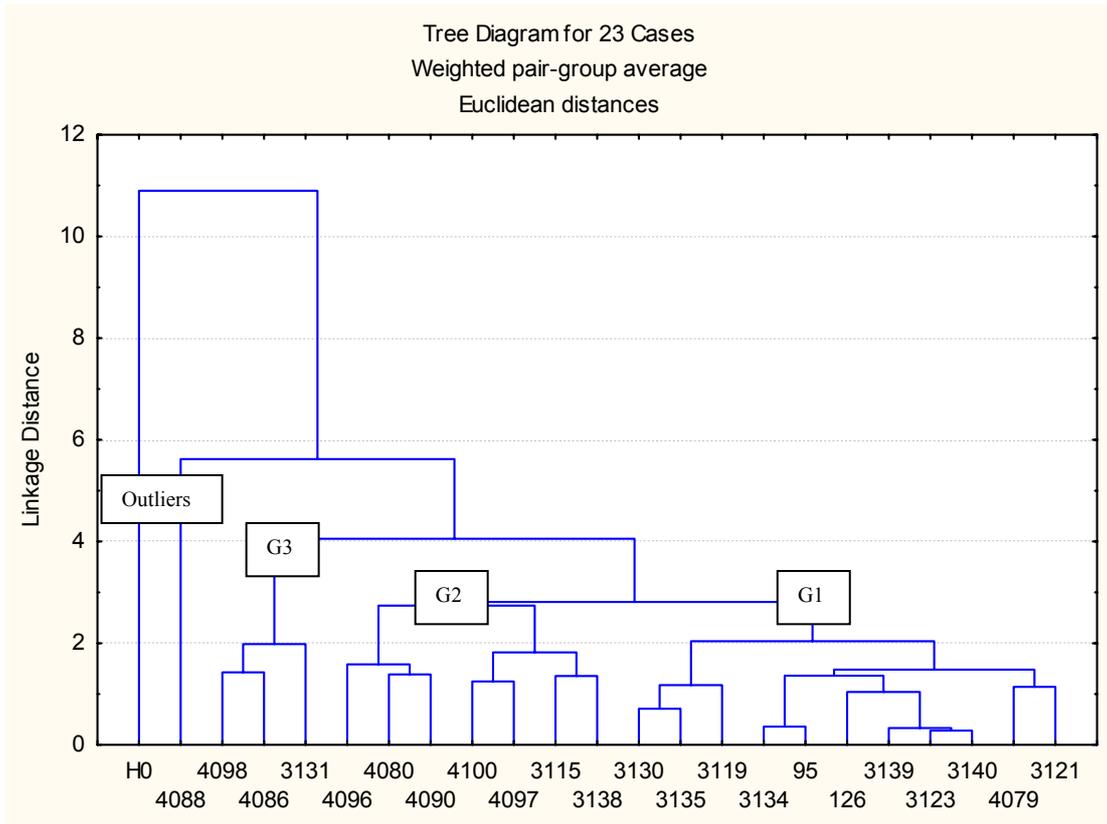


Figure 6: Dendrogram showing clustering of 23 individual females fitted with VHF transmitters from both seasons into groups based on year, foraging trip duration, shore bout duration, the proportion of time ashore, and the number of overnight foraging trips performed.

Table 5: Results of backwards discrimination factor analysis for 23 adult female fur seals with VHF transmitters in 2004 and 2005. Significant p-values for the variables used in the analysis are shown in bold. Also in bold is the percentage of females correctly assigned to a strategy.

	Wilks' Lambda	Partial Lambda	F-remove (3,15)	p-level	Tolerance	1-Tolerance (R-Square)
Year	0.041	0.701	2.137	0.138	0.541	0.459
Number OFTs	0.353	0.081	56.623	0.000	0.343	0.657
Foraging Trip Duration	0.067	0.426	6.739	0.004	0.252	0.748
Shore Bout Duration	0.076	0.376	8.293	0.002	0.214	0.786
Proportion of time ashore	0.062	0.461	5.844	0.008	0.189	0.811

Table 6 Classification matrix for 23 females categorised by the above model, showing the proportion of females correctly categorised.

	Percent Correct	G_1:1 p=.478	G_2:2 p=.304	G_3:3 p=.130	G_4:4 p=.087
G_1:1	90.91	10	0	1	0
G_2:2	100.00	0	7	0	0
G_3:3	100.00	0	0	3	0
G_4:4	100.00	0	0	0	2
Total	95.65	10	7	4	2

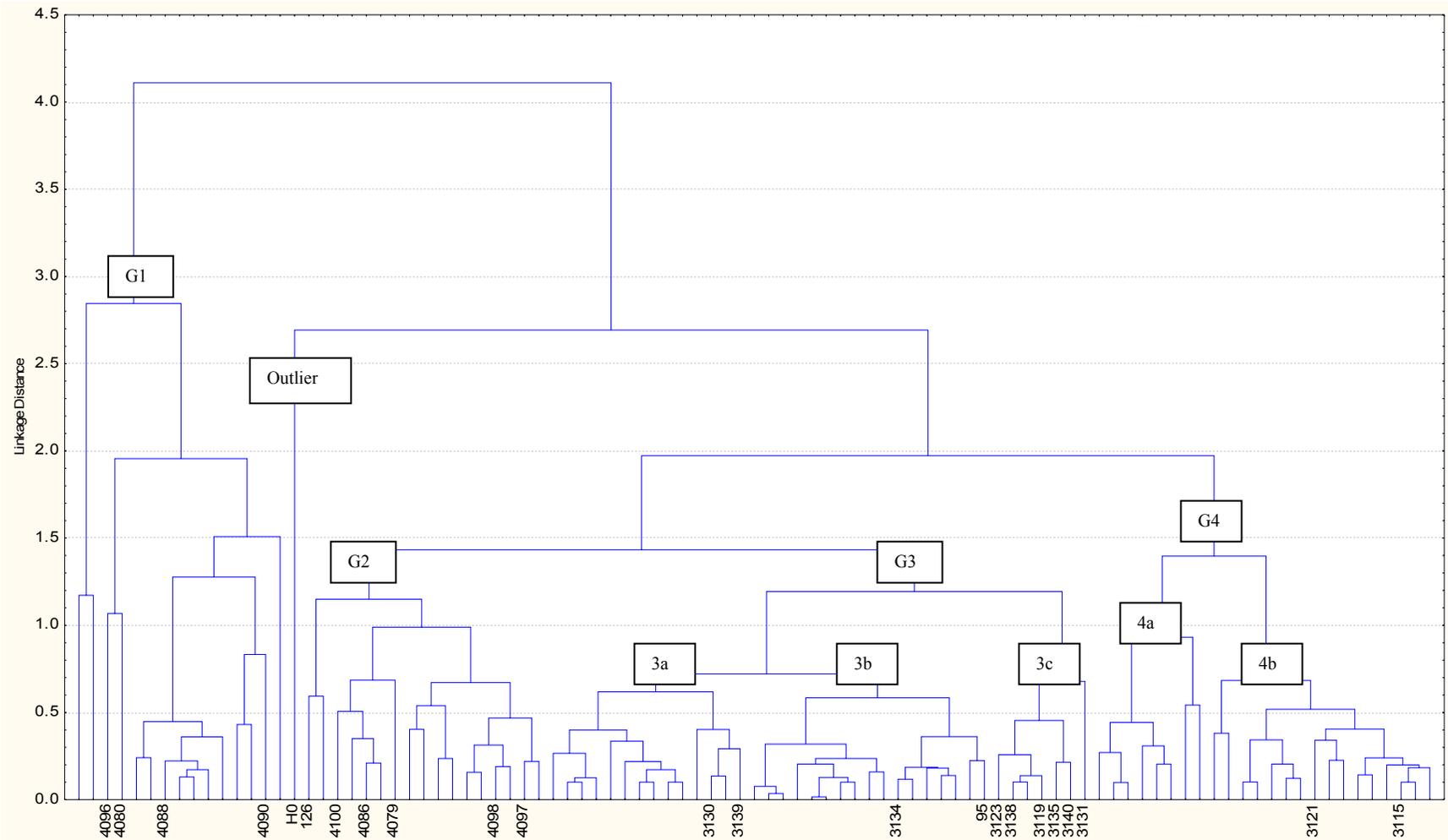


Figure 7: Dendrogram showing clustering of 95 individual females from both seasons into 4 groups based on year, foraging trip and shore bout duration.

Table 7: Results of backwards discrimination factor analysis for 95 adult female fur seals in 2004 and 2005. Significant p-values for the variables used in the analysis are shown in bold. Also in bold is the percentage of females correctly assigned to a strategy.

	Wilks' Lambda	Partial Lambda	F-remove (3,87)	p-level	Tolerance	1-Tolerance (R-Squared)
Year	0.1076	0.3613	51.275	0.0001	0.7615	0.2384
Foraging Trip Duration Shore Bout	0.1092	0.3561	52.427	0.0001	0.6318	0.3682
Duration	0.0436	0.8926	3.489	0.0191	0.3440	0.6559
Proportion of time ashore	0.0422	0.9211	2.485	0.0659	0.2959	0.7040

Table 8: Classification matrix for 95 females categorised by the above model, showing the proportion of females correctly categorised.

	Percent Correct	G_1:1 p=.15957	G_2:2 p=.18085	G_3:3 p=.40426	G_4:4 p=.25532
G_1:1	100.00	15	0	0	0
G_2:2	100.00	0	17	0	0
G_3:3	100.00	0	0	38	0
G_4:4	50.00	1	6	5	12
Total	87.23	16	23	43	12

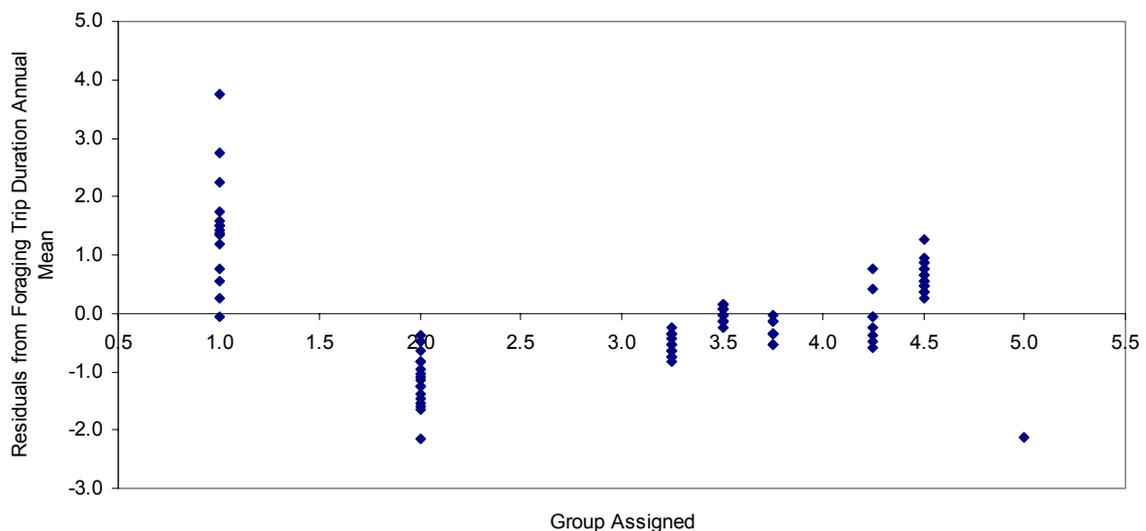


Figure 8: Grouping of 95 females in 2004 and 2005 based on foraging trip duration and each female's deviation from the mean for which they were observed (2004 = 2.74 days, and 2005 = 4.25 days). Each point represents an individual female and they are arranged on the x-axis according to the group they were assigned (3a = 3.25, 3b = 3.5, 3c = 3.75, 4a = 4.25, 4b = 4.5, outliers = 5). Some overlap may occur between females with very similar foraging trip residuals, and as a result there may appear to be fewer than 95 points.

Proportion of time spent ashore based on days post-partum

The proportion of time females spent ashore was analysed based on the time in the females' lactation cycle, to see if females spent progressively more time at sea as lactation increased. The results are displayed in Table 9, and are broken into five time blocks of equal length. To account for the lack of independence in this test by following the same individuals through time, a Bonferonni correction has been made to the p-values. The p-values were adjusted according to the number of females available for the first time block in each year (54 in 2004 and 42 for 2005) thus the p-values required for acceptance were $p < 0.0009$ for 2004, and $p < 0.0012$ for 2005). Although in both years a difference was observed between the first time block and the rest the only significant changes in the proportion of time spent ashore were apparent during 2005 ($p < 0.0001$). More time was spent ashore in the first 25 days post-partum than later in lactation, however, the variation in time spent ashore decreased as lactation progressed. In 2004, time spent ashore varied little between 26 and 125 days (0.30-0.39). More variation was observed in 2005 with a noticeable decrease in time spent ashore at 101-125 days, however, only three females had data extending this far into the lactation cycle.

Table 9: The proportion of time females spent ashore based on days post-partum. Time blocks were divided into five blocks of 25 days each. Significant p-values from the ANOVA are displayed in bold. Bonferonni corrected p-values required for significance are $p < 0.0009$ for 2004 and $p < 0.0012$ for 2005.

	Days Post Partum	1 - 25 days	26 - 50 days	51 - 75 days	76 - 100 days	101 - 125 days	F-stat P-value
2004	Proportion of time ashore	0.68	0.39	0.30	0.36	0.33	53.90
	SD	0.13	0.17	0.14	0.13	0.04	0.001
	N	54	54	54	40	3	
	Proportion of time ashore	0.50	0.31	0.43	0.36	0.24	13.86
2005	SD	0.09	0.12	0.16	0.18	0.17	<0.0001
	N	42	37	10	6	3	

Female attendance patterns in consecutive years

Nineteen females were reliably observed in both 2004 and 2005 (Table 10). The behaviour of these females was compared between years using a paired sample t-test, and although some females did show significant changes in behaviour between the two seasons, the overall difference in shore bout duration and proportion of time spent ashore were undetectable (mean difference in SB: 0.05, $p = 0.73$; mean difference in PROP: 0.04, $p = 0.10$). There was, however, a significant change in the foraging trip

duration in the second year (mean difference in FT: -1.86, $p < 0.0001$) with females spending more time at sea in 2005 (Table 10).

Table 10: Mean shore bout duration, foraging trip duration and proportion of time spent ashore in consecutive years for 19 females. Differences in their results between years are shown (DIFF) and results of Paired sample t-test are shown with significant p-values in bold.

	<u>Shore Bout Duration</u>			<u>Foraging Trip Duration</u>			<u>Proportion of Time Ashore</u>		
	<u>(days)</u>	<u>(days)</u>	<u>(days)</u>	<u>(days)</u>	<u>(days)</u>	<u>(days)</u>	<u>(days)</u>	<u>(days)</u>	<u>(days)</u>
Females	2004	2005	DIFF	2004	2005	DIFF	2004	2005	DIFF
1425	1.40	1.80	-0.40	3.20	2.70	0.50	0.30	0.40	-0.10
3133	2.40	2.00	0.40	2.60	3.11	-0.51	0.52	0.39	0.12
BOBT	1.60	3.00	-1.40	2.10	6.50	-4.40	0.38	0.32	0.06
616	1.90	2.43	-0.53	1.90	2.67	-0.77	0.48	0.52	-0.03
3134	1.90	1.44	0.46	2.60	2.78	-0.18	0.40	0.34	0.06
7559	1.70	1.88	-0.18	2.00	3.43	-1.43	0.41	0.38	0.03
BRBT	2.00	2.67	-0.67	2.80	4.50	-1.70	0.38	0.49	-0.12
EI	1.40	2.00	-0.60	3.10	5.75	-2.65	0.23	0.30	-0.07
Ph	1.90	1.75	0.15	2.80	2.88	-0.08	0.47	0.38	0.09
627	1.90	1.11	0.79	3.50	3.00	0.50	0.30	0.29	0.00
25	1.70	1.80	-0.10	3.60	7.00	-3.40	0.27	0.24	0.02
7499	1.80	1.67	0.13	3.20	5.60	-2.40	0.29	0.26	0.02
7561	1.40	1.20	0.20	3.60	8.00	-4.40	0.16	0.13	0.03
7570	1.50	1.60	-0.10	2.30	6.00	-3.70	0.30	0.25	0.05
95	2.20	1.00	1.20	2.40	4.67	-2.27	0.39	0.22	0.17
0793	1.60	1.60	0.00	2.90	5.75	-2.85	0.25	0.26	-0.01
3123	2.40	1.17	1.23	2.40	4.20	-1.80	0.50	0.25	0.25
Le	1.70	1.43	0.27	2.40	5.83	-3.43	0.38	0.22	0.15
Lu	1.60	1.50	0.10	2.90	3.20	-0.30	0.34	0.36	-0.02
Average	1.79	1.74	0.05	2.75	4.61	-1.86	0.35	0.32	0.04
SD	0.31	0.52	0.64	0.52	1.67	1.60	0.10	0.10	0.09
T - stat			0.35			-5.06			1.74
P - value			0.73			<0.0001			0.10

Discussion

Female attendance patterns

Maternal strategies in otariid seals have been shown to vary between polar, tropical and temperate regions with subpolar species exhibiting short fixed strategies, tropical species exhibiting long variable strategies, and temperate species intermediate between the two (Gentry *et al.* 1986; Trillmich 1990). However, within species, noticeable differences in maternal strategies have been documented between populations (*A. forsteri*: Stirling 1971; Harcourt *et al.* 2001, *A. gazella*: Goldsworthy 1999; Robinson *et al.* 2002, *A. tropicalis*: Lea *et al.* 2002; Beuplet *et al.* 2004, *Eumetopias jubatus*: Millette and Trites 2003). Within *A. forsteri*, differences have been observed in the length of the lactation period (Stirling 1971; Mattlin 1978; Haase 2004; Chapter 3), and maternal attendance and dive behaviour (Harcourt *et al.* 1995; Harcourt *et al.* 2001). The results from these and other studies have suggested that various maternal traits are influenced more by bathymetry, resource availability and local environment than latitudinal changes (Harcourt *et al.* 1995; Robinson *et al.* 2002).

In the current study maternal time spent at sea on individual foraging trips averaged 2.74 days in 2004 and 4.25 days in 2005. This is similar to some of the information quoted for *A. forsteri* maternal foraging trips early in lactation (Cape Guantheaume, 2.6 days – Goldsworthy 1992; Otago Peninsula, 3.6 days – Harcourt *et al.* 1995; Maatsuyker Island, 3.5 days – Lea and Hindell 1997) however, maternal time spent at sea was remarkably short compared with foraging trip durations reported incorporating later periods of lactation (Cape Guantheaume, 7.71 days – Goldsworthy 1992; Maatsuyker Island, 7.5 days – Lea and Hindell 1997; Otago Peninsula, 7.6 days (autumn) and 11.8 days (winter) – Harcourt *et al.* 2002). Time spent onshore was similar to or slightly longer than that reported from other colonies of *A. forsteri* (1.6-2.6 days vs. Cape Guantheaume, 1.2 days – Goldsworthy 1992; Maatsuyker Island, 1.2 days – Lea and Hindell 1997; Otago Peninsula, 1.4-3.1 days – Harcourt *et al.* 2002).

Grouping of females

Evidence for distinct attendance patterns using VHF data alone, and VHF and behavioural data combined, was shown in this study with differing results (Figures 6

and 7). The patterns based on both behaviour and VHF information included a greater sample size and female behaviour was primarily characterised by year and by female foraging trip duration (Table 8), as shore bout duration was fairly consistent, between 1.6-2.6 days, (Table 4). However, the inclusion of information on overnight foraging trips, available only for VHF females, suggests that in the Kaikoura region, overnight foraging trips occur at high enough rates to be important in shaping distinct maternal attendance patterns (Table 5). Therefore, behavioural data alone are unlikely to be an adequate indicator of female attendance patterns in this region. On the other hand, behavioural data are still useful in providing information on a greater sample size of females and the inter-annual changes in time spent at sea and its subsequent effect on pup growth and condition.

Other recent studies also have detected distinct foraging, maternal attendance and diving strategies in otariids based on a number of variables associated with foraging trip duration and dive behaviour (Lea *et al.* 2002; Baylis 2003; Haase 2004). A study investigating foraging behaviour of pre-weaning age *A. forsteri* pups at Kangaroo Island also detected distinct groups related to pup diving experience and aptitude (Baylis 2003). In a study on adult female *A. gazella*, a species with a short, fixed lactation length, at Iles Kerguelen, females were shown to fall into four distinct dive behaviour groups based on 12 dive parameters collected using time depth recorders (TDRs) (Lea *et al.* 2002). Foraging trip length was one of the key factors along with dive depth and proportion of time spent diving, in determining the grouping of females (Lea *et al.* 2002). Yet another study based at Kangaroo Island investigating maternal provisioning strategies of *A. forsteri*, detected 2 main groups, each with 2 subgroups (Haase 2004). Of the six behavioural parameters used to identify maternal provisioning strategies, Haase (2004) also found that foraging trip duration played a significant role in determining groups, whereas shore bout duration was less critical and did not vary significantly between the groups or subgroups.

In the current study, there was a significant increase in mean foraging trip duration in the second season from 2.74 to 4.25 days (Table 4). The observed changes in foraging trip duration within the colony ($n = 95$ females) over two years at Ohau Point suggests behavioural adjustment in response to changing environmental variables and/or resource availability. This increase in foraging trip duration in the 2004/05 austral summer coincided with a highly negative Southern Oscillation Index (SOI) indicative

of an El Niño event and warmer than average sea surface temperatures (SSTs) (NIWA 2005; Chapter 5).

Since foraging trip duration was found to be the most influential variable in determining groups and the mean foraging trip duration was significantly different between years, clustering of all individuals from both years could not be carried out in the same manner as Lea *et al.* (2002) and Haase (2004) did. As a consequence of this year had to be included as a predicting factor in the groupings. By clustering all individuals in one analysis, Lea *et al.* (2002) and Haase (2004) were able to assess the importance of each behavioural group detected over multiple seasons as defined by the proportion of females assigned to a group each year. For *A. forsteri* at Kangaroo Island no difference was found in the number of individuals from each year assigned to each of the groups despite a 10% increase in the number of females exhibiting short foraging trips in 2003 (Haase 2004). On the other hand, *A. gazella* at Iles Kerguelen did exhibit a shift in diving behaviour with significantly more females assigned to the deep diving group in 1998 versus other years (Lea *et al.* 2002). Due to the importance of year in classifying female attendance patterns in the current study, such a comparison between studies is not possible, as groups 1 and 2 were comprised of females observed in 2005, while group 3 were those from 2004. Group 4 was the only group to contain females from both years (66% from 2004). However, it is worth pointing out that this fits with the general trends observed between years as group 1 females tended to perform long foraging trips while group 3 females tended towards shorter foraging trips (Figure 8).

In order to assess whether or not maternal attendance patterns were consistent over years at Ohau Point, the behaviour of 19 known females sampled in consecutive years was analysed. Although all 19 females showed similar shore bout durations, and proportion of time spent ashore each year, they also showed significant changes in foraging trip duration (Table 10). This observed difference in foraging trip duration within individuals again supports the idea that females at Ohau Point were adapting their patterns to cope with environmental variations between years. Similarly, in the study of *A. forsteri* at Kangaroo Island, 32 females were observed in multiple years, and 63% of them were reported to have switched provisioning groups between years with no predictable pattern for switching evident (Haase 2004). Only five females were sampled in multiple years at Iles Kerguelen (Lea *et al.* 2002) making a

comparison between this study and the current study difficult. The implications of such changes in maternal attendance patterns on pup growth and condition will be discussed in the following chapter.

Night-time foraging and location of food source

The data presented showed that females typically depart the colony in late afternoon (c.1600-1800 hrs) and return onshore in the middle of the morning (c.0800-1000 hrs) indicating that they are doing much of their foraging at night. This is consistent with prior knowledge of this species' diel habits (Trillmich 1990; Harcourt *et al.* 1995) and similar to that observed for *A. forsteri* at Cape Gantheaume, Kangaroo Island: mean arrival time 0945, ranging between 0400-1400, with departures mainly occurring between 1200-1800 hours (Goldsworthy 1992).

The high occurrence of overnight foraging trips suggests that females at Ohau Point live close enough to a reliable food source to make such short (mean OFT durations: 13.1 and 14.5 hours for 2004 and 2005, respectively) feeding trips profitable. This is further supported by the high proportion of females performing overnight foraging trips (OFTs) (92-100%) and the relative importance of overnight foraging trips (approximately 29% and 42% of all foraging trips in 2004 and 2005, respectively). These OFTs occurred at highest frequencies around 40-60 days post partum (dpp), and in 2005 a second mode was detected around 80-90 dpp (Figure 4). Although overnight or "mini" foraging trips have been commonly reported in otariids they do not normally occur at a high frequency (Haase 2004). However, work on *A. gazella* and *A. tropicalis* at Macquarie Island showed that both species regularly used overnight foraging trips (15% and 25% of foraging time, Goldsworthy 1999) and on such trips, seals were foraging at a location within 10 km from the colony (Robinson *et al.* 2002). Also, overnight foraging trips were still utilised by both species throughout the first 120 days of lactation, although to a lesser degree in *A. gazella* (Goldsworthy 1999). For *A. tropicalis* the percentage of foraging time apportioned to OFTs was greatest early in lactation (approximately 50% of all FTs) and again at 80-100 dpp (50% of all FTs), similar to that observed in the current study (Figure 4). Both the Ohau Point and Macquarie Island colonies are located close to a deep-sea canyon with a major upwelling (Ohau Point: 2 km, Benoit-Bird *et al.* 2004; Macquarie Island: 3 km, Robinson *et al.* 2002) and the close proximity to an area rich in prey

species may strongly influence some of the behavioural parameters observed in female foraging cycles, including the prevalence of overnight foraging trips.

Flexibility of maternal attendance patterns

The data presented here has documented the flexibility of female fur seal attendance patterns in a number of ways. Firstly, females spent more time on a single foraging trip in 2005 than in the previous year, coinciding with the 2005 El Niño event (Table 4). A lengthening of foraging trip duration by lactating females is commonly reported in response to decreased food availability in order to meet the nutritional demands of their pups (Ono *et al.* 1987; Trillmich *et al.* 1991; Beuplet *et al.* 2004). Also, shore bout durations were slightly longer in 2005, consistent with reported increases in shore bout duration in years of low food availability in order to maximise the transfer of nutrients to pups (McCafferty *et al.* 1998), although, in exceptionally poor years the opposite may be observed as the females are unable to meet the nutritional demands required to support a lengthy shore bout (Majluf 1991; Boyd 1999).

Typically, an increase in foraging trip duration would tend towards a decrease in the proportion of time spent ashore, and associated decrease in pup condition and growth (Ono *et al.* 1987; Haase 2004). However, at Ohau Point, no statistically significant difference was detected in the proportion of time spent ashore between the years. By increasing both the duration of shore bouts and the proportion of overnight foraging trips in 2005, females were able to compensate for the increased foraging trip duration observed and maintain a similar proportion of time spent ashore. Also, the time females spent ashore based on days post-partum did not change significantly between the period from 26 to 125 days post-partum (Table 9). Maternal time spent at sea typically increases as lactation progresses, in order to meet the nutritional demands of a growing pup (Harcourt *et al.* 1995; Harcourt *et al.* 2001). However, even though some longer (8-14 days) foraging trips were observed later in lactation at Ohau Point, they often followed a series of overnight foraging trips (Figures 2 and 3), which kept the proportion of time ashore around 30-39% in 2004 and 24-43% in 2005. The ability to perform overnight foraging trips is thought to be beneficial because it allows females to more easily balance the energy expenditure of foraging with nutrient transfer to a pup (Goldsworthy 1999). Short, frequent foraging trips are better for pup condition and growth because of reduced fasting time between maternal trips to sea (Goldsworthy 1999). However, these trips are more costly to a female than being able

to spend extended periods of time at one feeding patch (albeit further away) making alternation between overnight and extended foraging trips a useful strategy in pup rearing (Robinson *et al.* 2002).

Conclusion

The results presented here provide further support to the flexibility in maternal attendance patterns within *A. forsteri*, and support the findings of Chapter 3 (Colony dynamics and timing of weaning) which showed that environmental and climatic variables may play a significant role in shaping the maternal strategies and attendance patterns exhibited by *A. forsteri* in the Kaikoura region. Female *A. forsteri* at Ohau Point exhibited a high proportion of overnight foraging trips suggesting the utilisation of a close and rich food source. They also showed a dramatic change in maternal attendance patterns in response to a potential decrease in food availability during the 2004/05 El Niño event. It has been suggested that having a close, consistent food source may act as a buffer to minimise the negative effects typically observed in pup growth and condition during an El Niño (Boren 2001) and results from Chapter 2 (Colony growth and pup condition) showed that pups born during the 2004/05 season were in good condition in February despite the El Niño. It is possible that with the proximity of the canyon, females were able to adjust their attendance patterns between years to counter the potential negative effects on food availability associated with an El Niño event. The following chapter will develop these themes further by assessing the role that different female attendance patterns and environmental factors (eg. El Niño) can have on pup mass, growth and condition from birth to approximately 120 days of age.

References:

- Baylis, A. M. (2003). The ontogeny of dive behaviour in New Zealand fur seal pups (*Arctocephalus forsteri*). Postgraduate diploma in Zoology. Department of Zoology, LaTrobe University, Victoria, Australia.
- Beauplet, G., Dubroca, L., Guinet, C., Chernel, Y., Dabin, W., Gagner, C. and Hindell, M. (2004). Foraging ecology of subantarctic fur seals *Arctocephalus tropicalis* breeding on Amsterdam Island: seasonal changes in relation to maternal characteristics and pup growth. *Marine Ecology Progress Series* **273**, 211-225.
- Benoit-Bird, K., Würsig, B. and McFadden, C. (2004). Dusky dolphin (*Lagenorhynchus obscurus*) foraging in two different habitats: active acoustic detection of dolphins and their prey. *Marine Mammal Science* **20**, 215-231.
- Boness, D. J. and Bowen, W. D. (1996). The evolution of maternal care in pinnipeds. *BioScience* **46**, 645-654.

- Boren, L. J. (2001). Assessing the impact of tourism on New Zealand fur seals (*Arctocephalus forsteri*). MSc. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Boyd, I. (1999). Foraging and provisioning in Antarctic fur seals: interannual variability in time-energy budgets. *Behavioural Ecology* **10**, 198-208.
- Clutton-Brock, T. (1991). 'The evolution of parental care.' (Princeton University Press: Princeton, New Jersey.)
- Crawley, M. and Wilson, G. (1976). The natural history and behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Tuatara* **22**, 1-29.
- Dytham, C. (1999). 'Choosing and using statistics, a biologist's guide.' 1st. (Blackwell Science Ltd.: Oxford.)
- Gentry, R., Costa, D., Croxall, J., David, J., Davis, R., Kooyman, G., Majluf, P., McCann, T. and Trillmich, F. (1986). Synthesis and conclusions. In 'Fur seals: maternal strategies on land and at sea'. (Eds R. Gentry and G. Kooyman.) pp. 220-264. (Princeton University Press: Princeton, New Jersey.)
- Goldsworthy, S. (1992). Maternal care in three species of fur seal, *Arctocephalus* spp. at Macquarie Island. PhD thesis. Monash University, Melbourne, Australia.
- Goldsworthy, S. (1999). Maternal Attendance behaviour of sympatrically breeding Antarctic and Subantarctic fur seals, *Arctocephalus* spp., at Macquarie Island. *Polar Biology* **21**, 316-325.
- Goldsworthy, S. and Shaughnessy, P. (1994). Breeding biology and haul-out pattern of the New Zealand fur seal, *Arctocephalus forsteri*, at Cape Gantheaume, South Australia. *Wildlife Research* **21**, 365-376.
- Haase, T. (2004). The determinants of weaning in the New Zealand fur seal. Unpublished PhD. Department of Zoology, School of Life Sciences, La Trobe University, Victoria, Australia.
- Harcourt, R. G., Schulman, A. M., Davis, L. S. and Trillmich, F. (1995). Summer foraging behaviour by lactating female New Zealand fur seals (*Arctocephalus forsteri*) off Otago Peninsula, New Zealand. *Canadian Journal of Zoology* **73**, 678-690.
- Harcourt, R. G., Bradshaw, C. J. and Davis, L. (2001). Summer foraging behaviour of a generalist predator, the New Zealand fur seal (*Arctocephalus forsteri*). *Wildlife Research* **28**, 599-606.
- Harcourt, R. G., Bradshaw, C. J., Dickson, K. and Davis, L. S. (2002). Foraging ecology of a generalist predator, the female New Zealand fur seal. *Marine Ecology Progress Series* **227**, 11-24.
- Harting, A., Baker, J. and Becker, B. (2004). Non-metrical digital photo-identification system for the Hawaiian monk seal. *Marine Mammal Science* **20**, 886-895.
- Kovacs, K. M. and Lavigne, D. (1992). Maternal investment in otariid seals and walruses. *Canadian Journal of Zoology* **70**, 1953-1964.
- Lea, M.-A. and Hindell, M. (1997). Pup growth and maternal care in New Zealand fur seals, *Arctocephalus forsteri*, at Maatsuyker Island, Tasmania. *Wildlife Research* **24**, 307-318.
- Lea, M.-A., Hindell, M., Guinet, C. and Goldsworthy, S. (2002). Variability in the diving activity of Antarctic fur seals, *Arctocephalus gazella*, at Iles Kerguelen. *Polar Biology* **25**, 269-279.
- Majluf, P. (1991). El Nino effects on pinnipeds in Peru. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 55-65. (Springer-Verlag: London)

- Mattlin, R. (1978). Population biology, thermoregulation and site preference of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1828) on the Open Bay Islands, New Zealand. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch.
- McCafferty, D., Boyd, I., Walker, T. and Taylor, R. (1998). Foraging responses of Antarctic fur seals to changes in the marine environment. *Marine Ecology Progress Series* **166**, 285-299.
- Milette, L. L. and Trites, A. (2003). Maternal attendance patterns of Steller sea lions (*Eumatopias jubatus*) from stable and declining populations in Alaska. *Canadian Journal of Zoology* **81**, 340-348.
- Müller, G. (2004). The foraging ecology of South American sea lions (*Otaria flavescens*) on the Patagonian shelf. PhD thesis. Mathematics and Sciences Faculty, Christian-Albrechts-Universität, Kiel, Germany.
- NIWA (2005) The Climate Update. **74**, pp. 4. Wellington, New Zealand.
- Ono, K., Boness, D. J. and Oftedal, O. (1987). The effect of a natural environmental disturbance on maternal investment and pup behaviour in the California sea lion. *Behavioural Ecology and Sociobiology* **21**, 109-118.
- Orians, G. and Pearson, N. (1979). On the theory of central place foraging. In 'Analysis of Ecological Systems'. (Eds D. Horn, E. Stairs and R. Mitchell.) pp. 155-77. (Ohio State University Press: Columbus, Ohio, USA)
- Robinson, S., Goldsworthy, S., vandenHoff, J. and Hindell, M. (2002). The foraging ecology of two sympatric fur seal species, *Arctocephalus gazella* and *Arctocephalus tropicalis*, at Macquarie Island during the austral summer. *Marine and Freshwater Research* **53**, 1071-1082.
- Stirling, I. (1971). Studies on the behaviour of the South Australian fur seal, *Arctocephalus forsteri* (Lesson) II. adult females and pups. *Australian Journal of Zoology* **19**, 267-273.
- Stokes, D. and Boersma, P. (1999). Where breeding Magellanic penguins *Spheniscus magellanicus* forage: satellite telemetry results and their implications for penguin conservation. *Marine Ornithology* **27**, 59-65.
- Trillmich, F. (1990). The behavioural ecology of maternal effort in fur seals and sea lions. *Behaviour* **114**, 4-19.
- Trillmich, F., Ono, K., Costa, D., DeLong, R., Feldkamp, S., Francis, J., Gentry, R., Heath, C., LeBoeuf, B., Majluf, P. and York, A. (1991). The effects of El Nino on pinniped populations in the Eastern Pacific. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 247-270. (Springer-Verlag: London)

Chapter 5
**Pup growth patterns in the Kaikoura region and
implications of maternal attendance patterns on
pup growth and behaviour**

Laura J. Boren, Chris G. Muller, Sacha Dowell, Abigail Caudron and Neil J. Gemmell

Proposed journal for submission: *Canadian Journal of Zoology*

Chapter 5: Pup growth patterns in the Kaikoura region and implications of maternal attendance patterns on pup growth and behaviour

Abstract

Patterns of pup growth have been studied extensively in many species of pinniped in relation to a host of maternal traits. In addition, pup growth and condition have been suggested to be useful tools to indicate resource availability to seal populations. In Kaikoura, a region of recent re-colonisation by the New Zealand fur seal (*Arctocephalus forsteri*), the growth patterns of pups in relation to behaviour and maternal traits were studied over four austral summers (2001/02 – 2004/05). Male pups were typically heavier than female pups in all years; however, there was little difference in the rate of growth between genders. Growth rates were relatively high in comparison to those reported for this species from other sites, with growth rates for individual pups reaching 350 g/day, and average growth rates for the peri-natal period reaching 163.4 g/day. In 2004 and 2005 average growth rates of cross-sectionally sampled pups from birth to approximately 116 days of age were: males (66.5 g/day), females (58.9 g/day), and males (109.5 g/day) and females (104.1 g/day), respectively. The high rates of growth observed in 2005 were significantly different to those observed in 2004 from both cross-sectional and longitudinal analysis and occurred in a year when adult females were at a higher average mass (41 kg vs. 39 and 34 kg). There was a significant relationship between female size and condition with pup size and condition, but not with pup growth rates. This suggests that maternal traits and attendance patterns were not a key influence in intra-annual patterns of pup growth and that multiple methods could be employed to achieve the same result. However, the most influential factors driving pup growth between years were female size at parturition and the ability of females to adapt to changing environmental conditions. The proximity of the Kaikoura Canyon to the breeding colony, may allow for adult females to make such adjustments to successfully raise pups to weaning under variable conditions.

Introduction

The growth patterns of otariids are vastly different than those observed for other species of pinnipeds that exhibit a short lactation period, with females remaining onshore to nurse their offspring (Lee *et al.* 1991; Lea and Hindell 1997). As lactating female otariids alternate between nursing their pups onshore and foraging trips away from the colony, the pups experience periods of rapid growth interspersed with periods of weight loss (Guinet *et al.* 1999) This foraging cycle exhibited by females of the smaller pinniped species (otariids and some of the smaller phocids) results in a longer lactation duration to ensure pups have reached an adequate weight before weaning (Trillmich 1990; Chapter 3).

New Zealand fur seals, *Arctocephalus forsteri*, exhibit a lactation duration of approximately 285 days until weaning (Stirling 1970; Miller 1971; Mattlin 1978; Goldsworthy 1992; Goldsworthy and Shaughnessy 1994; Haase 2004; Schulz and Bowen 2004; Chapter 3). During this protracted period of maternal investment and pup growth, a pup's weight gain can be influenced by a number of factors, including a host of maternal traits (e.g. maternal size, condition, milk composition and foraging strategies - Schulz and Bowen 2004), environmental variables (e.g. resource availability, local bathymetry and climactic patterns - Trillmich *et al.* 1991; Bradshaw *et al.* 2000), and gender differences (e.g. differential maternal investment between genders – Crawley 1975; Boyd and McCann 1989; Goldsworthy 1992; Goldsworthy 1995; Chilvers *et al.* 1995; Lea and Hindell 1997).

Maternal size and condition are thought to have a direct effect on the growth and condition of offspring, whereby larger females produce larger pups that grow faster and wean at a greater mass (Kovacs and Lavigne 1996). In phocid females such as gray seals (*Halichoerus grypus*), which sustain the energetic demands of lactation through fat stores while fasting, heavier individuals are able to lactate longer, have higher total milk outputs and produce larger pups at weaning (Mellish *et al.* 1999). For example, pup birth mass and rate of growth have been shown to be positively related to maternal post-partum mass in gray seals, *H. grypus*, (Pomeroy *et al.* 1999). However, despite the difference in maternal strategies between otariids and phocids,

increased maternal size should have a similar benefit in otariid females since bigger seals tend to have more energy reserves in relation to their metabolic costs (Costa 1991). Larger females not only have the potential to store more reserves and produce richer milk, but may also be older, more experienced foragers (Lunn *et al.* 1994), all of which may contribute to a pup's birth mass, weaning mass and overall weight gain.

A female's foraging strategy may also be closely linked to pup growth as pups fast for periods while their mothers are at sea, therefore longer foraging trips would yield a slower rate of growth (Lunn *et al.* 1993; Goldsworthy 1995; Guinet *et al.* 1999; Beauplet *et al.* 2004). This was found to be the case in *A. forsteri* at Maatsuyker Island, Tasmania, Australia, where pups of females that made shorter foraging trips grew faster (Lea and Hindell 1997).

Environmental variables, including the El Niño Southern Oscillation (ENSO) that may affect local resource availability are also likely to affect pup growth (Trillmich *et al.* 1991). In times of reduced food availability during ENSO events the subsequent increased maternal absences have resulted in decreased time spent suckling, slower weight gains and increased pup mortality for several species of pinnipeds (Ono *et al.* 1987; Majluf 1991; Trillmich and Dellinger 1991).

Pup growth may also be influenced by the pup itself in terms of the rate of transfer of nutrients. Pups typically initiate and terminate the majority of suckling bouts while their mothers are ashore (Chilvers *et al.* 1995). As lactation progresses and pup demands increase, pups of mothers that are able to meet the nutritional demand of their pup, may be more active and even miss subsequent suckling opportunities (Haase 2004). On the other hand, pups in poor condition may be less active and attempt to milk steal more frequently (Ono *et al.* 1987) lending support to the idea that pups are responsible for their own resource allocation.

Fur seals are sexually dimorphic species with adult males typically weighing several times (3-6) more than an adult female enabling them to gain and defend breeding territory (Crawley 1975; Crawley and Wilson 1976). Previous studies have reported that male pups are consistently heavier, and grow faster than female pups (Crawley 1975; Mattlin 1981; Goldsworthy 1992) suggesting differential maternal allocation

between the sexes to account for a greater cost in rearing male offspring (Boyd and McCann 1989; Goldsworthy 1992). It has also been suggested that in years of greater food availability the differential allocation between genders can be more pronounced, with females investing significantly more in their male offspring than in years of poor food availability (Lea and Hindell 1997; Bradshaw *et al.* 2003).

Environmental conditions influence maternal condition, foraging strategies and the potential differential allocation to young, which in turn affects pup growth and condition. Consequently, it may be possible to use pup growth or condition as an indicator of resource availability. For example, Bester and VanJaarsveld (1997) found that lower growth rates for *A. tropicalis* pups at Gough Island were probably indicative of a lower prey abundance within the foraging range of lactating females from this population. Pup condition has also been used as a successful indicator of prey availability for modelling *A. forsteri* re-colonisation within New Zealand (Bradshaw *et al.* 2002).

While much work has been done to investigate maternal strategies and pup growth in several pinniped species, differences in the methodologies often make both inter- and intra-specific comparisons difficult (Schulz and Bowen 2004). The two most critical aspects to take into consideration when making comparisons are: the portion of the lactation period the estimate covers, and whether estimates were based on cross-sectional or longitudinal methods (Schulz and Bowen 2004).

Pup growth in otariids is not linear throughout lactation (Trites 1993). The fastest growth occurs early in lactation (between 0-50 days), and is usually followed by slower growth after approximately two-months of age (Trites 1993). Given this structure to the lactation period, estimates made for a fraction of lactation are not necessarily representative of growth during the whole of the lactation period. Although estimated rates of pup growth exist for 15 of 16 otariid species (*A. pusillus* and *Zalophus* subspecies included – Schulz and Bowen 2004) estimates for the entire duration of lactation only exist for *A. gazella* (Goldsworthy 1992; Lunn *et al.* 1993), *A. tropicalis* (Goldsworthy 1992; Georges and Guinet 2000), *Callorhinus ursinus* (Boltnev *et al.* 1998), and *A. forsteri* (Mattlin 1981; Goldsworthy 1992; Haase 2004). Of the remaining studies investigating *A. forsteri* pup growth most focus on different

stages of growth, e.g. peri-natal / early-lactation: (Lea and Hindell 1997); and mid-lactation: (Chilvers *et al.* 1995). Therefore, when comparing data on pup growth reported from different studies it is important to be aware of what portion of the lactation period the study covered, and ideally growth rates for the duration of the lactation period are preferred.

Most studies of *A. forsteri* pup growth, including Mattlin's (1981) study of pups at Open Bay Island and Goldsworthy (1992) and Haase's (2004) study of pups at Kangaroo Island are based on cross-sectional sampling. While cross-sectional studies (random sampling of the population at each sampling period) are easier and allow for an increased sample size they do not adequately control for individual variation, which may be affected by: date of birth, size at birth, gender, maternal size and foraging strategy etc. (Goldsworthy 1992; Lea and Hindell 1997). Longitudinal studies, following known individuals and where possible known mother-pup pairs throughout the lactation cycle, provide more accurate estimates of growth and allow for further investigation into the variables influencing growth (Schulz and Bowen 2004).

The aim of the current study was firstly to examine pup growth in *A. forsteri* pups at Ohau Point, Kaikoura using both cross sectional and longitudinal sampling throughout the lactation period. Within this, separate goals were set to determine if mothers do invest more in male pups than female pups. We also describe inter-annual effects on pup growth over a four year period, including a strong (2003) and a weak (2005) El Niño event. A further goal was to determine the influence of maternal size, condition and foraging trip duration on pup growth. Finally, we investigate any potential implications of pup body condition on their energy budget and time spent with their mother.

Methods

Site description

This study was carried out at two fur seal breeding colonies located on the Kaikoura coast (42°25'S/173°43'E), on the South Island of New Zealand.

Ohau Point, a rapidly expanding colony, is adjacent to State Highway 1 approximately 26 km north of the Kaikoura township (Figure 1). The colony's pup production increased during the course of this study to nearly 600 pups born in the 2004/2005 breeding season (Chapter 2), with an estimated adult female population of around 900-1000 (Chapter 4) and an estimated total population of between 2500-3500 seals (based on the multiplication factor: 4.9 x pup production, Taylor 1982).

Lynch's Reef, a small breeding group, is located on a small reef off the north edge of the Kaikoura Peninsula, approximately 5 km from the township (Figure 1). The population here is limited by the area available and produces around 10 pups per year (Bradshaw *et al.* 2000; Chapter 2). The total population at this site, estimated from visual counts is upwards of 150 seals (Boren 2001).

Both colonies have close access to the Kaikoura Canyon (2-20 km to the 1000 m isobath, Benoit-Bird *et al.* 2004), and both colonies are exposed to various levels of eco-tourism. Ohau Point is limited to land-based tourism from a lookout at the South end of the colony, while tourists can view seals at Lynch's Reef from land, kayak, boat or via swimming (Boren *et al.* 2002).

The growth study was carried out over four austral summers: 2001/02, 2002/03, 2003/04, and 2004/05. However, since the majority of the data was collected in the new year, I will refer to the seasons from here on as: 2002, 2003, 2004, and 2005, respectively. Detailed behavioural data were collected on a subset of study pups in the final two seasons (2004 and 2005), and morphometric condition data were collected on 51 adult females caught in the latter three seasons (2003-2005).

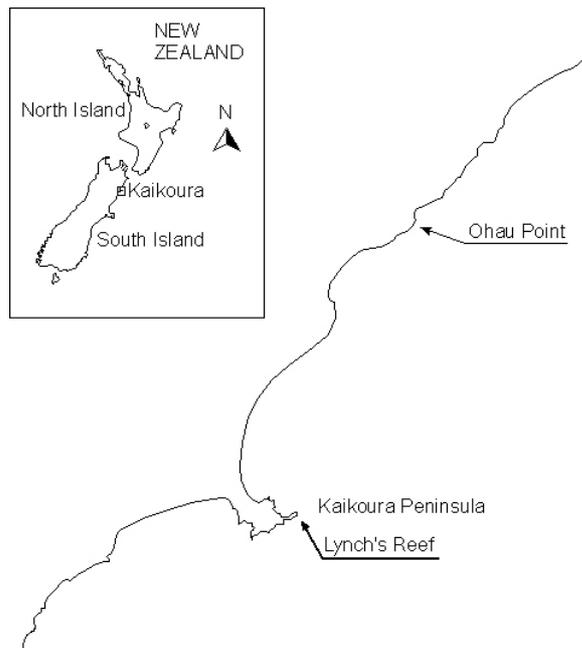


Figure 1: The Kaikoura Coast showing the Kaikoura Peninsula and the locations of the Ohau Point and Lynch's Reef seal colonies.

Marking of study animals

Pups and adult females were initially caught in December, shortly after birth for all years except 2002, and given a temporary mark. Pups initially received either a cap or a haircut as described in Chapter 4 (L. Chilvers, pers. comm.; Mattlin 1978).

Adult females were flipper tagged with white Allflex brand sheep ear-tags with four digits, as were pups that were followed for long-term when individuals exceeded 6 kg (generally the end of January onwards).

Capture and measurement

Adult females were captured using a hoop-net as described in Chapter 4, and weighed on a Salter scale (100 x 0.5 kg). The female was then placed on a restraining board with adjustable straps and dorsal straight length (DSL) and axillary girth (AG) were measured to the nearest 0.5 cm. Eighteen females were caught and measured in 2003, with 19 and 14 females captured and measured in 2004 and 2005, respectively.

Pups were caught by hand or with a noose and put in a fabric sack and weighed from a Salter spring balance (20 x 0.2 kg). Pups were then hand restrained and DSL and AG measurements taken as described in Chapter 2.

Identified pups were re-caught and weighed a number of times each season. In 2002, 76 pups, 68 at Ohau Point and 8 at Lynch's Reef, were caught in February, and were re-weighed once a month until the 16th of June, 2002. In 2003, a total of 68 pups, 58 at Ohau and 10 at Lynch's Reef, were caught in December, and were re-weighed approximately once every 10-14 days until the 19th of February, 2003. In 2004 several concurrent projects required condition and behavioural information on a larger sample of pups, so effort was focused on 170 pups initially marked in December at Ohau Point. Pups were weighed fortnightly until the 12th of February, 2004 and then two more times in late March and early October 2004, just prior to weaning. In 2005, 62 pups were caught in December at Ohau Point and were re-weighed fortnightly until the 30/31st of January, 2005, and then again on the 1st of April, 2005.

Birth dates were known or estimated for 40 pups in 2004 and 52 in 2005, through behavioural observations and/or state of the umbilicus/placenta, the colour of the inter-digital skin on the hind-flippers, length and flexibility of hind-flipper nails, and teeth/gum colour upon capture. For these pups growth could also be calculated longitudinally in order to account for age.

Weighing sessions were always carried out when weather and sea conditions allowed safe access in the colony, and minimised disturbance to the seals. Therefore, timing between some weight trials were shorter or longer than the desired fortnight or month. Not all pups were re-caught each time.

Maternal foraging trip duration

Information on female foraging trip duration for comparison with pup growth was collected through VHF transmitters and daily sightings of known females as described in detail in Chapter 4.

Behavioural data collection

Behavioural data were collected on a subset of pups during the 2004 and 2005 seasons at a rock platform at the south end of the colony. This area has approximately 80-100 pups born in it each year, is reasonably visible from a viewing spot on the side of the hill, and is relatively open allowing for more reliable sighting of pups. A total of 44

known pups were observed during the 2004 season from 10 Dec – 3 May. In 2005, 36 known pups were observed from 10 Dec – 28 Jan.

Observations were carried out on a daily basis weather permitting and ranged in time from 2 to 8 hours per day. Instantaneous scans (Altmann 1974) were carried out every 15 minutes and pups were recorded as either “N” nursing, “P” present - associating with its mother but not nursing (within 1m of each other) or “A” away from mother or mother absent.

Data analysis

General Mass and Growth rates

Mass and growth rates for weighing sessions and growth periods were compared between genders each year by two sample t-tests (Dytham 1999). P-values were adjusted using a Bonferonni calculation to account for multiple t-tests being carried out (Zar 1984; Haase 2004). Growth was calculated in two ways. Initially, since birth dates were not known for all pups and for all seasons, growth rates were calculated based on median pupping dates, and the approximate age of pups at the time of weighing. Growth rates were calculated for a number of different growth periods each year (Chilvers *et al.* 1995) and were calculated for each individual pup using the following formula (Lea and Hindell 1997):

$$(\text{Mass 2} - \text{Mass 1}) / \text{days}$$

Birth dates were known for 92 pups in the 2004 and 2005 seasons (n = 40 and 52, respectively). For these pups, growth rates were calculated longitudinally by deriving the regression equation for each pup based on their mass at given ages. However, as not all pups were re-caught at approximately 50 and 120 days of age, sample sizes for the two different time comparisons were smaller than the original 92 (0-50 days n = 30 and 41 respectively, and 0-120 days n = 18 and 25, respectively).

Comparisons were made between years and genders for mass and growth rates using 2-way ANOVA's. A multiple 2-way ANOVA was not possible because of the repeated measures nature of the data, and a repeated measures ANOVA was also not possible since not all pups were caught on each occasion. To account for multiple

independent 2-way ANOVA's being carried out Bonferonni adjustment was made to reduce the p-value at which significance was accepted.

Adult female size in relation to pup size

Adult female mass and condition (Mass/DSL) were compared between years via one-way ANOVA. Possible relationships between female and pup size were investigated through linear regression (Dytham 1999) of adult females' mass and condition against their pups' birth mass, birth condition, February mass and February condition.

Pup mass and growth in terms of maternal foraging trip duration

The influence of maternal size and maternal absence on pup size at 56 days of age, and growth from birth to 56 days, was tested via multiple regressions. Relationships between female foraging trip duration and pup size at birth, at 56 days of age, and growth from birth to 56 days were tested for by a regression (Dytham 1999).

Behaviour: General analysis

The proportion of time spent in each behaviour (N, P, and A) was calculated for individual pups based on the number of observations the individual pups were present for each day. General trends in numbers of pups seen nursing and associating with their mothers were calculated using all pups. However, for more detailed analysis pups needed to be in view for 33% of the observation period to count. This proportion of time was chosen to ensure that the pups were in view for a significant proportion of the observation period while maximising the available sample size. For example, setting the criteria higher at 50 or 75% would have resulted in excluding a large portion of data where pups were in view for over two hours.

Forty-four and 36 known pups were observed respectively during the 2004 and 2005 field seasons. The average number of 15-minute scans performed per day was 23.98 (about 6 hrs) in 2004 and 19.94 (about 5 hrs) in 2005. Although on some days, poor visibility and/or dangerous conditions limited observations to about 2 hours in duration, the mode for observation time in each season was 8 hours and 4 hours for 2004 and 2005 (32 and 16 counts), respectively. On average between 70-80% of known pups were visible each day and 60-70% of known pups were in view for a significant amount of time. On any given day an average of 20-30% known pups

could be seen nursing, and 33% of known pups could be seen in other interactions with their mother.

The mothers of many of the study pups could not be reliably identified so their presence could only be recorded through association with their pup, and accurate attendance patterns were consequently hard to predict. Therefore, a parameter was calculated; the proportion of time the pup's mother was ashore from the pup's point of view (PROP) to provide an indication of her foraging strategy.

$$\text{PROP} = \frac{\text{(Number of days pup observed at least once with mother)}}{\text{(Total number of days pup observed)}}$$

This value is likely to be a slight underestimate of the actual time a female spent ashore because there may be days when a pup was not observed with its mother, but she was onshore. This situation is similar to a "missed shore bout" as shown by Haase (2004) and increases with pup age.

Pup behaviour by month in relation to mass and condition

Correlations were tested for between pup mass and condition each month against the various behaviours.

Behaviour between years

Behaviour was initially tested for differences between genders using two-sample t-tests. No difference was detected so male and female pups were pooled for the analysis of behaviour between years. Data were also tested for normality via a K-S test, and any non-normal parameters were arcsine transformed (proportion data, Dytham 1999). The proportion of time pups spent undertaking each type of behaviour and the proportion of days pups were seen with their mother were analysed between years using a MANOVA (Dytham 1999).

Results

General patterns- mass, growth and behaviour

Mass and growth of pups were initially analysed by year and comparisons were made between the genders for each weight trial and growth period.

Mass

Birth masses of pups were collected in two seasons, 2004 and 2005 (Figure 2, Table 1). Male pups averaged 4.93 and 4.59 kg, while females averaged 4.61 and 3.77 kg for the two seasons, respectively. For all four seasons, pups were caught at approximately two-months of age (56-59 days old). At this age in 2002, males averaged 8.91 kg and females averaged 8.09 kg (Figure 2, Table 1). In 2003, average mass was 8.64 and 7.28 kg for males and females, respectively. In 2004, male mass was 8.95 kg and female mass was 8.04 kg. In 2005, average mass for male and female pups was 9.28 and 8.21 kg, respectively. In 2004, pups were weighed prior to weaning, with mean mass for males and females, 13.05 and 11.13 kg, respectively (Table 1). In all years males were typically heavier than females, although this difference was not always significant. Significant gender differences were only observed twice in 2002 at 59 and 158 days ($p = 0.004$, $p = 0.010$, Bonferonni adjusted $p = 0.01$), four times in 2003 at 39, 48, 56 and 68 days ($p = 0.0001$, $p = 0.001$, $p < 0.0001$, $p = 0.006$, Bonferonni adjusted $p = 0.0063$), twice in 2004 at 42 and 56 days ($p < 0.0001$, $p < 0.0001$, Bonferonni adjusted $p = 0.005$) and five times in 2005 at 5, 17, 36, 44 and 56 days ($p = 0.0007$, $p = 0.0055$, $p = 0.0017$, $p = 0.0007$, $p = 0.0017$, Bonferonni adjusted $p = 0.0063$).

Rate of Growth

Over all four years there was little difference in pup growth rates between genders (Table 2). Only on two occasions did males grow faster than females; in 2004, between birth and 31 days (males: 105.14 g/day, females: 82.06 g/day, $p = 0.0031$, Bonferonni adjusted $p = 0.0038$) and in 2005 between 22 and 36 days ($p = 0.0016$, Bonferonni adjusted $p = 0.0056$). As expected growth rates were higher, earlier in the breeding season (Figure 2; Table 2). In 2004 and 2005 growth slowed down after 44 to 68 days of age, while a second drop in growth rates appeared after 110 days in 2004. In 2002 growth didn't appear to slow until after 158 days of age, however, in this season pups were not measured until 59 days of age. No noticeable change in rate of growth occurred in 2003, when pups were only sampled during the peri-natal period to 76 days old.

Pup Behaviour

In 2004 there was no relationship between the number of counts and the average number of pups per count although in 2005, there was a significant inverse relationship between these parameters. This was probably an artefact induced by observers becoming more skilled at sighting pups, and a reduced number of counts carried out towards the end of the season. In 2004 the proportion of pups seen per day was significantly related to the number of counts carried out with a predicted value of 95% of pups being sighted in 24 counts ($p < 0.0001$, Bonferonni adjusted $p = 0.0083$). However, this relationship was not observed in 2005. In both years there was a significant inverse relationship between the proportions of pups in view for 33% of the time with more pups being in view longer at 9 counts (86-100% predicted).

Relationship between pup behaviour and condition

In 2004, there was no relationship between pup gender and behaviour observed ($p = 0.884$) and there was no relationship between pup mass and condition with how pups behaved (correlation p -values range: 0.072-0.976). Again in 2005 there was no difference in behaviour based on gender ($p = 0.7783$). No significant relationship was seen between mass or condition and pup behaviour (correlation p -values range: 0.054-0.668), although, January (25-56 days old) N and PROP showed strong positive relationships with both mass and condition (N: $R = 0.36, 0.34, p = 0.062, 0.077$) PROP: $R = 0.36, 0.37, p = 0.057, 0.054$), suggesting that heavier pups were observed nursing more often and sighted with their mother on more days than lighter pups.

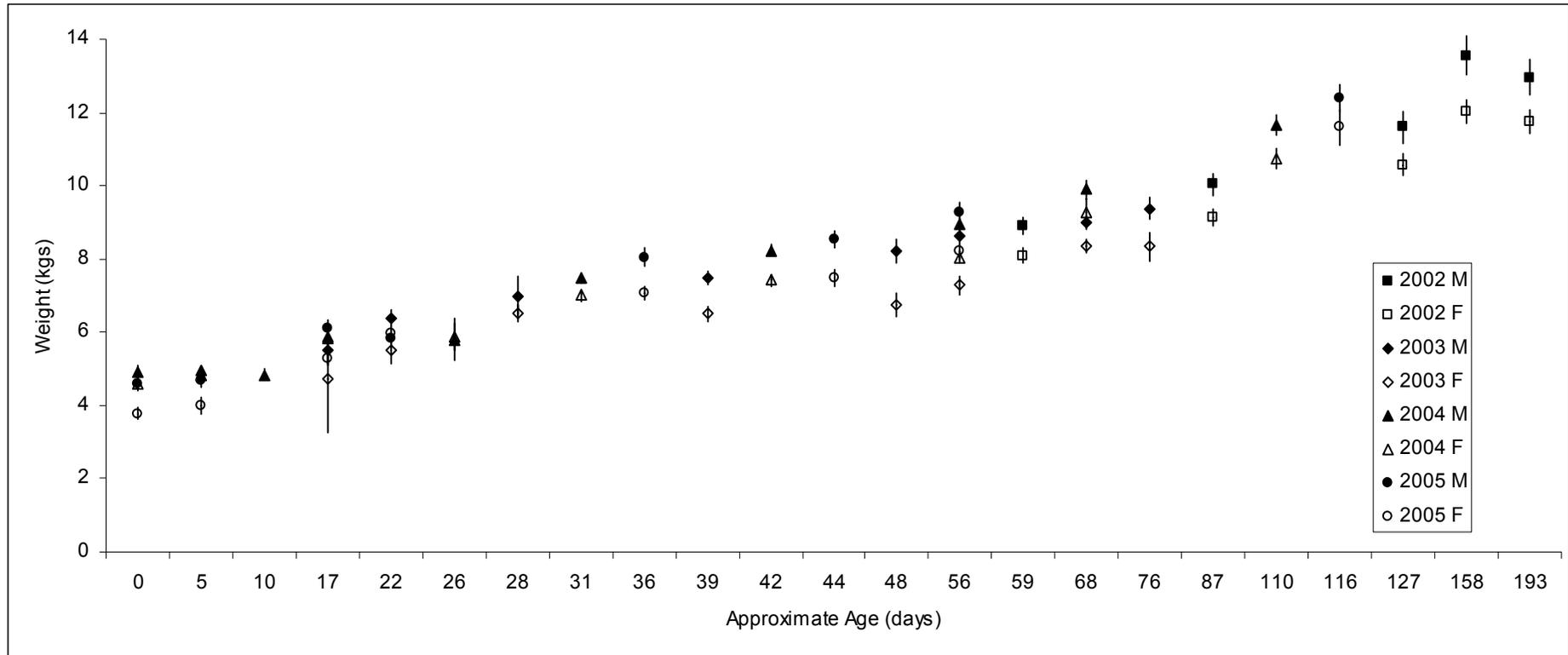


Figure 2: Pup mass based on age (days from median pupping date) for each of four breeding seasons. Weaning weights collected in 2004 are not included in this figure.

Table 1: Mass of pups in kilograms weighed at different times over four seasons. Data are displayed for males (M) and females (F) as well as genders combined (Both). Standard deviations, and sample sizes (N) are also shown.

		Males			Females			Both		
		N	Mass (kg)	SD (kg)	N	Mass (kg)	SD (kg)	N	Mass (kg)	SD (kg)
2002	1-2 Feb	37	8.9	1.2	31	8.1	1.1	55	8.3	1.2
	2-3 Mar	21	10.0	1.4	24	9.1	1.1	45	9.6	1.3
	11-Apr	13	11.6	1.6	12	10.6	1.0	25	11.1	1.4
	12-May	14	13.6	1.9	9	12.0	0.9	23	13.0	1.7
	16-Jun	9	13.0	1.4	8	11.8	0.9	17	12.4	1.3
2003	22-23 Dec	9	5.5	1.0	2	4.8	1.5	11	5.4	1.0
	27/28 Dec	22	6.4	1.1	15	5.5	1.3	37	6.0	1.2
	2-4 Jan	8	7.0	1.4	10	6.5	0.7	18	6.7	1.0
	13-14 Jan	46	7.5	1.2	37	6.5	1.2	44	6.9	1.3
	22-23 Jan	25	8.2	1.5	18	6.7	1.3	43	7.6	1.6
	30-Jan	47	8.6	1.6	29	7.3	1.3	52	7.7	1.4
	11-Feb	58	9.0	1.3	54	8.4	1.3	35	8.2	1.3
2004	19-Feb	30	9.4	1.6	19	8.3	1.6	49	9.0	1.7
	28 Nov – 5 Dec	44	4.9	1.0	42	4.6	0.8	86		
	10-11 Dec	29	4.9	0.6	28	4.8	0.8	57	4.9	0.7
	14-15 Dec	6	4.8	0.4				6	4.8	0.4
	22-23 Dec	34	5.9	1.0	26	5.8	1.1	60	5.9	1.0
	31-Dec	10	5.8	1.8	12	5.9	1.3	22	5.8	1.5
	4-5 Jan	81	7.5	1.3	66	7.0	1.2	147	7.3	1.3
	16-17 Jan	84	8.2	1.4	64	7.4	1.2	148	7.9	1.4
	28-30 Jan	67	8.9	1.4	47	8.0	1.1	114	8.6	1.4
	12-Feb	27	9.9	1.3	23	9.3	1.7	50	9.6	1.5
2005	25-26 Mar	48	11.7	1.8	34	10.7	1.7	82	11.3	1.8
	11-Oct	37	13.1	2.7	15	11.1	3.0	52	12.5	2.9
	30 Nov-12 Dec	25	4.6	0.9	17	3.8	0.7	42	4.3	0.9
	11-15 Dec	10	4.7	0.7	8	4.0	0.7	18	4.4	0.7
	22-Dec	28	6.1	1.2	23	5.3	0.9	51	5.7	1.2
	27-Dec	10	5.8	0.9	9	6.0	1.0	19	5.9	0.9
	9-10 Jan	29	8.1	1.4	26	7.1	1.0	55	7.6	1.3
	18-Jan	29	8.5	1.2	22	7.5	1.1	51	8.1	1.2
	30-31 Jan	29	9.3	1.5	25	8.2	1.0	54	8.8	1.4
	1-Apr	19	12.4	1.6	10	11.6	1.5	29	12.1	1.6

Table 2: Growth of male and female pups based on different periods sampled, approximate ages based on median pupping dates for the year. P- values are shown with significant differences after Bonferroni correction in bold. Bonferroni values for 2002 = 0.0083, 2003 = 0.0056, 2004 = 0.0038, and 2005 = 0.0056.

Age (days)		Male			Female			P-value
	n	Growth (g / day)	SD	n	Growth (g / day)	SD		
59-87	18	51.98	58.74	19	45.49	40.09	0.6954	
87-127	7	58.19	39.40	9	31.44	26.80	0.1274	
127-158	8	57.26	45.40	2	54.84	27.40	0.9457	
158-193	6	16.67	29.90	2	-2.86	20.20	0.4343	
59-127	11	40.84	20.50	9	42.19	10.00	0.8591	
59-193	8	35.37	7.70	8	34.35	6.90	0.7846	

Age (days)		Male			Female			P-value
	n	Growth (g / day)	SD	n	Growth (g / day)	SD		
17-39	5	50.00	25.10	1	36.36			
22-39	16	49.26	33.75	12	44.12	43.26	0.3681	
28-39	2	45.45	12.86	7	35.06	30.80	0.2566	
39-48	18	85.35	66.96	12	40.53	98.17	0.0920	
48-56	22	4.55	95.79	18	31.60	97.59	0.1925	
56-68	18	57.41	84.40	16	76.04	60.39	0.2306	
68-76	18	81.94	129.57	13	29.81	109.75	0.1184	
17-56	6	52.14	11.08	1	64.10			
22-76	17	59.15	20.63	8	42.82	28.42	0.0869	

Age (days)		Male			Female			P-value
	n	Growth (g / day)	SD	n	Growth (g / day)	SD		
0-31	41	105.14	33.97	28	82.06	24.92	0.0031	
5-31	27	107.11	61.04	22	90.64	14.97	0.0930	
10-31	6	109.13	23.10		0.00	0.00		
17-31	31	128.16	128.99	21	75.46	45.95	0.0216	
26-31	9	88.89	138.69	12	92.50	145.11	0.4772	
31-42	78	62.93	62.14	56	43.53	65.32	0.0431	
42-56	64	51.44	80.78	42	54.95	56.71	0.3969	
56-68	21	114.29	92.44	17	104.52	98.36	0.3783	
68-110	21	28.68	35.18	11	31.29	22.84	0.4011	
110-310	10	11.00	6.10	4	3.88	7.78	0.0809	
17-56	26	71.06	24.76	17	50.30	23.88	0.0047	
56-110	40	52.54	25.31	26	46.36	23.80	0.1593	
0-110	23	66.54	15.06	17	58.88	10.42	0.0324	

Age (days)		Male			Female			P-value
	n	Growth (g / day)	SD	n	Growth (g / day)	SD		
5-10	9	46.46	105.91	8	58.75	112.71	0.4103	
10-17	9	96.68	57.93	8	110.91	67.02	0.3244	
17-22	8	72.50	136.04	8	130.00	124.21	0.1961	
22-36	7	163.38	61.60	9	58.12	50.24	0.0016	
36-44	28	129.00	17.91	22	130.05	15.31	0.4116	
44-56	28	58.48	86.00	22	56.32	61.96	0.4592	
17-56	26	82.74	28.60	22	72.79	15.98	0.0685	
56-116	18	55.14	17.00	10	56.92	17.63	0.3993	
5-116	16	109.54	14.2	9	104.05	13.93	0.1803	

Comparisons between years

Mass

The weights of male and female pups were compared between years at three chosen age blocks: Birth (0-5), 56-59 and 110-127 days old (Figure 3). Pups were weighed at 5 days of age in the two latter seasons, and were significantly heavier at or near birth in 2004 than in 2005 ($p < 0.0001$, Bonferonni adjusted $p = 0.0125$), males were also heavier at this time (Figure 3a). Pups were weighed at approximately 56-59 days of age in all four seasons (late-January / early-February) and pups were found to be lightest in 2003, intermediate in 2002 and 2004 and heaviest in 2005 ($p = 0.0060$), again there was also a significant difference in genders at this time (Figure 3b). Finally pups were weighed between 110-127 days in 2002, 2004 and 2005 (late-March / early April), although 2005 pups appeared slightly heavier at this time, the difference between years was not significant, although males were significantly heavier than females at this time for all seasons ($p = 0.0083$, Figure 3c). At all three ages there was no significant relationship between gender and year, suggesting that gender differences in weight were consistent among years ($p = 0.0281$, $p = 0.7183$, and $p = 0.9473$, Figure 4).

Growth

Growth rates in 2004 and 2005 were compared in two ways. Masses of pups at different ages based on median pupping dates for the year are shown cross-sectionally in Figure 4. For 40 pups in 2004 and 25 in 2005 that were caught at or near birth (0-5 days old) and again at approximately 120 days old individual growth curves were calculated. During this time frame, there was a significant difference observed between years with 2004 pups exhibiting a slower overall growth rate than was observed in 2005 (58-66 g/day vs. > 100 g/day in 2005, $p < 0.0001$, Figure 4).

Although the way growth rate was calculated accounts for individual pup variation, it does not take into account birth date, as birth dates for some of these pups are unknown. Therefore, growth rates were also calculated longitudinally in 2004 and 2005 (Figure 5) for 40 pups in 2004 and 52 in 2005. As not all pups were re-caught at similar ages, a smaller sample size was available for statistical comparison between years ($n = 40$ in 2004 and 52 in 2005). While no significant differences were detected in growth between sex ($F_{1,39} = 2.4547$, $p = 0.125$) or between years ($F_{1,39} = 0.2772$, p

= 0.602) from birth to approximately 120 days old the sample size was small for this analysis ($n = 8, 10$ and $n = 9, 16$, for females and males in 2004 and 2005, respectively). However, for the shorter time frame of birth to 50 days, where a larger sample size was available for comparison significant differences were detected both in year ($F_{1, 67} = 6.051$, $p = 0.016$) and sex ($F_{1, 67} = 10.321$, $p = 0.002$) with pups in 2005 growing at a faster rate than in 2004, and males growing faster than females (2005 M = 89.6 g/day, 2005 F = 78.1 g/day, 2004 M = 81.3 g/day, and 2004 F = 65.2 g/day).

Behaviour

Each season pups on average spent between 10-12% of their time nursing, 10-12% of their time in another interaction with their mother, and about 78% of their time away from their mother (Figure 6). There was no significant difference in pup behaviour detected between years ($p = 0.1699$).

ENSO effects

Recent Southern Oscillation Index (SOI) values during the course of this study are shown in Figure 7 for reference purposes. Dashed lines indicating when pupping occurred for the four seasons of this study have been added. The Index is calculated from the difference in atmospheric pressure between Darwin and Tahiti and a strong link exists between the SOI and tropical Pacific sea temperatures (NIWA 2005). Positive values are associated with a La Niña (LA) event, while negative values are associated with an El Niño (EN) event, generally the index needs to be higher than +1.0 or lower than -1.0 to significantly effect the New Zealand environment (NIWA 2005). For the first season of this study (2002) the climate was shifting from an LA to an EN event. The EN conditions strengthened and remained for the 2003 season. In 2004 more mild conditions came about although not a strong sustained LA and EN conditions returned for end of 2004 and into 2005 (NIWA 2005).

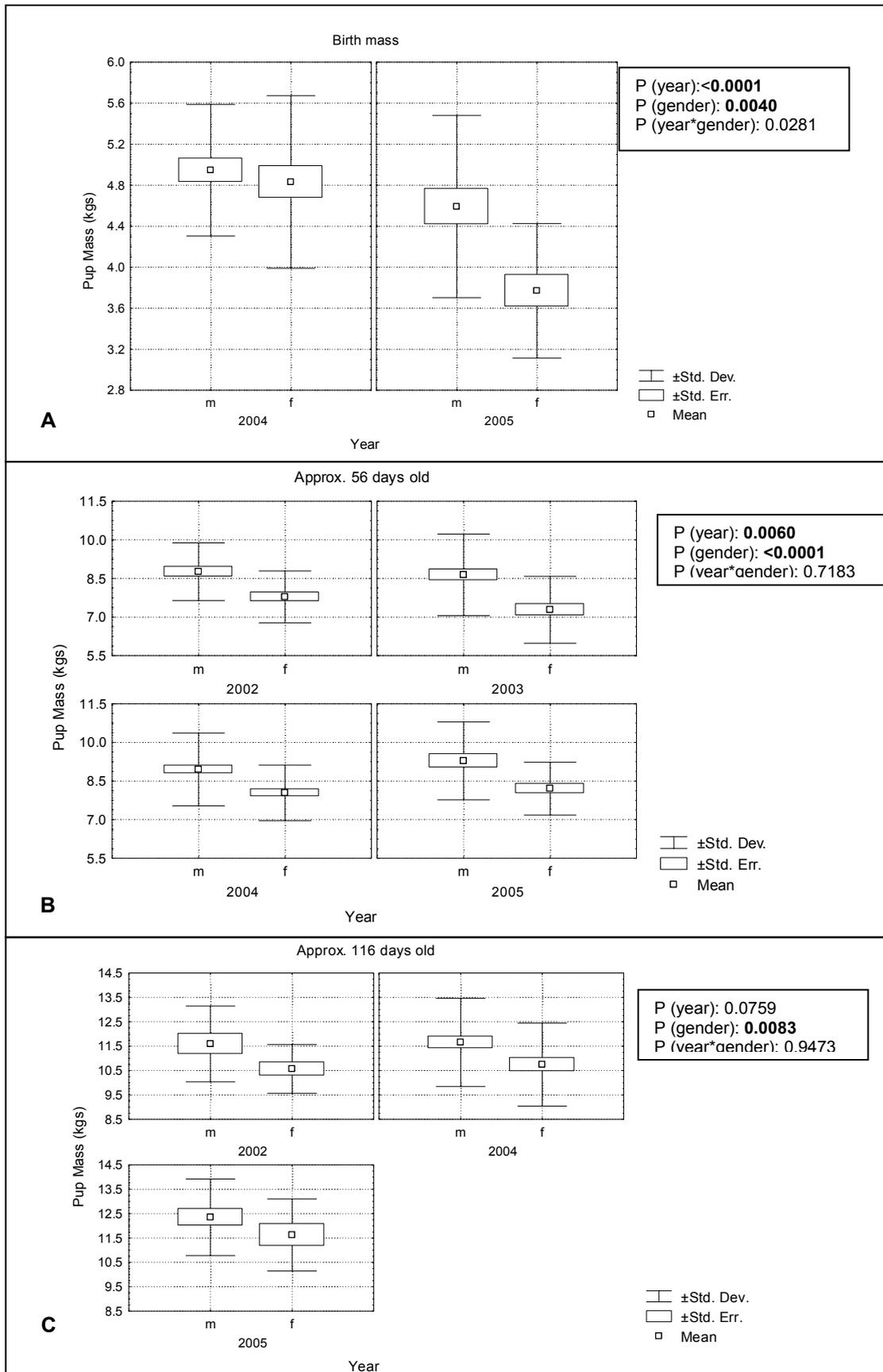


Figure 3: Pup mass during different years at: A) birth, approximately B) 56 and C) 116 days of age. P-values for difference between year and gender are displayed, with significant p-values in bold.

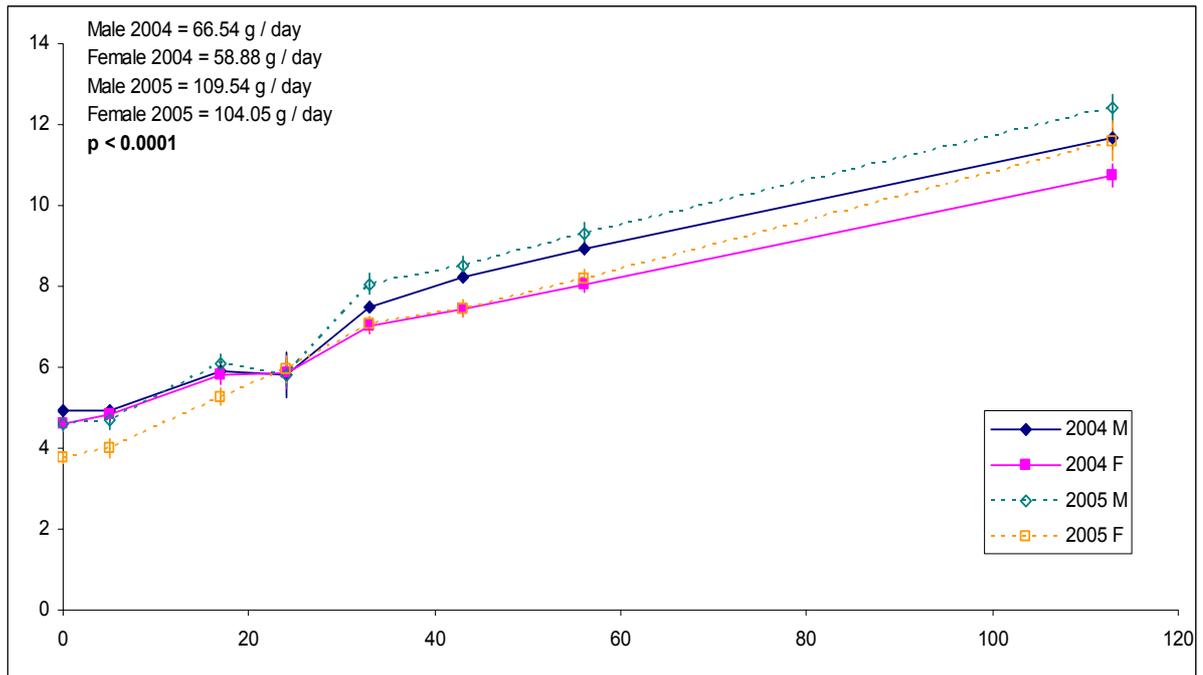


Figure 4: Male and Female pup mass at different ages in 2004 and 2005, sample sizes ranged between 22-148 pups in 2004, and 18-54 pups in 2005. Average rates of growth calculated for 40 individuals in 2004 and 25 individuals in 2005 for this time frame are shown along with the p – value for differences between years.

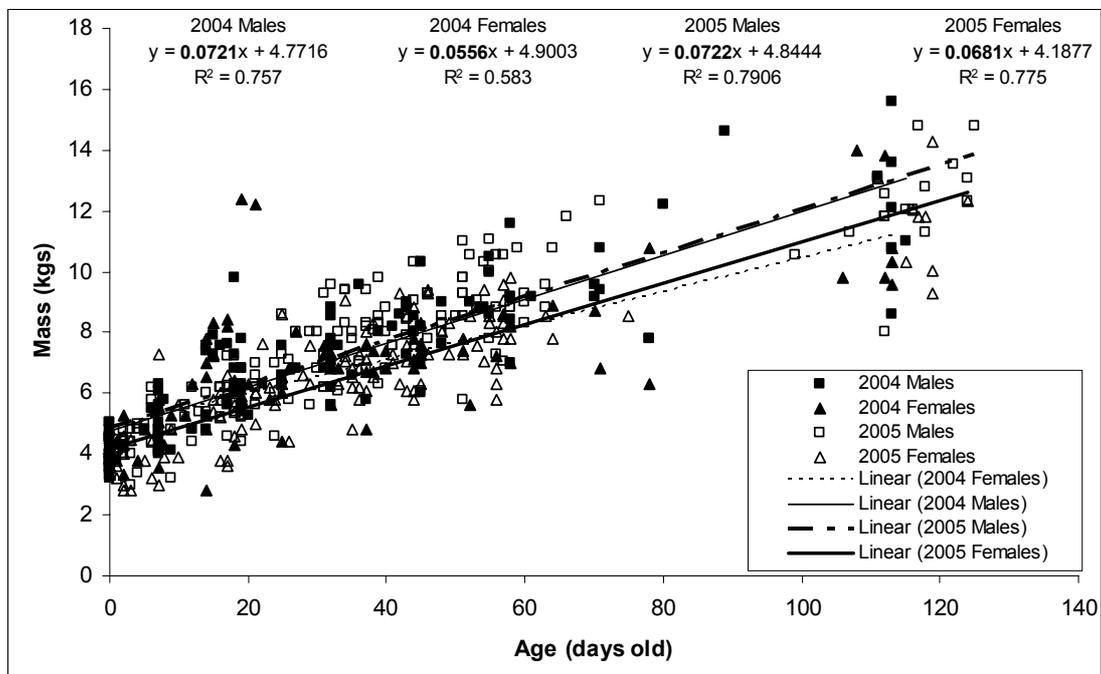


Figure 5: Mass at various ages for pups of known birth date, 40 in 2004 and 52 in 2005. Regression lines of best fit are shown with the regression equations and R^2 value.

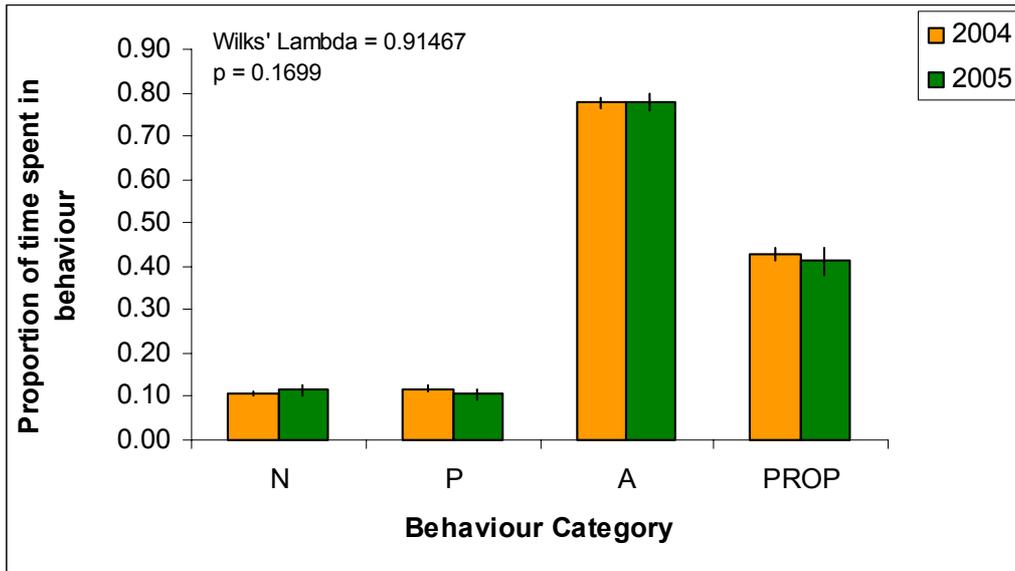


Figure 6: Proportion of time pups spent N – Nursing, P – associating with mother, A – away from mother, each year. Also shown are the proportion (PROP) of days pups were observed with their mother at some time.

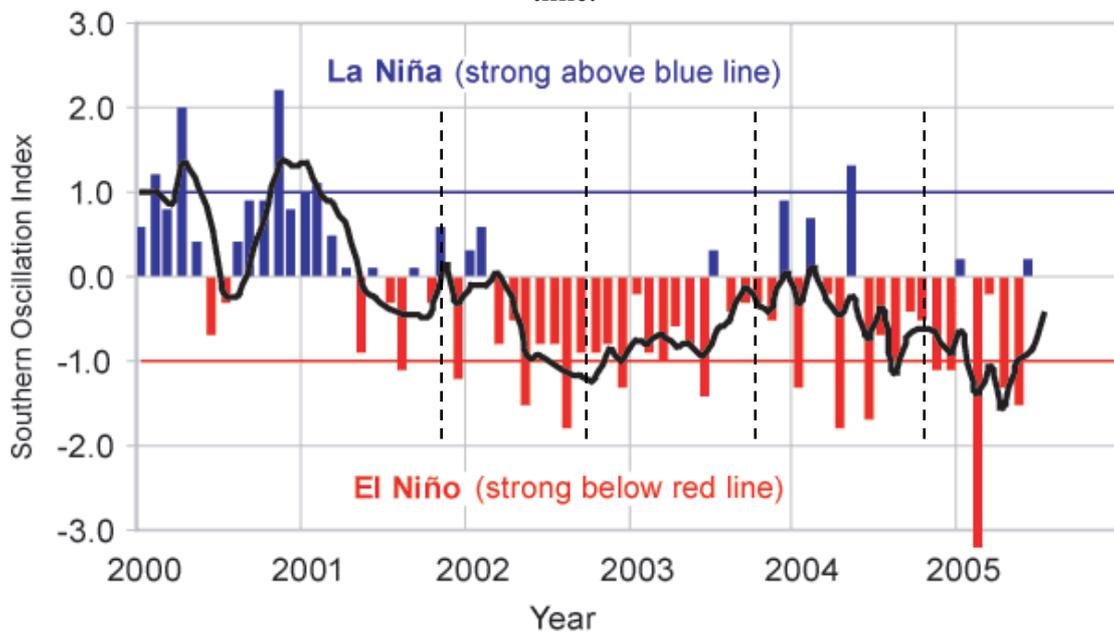


Figure 7: Southern Oscillation Index values from 2000 to 2005 (NIWA 2005). Dashed lines indicate approximate pupping times at Ohau Point for the four years of this study.

Influence of maternal traits

Adult female mass and condition

Adult females were significantly heavier and in better condition in 2005 (41.85 kg, 0.35 kg/cm, Figure 8), while females in 2003 were the lightest and in the poorest condition (34.32 kg, $p = 0.01$; 0.28 kg/cm, $p < 0.0001$, Bonferonni adjusted $p = 0.0167$).

Pup mass and condition related to mother's mass and condition

Female size and condition was not related to pup birth mass or birth condition (Regression results: $p = 0.803$, $p = 0.174$, Bonferroni adjusted $p = 0.0125$, Figure 9). However, they were significantly related to pup mass and condition in February (56 day old) (Regression results: $p = 0.001$, $p = 0.007$).

Maternal mass and foraging trip duration related to pup size and growth

A subset of individuals where female mass, female foraging trip duration and pup weight at 56 days is known (2004: $n = 15$, 2005: $n = 8$) were tested for relationships between these variables. There is no clear relationship between pup size and maternal foraging trip duration and neither parameter contributed significantly to pup size (Multiple Regression results: Maternal mass $R = 0.10$, $p = 0.66$; Foraging trip durations $R = -0.09$, $p = 0.71$). These mother-pup pairs were also analysed for relationships between the two maternal parameters and pup growth to 56 days. Again, no significant relationship was observed (Maternal mass: $R = 0.069$, $p = 0.78$; Foraging trip durations $R = 0.048$, $p = 0.84$).

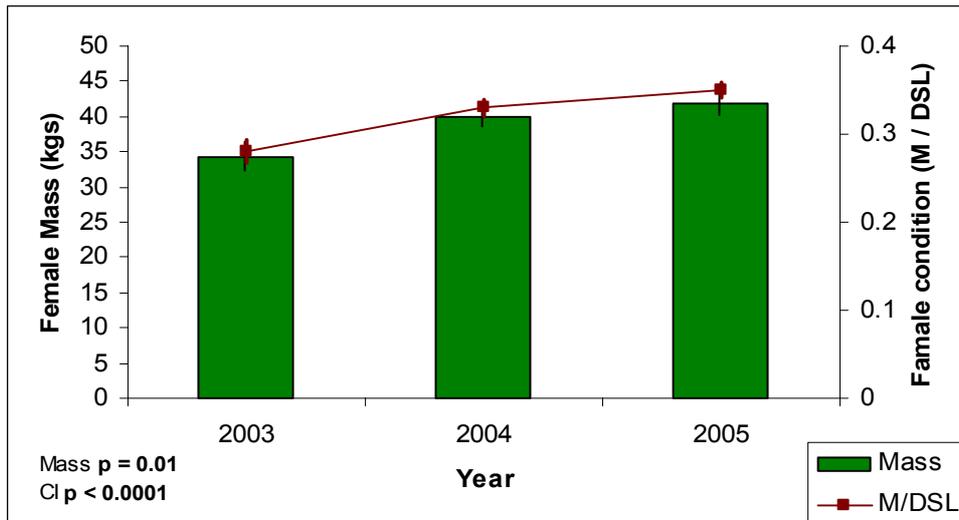


Figure 8: Adult female mass and condition (M / DSL) in 2003 ($n = 17$), 2004 ($n = 19$) and 2005 ($n = 14$). Significant p – values for between year comparisons are in bold.

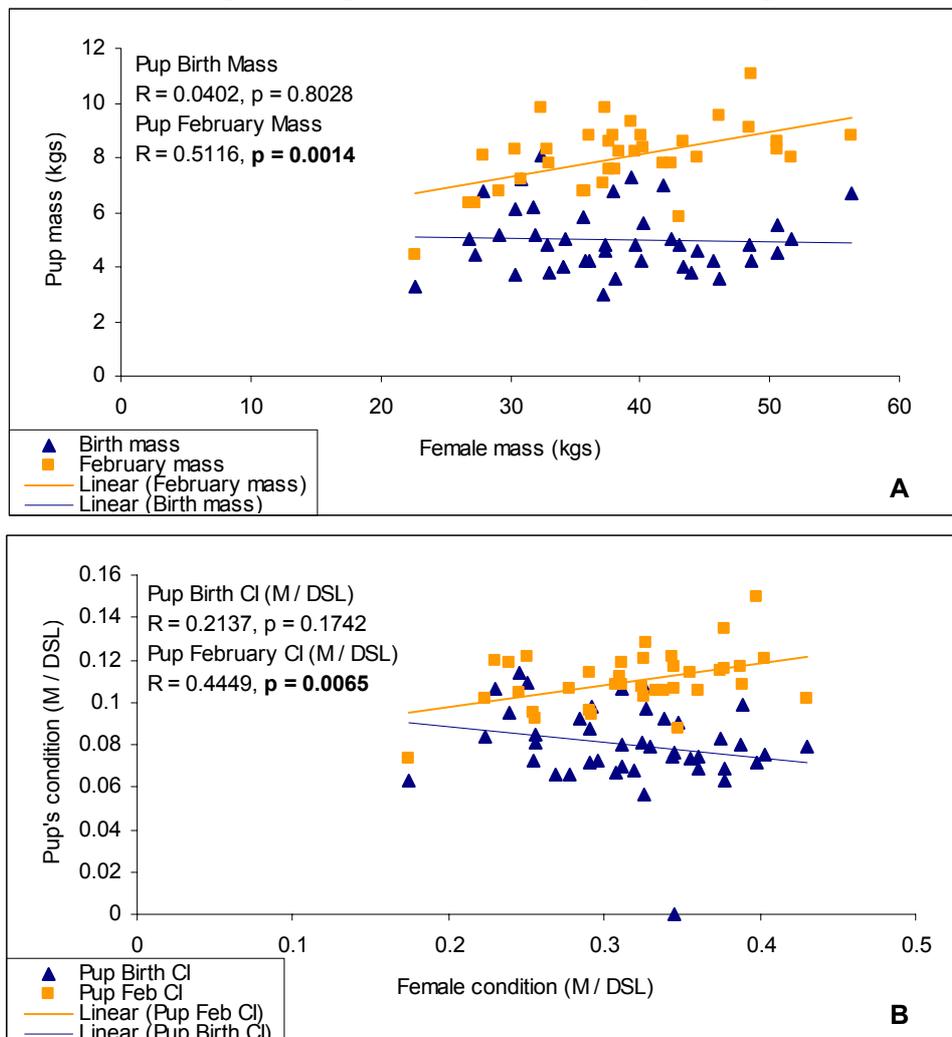


Figure 9: Relationship between: A) female mass and pup birth mass ($n = 41$) and February (56 days) mass ($n = 36$), and B) female condition and pup birth ($n = 41$) and February condition ($n = 36$). A line of best fit is included for all regressions with associated R and p – values. Significant p – values are in bold.

Discussion

General Patterns

Rates of mass gain observed at Ohau Point were high for *A. forsteri* pups early growth: mean 0-50 days (73.6 g/day vs. mean 51.8 g/day Open Bay Islands: Mattlin 1981; mean 62.3 g/day Kangaroo Island: Goldsworthy 1992); mean 0-116 days (84.8 g/day vs. 45.7 g/day Kangaroo Island: Haase 2004) and within the normal range for the entire lactation period: mean 0-300 days (26.9 g/day vs. 24 g/day Open Bay Islands: Crawley 1975; mean 30 g/day Open Bay Islands: Mattlin 1981; 37.4 g/day Kangaroo Island: Haase 2004). Growth rates from age 0-50 days in 2004 were lower than that observed at Maatsuyker Island (mean 109 g/day: Lea and Hindell 1997), but similar in 2005, and growth rates from 59-193 days at Ohau Point are slightly lower than for pups at Cape Foulwind mean for 60-200 days (40 g/day: Chilvers *et al.* 1995). Growth observed at Ohau Point was also within the normal range for other temperate breeding *Arctocephaline* species: *A. tropicalis* (approx. 40 g/day Amsterdam Island: Georges and Guinet 2000); and *A. pusillus doriferus* (approx. 60 g/day Kanowna Island, Bass Strait, Australia: Arnould and Hindell 2002). The results presented for pups at Ohau Point also show faster growth in the peri-natal period, while slowing through the winter (mean growth 49 g/day for 3 seasons 56-116 days) and dropping off dramatically during late lactation (growth from 110-310 days in 2004: 11.4 and 3.9 g/day, Table 2) as is expected since maternal absences increase at this time to cope with the increased demand of provisioning by pups (Harcourt *et al.* 2002; Chambellant *et al.* 2003).

Although male pups were typically heavier than female pups, there was no significant difference in rate of growth between genders observed in this study (Figure 2 and Table 1). Similar results were found for *A. forsteri* pups at Maatsuyker Island (Lea and Hindell 1997) and Kangaroo Island (Goldsworthy 1992; Haase 2004), for *A. tropicalis* at Amsterdam Island (Chambellant *et al.* 2003), *A. gazella* at Bird Island, South Georgia (Lunn *et al.* 1993), *A. pusillus doriferus* Kanowna Island (Arnould and Hindell 2002) and *Eumatopias jubatus* in Southeast Alaska (Brandon *et al.* 2005). However, for *A. gazella* at Heard Island in the southern Indian Ocean, pup growth to 100 days was significantly greater for male versus female pups (79.6 vs. 60.6 g/day, Goldsworthy 1995).

While other studies have shown significant gender differences in rates of growth in fur seals (Mattlin 1981; Chilvers *et al.* 1995; Goldsworthy 1995; Kirkman *et al.* 2002) some of the variation may be influenced by the type of sampling (Cross-sectional vs. Longitudinal). For example, Lunn *et al.* (1993) found that longitudinal sampling of individual *A. gazella* pups showed no significant difference between genders, while cross-sectional sampling within the same study did. In the current study, the reverse was the case, where gender differences in growth were only detected via longitudinal sampling taking age into account, and only for the early growth period (birth to 50 days). It has since been proposed that the observed differences in mass and growth between genders are related to the way in which male and female pups assimilate nutrients (males: lean tissue growth, females: adipose tissues – Arnould *et al.* 1996).

In a study to specifically investigate gender differences in growth rates among *A. gazella* pups at Macquarie Island, it was found that longitudinally sampled males did grow faster than their female counterparts (Guinet *et al.* 1999). However, this was not found to be due to increased maternal investment in male progeny, rather it was a result of female pups losing mass at a faster rate than male pups during maternal absences (Guinet *et al.* 1999). A different study currently investigating growth rates in New Zealand sea lion pups, *Phocarctos hookeri*, has in fact shown the opposite, that male pups grow faster and lose weight faster than their female counterparts (Chilvers *et al.* in prep). Most research is now pointing to equal levels of maternal investment between the sexes in terms of rate of transfer of nutrients and that factors including pre-natal investment, individual lactation lengths and variation in mass loss between genders may account for the apparent increased cost and input required to rear a male pup (Boyd and McCann 1989; Lunn *et al.* 1993; Guinet *et al.* 1999).

Pup behaviour did not appear to show the expected relationship with pup mass and body condition. It is generally thought that otariid pups in poor condition will be less active, spend more time resting and attempt to milk steal more frequently (Ono *et al.* 1987) whereas, pups in increased condition and at more advanced stages of behavioural development are more active and may be more likely to miss suckling opportunities even when their mother is ashore (Haase 2004). The reason for the lack of relationship between pup behaviour and condition observed in the current study is unclear. It may be related to the inconsistent visibility of pups in the irregular terrain

at Ohau Point, and lack of a large number of identifiable mothers to aid in the correct categorisation of pup behaviour (e.g. mum present but pup resting nearby (P), vs. away from mother or mother not present (A)). A more detailed breakdown of pup activity budgets, and focusing only on pups with identifiable mothers may shed more light on this potential relationship; however, this was not a key focus for this study.

Comparison between years

Inter-annual variation in mass was observed with weights being intermediate in 2002, lowest in 2003 and highest in both 2004 and 2005. In the later two seasons pups started out heavier at birth in 2004, however, at 56 and 116 days of age pups born in 2005 were heavier than their 2004 counterparts. Similar relationships were found with growth, although 2002 predominantly sampled pups during the middle of lactation and 2003 was mainly early-lactation, in both of these years growth rates were relatively low (Table 2). Rates of growth were similar for 2002, 2004 and 2005 from approximately 56 and 116 days of age (range: 40.84-56.92 g/day, Table 2). From birth to approximately 116 days of age pups in 2005 grew faster than pups in 2004 (Figure 4). Also, for early growth, longitudinally sampled pups, for which birth dates are accounted, still exhibited higher rates of growth in 2005 than in 2004 (Figure 5). The differences observed here are potentially related to environmental changes, as the low growth rates in 2002 coincided with a negative Southern Oscillation Index value, indicative of an El Niño event (NIWA 2005). However, just coming out of a La Niña, meant that adult females might still be in reasonable condition going into the change (Boersma 1998). In 2003 the ENSO conditions remained and average female size and condition was low (Figure 7 and 8). The following season (2004) was more favourable and this coincided with females being in better condition, and average maternal mass and condition near parturition was higher than for 2003 (Figure 8). Although late 2004 and early 2005 brought about another ENSO event, females were in good condition at parturition in 2005 (Figure 7 and 8). Similar results have been found for *A. forsteri* and other pinnipeds where mothers and pups exhibit decreased condition and pups grow more slowly during an ENSO phase (Ono *et al.* 1987; Majluf 1991; Bradshaw *et al.* 2000)

Although mean maternal absences were longer in 2005 than 2004 (4.25 vs. 2.74 days, Chapter 4, Table 4) they were similar to *A. forsteri* females on the Otago Peninsula

(mean range: 3.4-11.8 days, Harcourt *et al.* 2002), and *A. forsteri* at Maatsuyker Island (mean: 4.6 days, Lea and Hindell 1997) and is probably not long enough to significantly reduce pup condition and growth. In comparison, an extreme case exists for *A. tropicalis* at Amsterdam Island where females' summer foraging trip durations averaged 15 days, while winter trips averaged 29 days; these exceptionally long foraging trip durations resulted in relatively slow growth for the pups in winter vs. summer (summer: 21.5 g/day, winter: 1.6 g/day, Beauplet *et al.* 2004).

Despite a difference in growth rates in 2004 and 2005, there was no observable change in pup behaviour between those two seasons (Figure 6). Although one would expect decreased nursing and mother-pup association times in the later (ENSO) year when mean maternal absences were longer (Ono *et al.* 1987) the proportion of time adult females spent onshore in these years was not significantly different (Chapter 4, Tables 3 and 4). Concurrent with the increase in foraging trip duration in 2005, shore bout durations increased (mean: 2.03 vs. 1.74 days, Chapter 4, Table 4). In addition, the relative proportion of overnight to extended foraging trips increased (mean: 42% vs. 29%, Chapter 4, Table 3), meaning that while longer EFTs were being undertaken, there were fewer of them being interspersed between more frequent OFTs. The use of OFTs were not uniform throughout lactation, and in both years were more frequent in early lactation around 30-60 days post partum, however, in 2005, there was also a second peak in frequency of OFTs around 90 days post partum although in general OFTs were less common this late in lactation (Chapter 4, Figure 4). These findings suggest that females were able to alternate between frequent OFTs and longer trips to sea in order to maintain the amount of time spent onshore with their pup (Chapter 4, Figures 2-4). When a colony is located near enough to a reliable food source the increased ability to use overnight foraging trips can be beneficial to reduce the time pups spend fasting and increase the time mothers spend ashore (Goldsworthy 1999). Also, extended foraging trips that are within the fasting ability of the pups are beneficial to adult females as they can acquire more nutrients at less cost by staying at a foraging site longer and reducing total travel to and from the colony (Goldsworthy 1999). Therefore, it is possible that despite potential environmental changes, adult females in the Kaikoura region are able to employ maternal attendance strategies specifically owing to a close food source that allow them to be available to their pup

for similar amounts of time. As a result pup behaviour and growth patterns remained similar in both 2004 and 2005.

Maternal influence

The relationship between maternal traits and pup growth and condition were tested in several ways. Initially, female size and condition at parturition were compared with pup size and condition at birth and 56 days of age (February). Although there was a positive relationship between maternal size and condition and February pup size and condition, this relationship was not apparent at birth as might be expected. In both otariids and phocids, larger females are reported as giving birth to larger offspring (otariids: Lee *et al.* 1991; Kovacs and Lavigne 1996; phocids: Pomeroy *et al.* 1999; Mellish *et al.* 1999) and this relationship in terms of “offspring/litter mass” holds true for many terrestrial mammals as well (primates and ungulates: Lee *et al.* 1991; eutherian mammals: Kovacs and Lavigne 1996; meerkats: Russell *et al.* 2004). In pinnipeds larger females typically produce and rear larger, healthier offspring (Mellish *et al.* 1999; Pomeroy *et al.* 1999). Reasons for the apparent lack of this relationship between maternal mass and pup birth mass observed in the current study are unclear. Despite the lack of relationship at birth in the current study, it appears that increased female size and condition at parturition did influence pup mass and condition at 56 days of age. This relationship may well extend to weaning, as other studies have found that pup size at weaning has a strong relationship with maternal size at parturition (Lee *et al.* 1991), however, in the current study, the sample size of pups caught prior to weaning with mothers of known size was too small to accurately test this.

There was no intra-annual difference in pup mass or growth based on the female parameters as a comparison of both female size and foraging trip duration with pup size in February showed that neither had a significant influence on pup size, and neither maternal parameters were significantly related to pup growth. This is contrary to other studies that have found that female’s that exhibited shorter foraging trips had pups that grew faster. This was the case with *A. forsteri* on Kangaroo Island (Haase 2004) and Maatsuyker Island (Lea and Hindell 1997) although the latter study was based on a small sample size of mother-pup pairs. In both of the previous studies (Lea and Hindell 1997; Haase 2004), there was a significant amount of variation in

foraging trip duration (range: 2.5-44.0 days, Haase 2004; range: 0.69-10.13 days, Lea and Hindell 1997) suggesting that some females were having to travel considerable distances to a foraging ground (Beauplet *et al.* 2004).

The attendance patterns discussed in Chapter 4 are indicative of Ohau Point females utilising a close food source, the Kaikoura Canyon (within 2 km offshore). If females are using a close, reliable food source then perhaps a variety of different strategies can be employed within a season to achieve similar results in terms of pup growth. A similar situation occurred for *A. gazella* and *A. tropicalis* at Macquarie Island, where females forage in a deep-sea trench near the colony (Goldsworthy 1999). Adult female fur seals at Macquarie Island have been shown to forage 30-60 km away during extended foraging trips (EFTs) and 10 km away for overnight foraging trips (OFTs) (Robinson *et al.* 2002). Females that performed more OFTs also spent proportionally more time ashore than females that didn't, while this should be more beneficial to a pup, there was no relationship detected between the proportion of OFTs performed and pup growth (Goldsworthy 1999). This result supports the idea that in the presence of a reliable food source, different maternal strategies may still yield similar results. Similarly, while female size and condition may be influential in pup size later in lactation, the lack of a strong a relationship with pup growth that one would expect may also be due to the increased accessibility of food for Kaikoura fur seals.

Conclusion

This study has shown that for *A. forsteri* at Ohau Point, maternal parameters such as size, condition and foraging trip duration did not have a significant influence on pup growth or condition. Although female size appeared to have an influence on pup size and condition after birth, it did not show a significant relationship with pup growth as expected. The lack of a strong relationship among these variables is probably indicative of the presence of a reliable food supply near to Ohau Point, which enables different individuals to use different means to achieve the same end result. The dramatic increase in growth rates observed in 2005 was not due to a difference in individual attendance patterns. Instead it was probably a combined result of increased female size and condition at parturition, and the ability to adapt to environmental changes through the use of a close, reliable food source. By lengthening foraging trip

duration within the fasting ability of their pups and without decreasing the proportion of time spent ashore females were able to maintain better condition, acquire greater nutrient stores from extended foraging trips, and still be available onshore to pups for similar nursing times.

References:

- Altmann, J. (1974). Observational study of behaviour: sampling methods. *Behaviour* **49**, 227-263.
- Arnould, J. and Hindell, M. (2002). Milk consumption, body composition and pre-weaning growth rates of Australian fur seal (*Arctocephalus pusillus doriferus*) pups. *Journal of Zoology, London* **256**, 351-359.
- Arnould, J., Boyd, I. and Speakman, J. (1996). Measuring the body composition of Antarctic fur seals (*Arctocephalus gazella*): validation of hydrogen isotope dilution. *Physiological Zoology* **69**, 93-116.
- Beauplet, G., Dubroca, L., Guinet, C., Chereil, Y., Dabin, W., Gagner, C. and Hindell, M. (2004). Foraging ecology of subantarctic fur seals *Arctocephalus tropicalis* breeding on Amsterdam Island: seasonal changes in relation to maternal characteristics and pup growth. *Marine Ecology Progress Series* **273**, 211-225.
- Benoit-Bird, K., Würsig, B. and McFadden, C. (2004). Dusky dolphin (*Lagenorhynchus obscurus*) foraging in two different habitats: active acoustic detection of dolphins and their prey. *Marine Mammal Science* **20**, 215-231.
- Bester, M. and VanJaarsveld, A. (1997). Growth in the subantarctic fur seal *Arctocephalus tropicalis* pups as a possible indicator of offshore food availability. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds M. Hindell and C. Kemper.) pp. 88-91. (Surrey Beatty & Sons, Chipping Norton: Australia).
- Boersma, P. (1998). Population trends of the Galápagos penguin: impacts of El Niño and La Niña. *Condor* **100**, 245-253.
- Boltnev, A., York, A. and Antonelis, G. (1998). Northern fur seal young: interrelationships among birth size, growth and survival. *Canadian Journal of Zoology* **76**, 843-854.
- Boren, L. J. (2001). Assessing the impact of tourism on New Zealand fur seals (*Arctocephalus forsteri*). MSc. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Boren, L. J., Gemmell, N. J. and Barton, K. J. (2002). Tourist disturbance on New Zealand fur seals, *Arctocephalus forsteri*. *Australian Mammalogy* **24**, 85-96.
- Boyd, I. and McCann, T. (1989). Pre-natal investment in reproduction by female Antarctic fur seals. *Behavioural Ecology and Sociobiology* **24**, 377-385.
- Bradshaw, C. J., Davis, L. S., Lalas, C. and Harcourt, R. G. (2000). Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. *Journal of Zoology, London* **252**, 41-51.
- Bradshaw, C. J., Davis, L., Purvis, M., Zhou, Q. and Benwell, G. (2002). Using artificial neural networks to model the suitability of coastline for breeding by New Zealand fur seals (*Arctocephalus forsteri*). *Ecological Modelling* **148**, 111-131.
- Bradshaw, C. J., Harcourt, R. and Davis, L. (2003). Male-biased sex ratios in New Zealand fur seal pups relative to environmental variation. *Behavioural Ecology and Sociobiology* **53**, 297-307.

- Brandon, E. A., Calkins, D. G., Loughlin, T. R. and Davis, R. W. (2005). Neonatal growth of Steller sea lion (*Eumatopias jubatus*) pups in Alaska. *Fisheries Bulletin* **103**, 246-257.
- Chambellant, M., Beauplet, G., Guinet, C. and Georges, J. (2003). Long-term evaluation of pup growth and preweaning survival rates in subAntarctic fur seals, *Arctocephalus tropicalis*, on Amsterdam Island. *Canadian Journal of Zoology* **81**, 1222-1232.
- Chilvers, B., Wilson, K. and Hickling, G. (1995). Suckling behaviours and growth rates of New Zealand fur seal, *Arctocephalus forsteri*, at Cape Foulwind, New Zealand. *New Zealand Journal of Zoology* **22**, 263-270.
- Chilvers, B., Robertson, B., Wilkinson, I. and Duignan, P. (in prep). Growth and survival from post-partum to 3 months of New Zealand sea lions, *Phocarctos hookeri*.
- Costa, D. (1991). Reproductive and foraging energetics of high latitude penguins, albatrosses and pinnipeds: implications for life history patterns. *American Zoologist* **31**, 111-130.
- Crawley, M. (1975). Growth of New Zealand fur seal pups. *New Zealand Journal of Marine and Freshwater Research* **9**, 539-545.
- Crawley, M. and Wilson, G. (1976). The natural history and behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Tuatara* **22**, 1-29.
- Dytham, C. (1999). 'Choosing and using statistics, a biologist's guide.' 1st. (Blackwell Science Ltd.: Oxford.)
- Georges, J.-Y. and Guinet, C. (2000). Maternal care in the subantarctic fur seals on Amsterdam Island. *Ecology* **81**, 295-308.
- Goldsworthy, S. (1992). Maternal care in three species of fur seal, *Arctocephalus* spp. at Macquarie Island. PhD thesis. Monash University, Melbourne, Australia.
- Goldsworthy, S.D. (1995) Differential expenditure of maternal resources in Antarctic fur seals, *Arctocephalus gazella*, at Heard Island, southern Indian Ocean. *Behavioral Ecology* **6**, 218-228.
- Goldsworthy, S. (1999). Maternal Attendance behaviour of sympatrically breeding Antarctic and Subantarctic fur seals, *Arctocephalus* spp., at Macquarie Island. *Polar Biology* **21**, 316-325.
- Goldsworthy, S. and Shaughnessey, P. (1994). Breeding biology and haul-out pattern of the New Zealand fur seal, *Arctocephalus forsteri*, at Cape Gantheaume, South Australia. *Wildlife Research* **21**, 365-376.
- Guinet, C., Goldsworthy, S. and Robinson, S. (1999). Sex differences in mass loss rate and growth efficiency in Antarctic fur seal (*Arctocephalus gazella*) pups at Macquarie Island. *Behavioural Ecology and Sociobiology* **46**, 157-163.
- Haase, T. (2004). The determinants of weaning in the New Zealand fur seal. Unpublished PhD. Department of Zoology, School of Life Sciences, La Trobe University, Victoria, Australia.
- Harcourt, R. G., Bradshaw, C. J., Dickson, K. and Davis, L. S. (2002). Foraging ecology of a generalist predator, the female New Zealand fur seal. *Marine Ecology Progress Series* **227**, 11-24.
- Kirkman, S., Bester, M., Hofmeyr, G., Pistorius, P. and Makhado, A. (2002). Pup growth and maternal attendance patterns in Subantarctic fur seals. *African Zoology* **37**, 13-19.
- Kovacs, K. M. and Lavigne, D. (1992). Maternal investment in otariid seals and walruses. *Canadian Journal of Zoology* **70**, 1953-1964.

- Lea, M.-A. and Hindell, M. (1997). Pup growth and maternal care in New Zealand fur seals, *Arctocephalus forsteri*, at Maatsuyker Island, Tasmania. *Wildlife Research* **24**, 307-318.
- Lee, P., Majluf, P. and Gordon, I. (1991). Growth, weaning and maternal investment from a comparative perspective. *Journal of Zoology, London* **225**, 99-114.
- Lunn, N., Boyd, I. and Croxall, J. (1994). Reproductive-performance of female Antarctic fur seals - the influence of age, breeding experience, environmental variation and individual quality. *Journal of Animal Ecology* **63**, 827-840.
- Lunn, N., Boyd, I., Barton, T. and Croxall, J. (1993). Factors affecting the growth - rate and mass at weaning of Antarctic fur seals at Bird Island, South Georgia. *Journal of Mammalogy* **74**, 908-919.
- Majluf, P. (1991). El Nino effects on pinnipeds in Peru. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 55-65. (Springer-Verlag: London)
- Mattlin, R. (1978). Population biology, thermoregulation and site preference of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1828) on the Open Bay Islands, New Zealand. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Mattlin, R. (1981). Pup growth of the New Zealand fur seal, *Arctocephalus forsteri*, on the Open Bay Islands, New Zealand. *Journal of Zoology, London* **193**, 305-314.
- Mellish, J., Iverson, S. and Bowen, D. (1999). Variation in milk production and lactation performance in grey seals and consequences for pup growth and weaning characteristics. *Physiological and Biochemical Zoology* **72**, 677-690.
- Miller, E. (1971). Social and thermoregulatory behaviour of the New Zealand fur seal. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
- NIWA (2005) The Climate Update. **74**, pp. 4. Wellington, New Zealand.
- Ono, K., Boness, D. J. and Oftedal, O. (1987). The effect of a natural environmental disturbance on maternal investment and pup behaviour in the California sea lion. *Behavioural Ecology and Sociobiology* **21**, 109-118.
- Pomery, P., Fedak, M., Rothery, P. and Anderson, S. (1999). Consequences of maternal size for reproductive expenditure and pupping success of grey seals at North Rona, Scotland. *Journal of Animal Ecology* **68**, 235-253.
- Robinson, S., Goldsworthy, S., vandenHoff, J. and Hindell, M. (2002). The foraging ecology of two sympatric fur seal species, *Arctocephalus gazella* and *Arctocephalus tropicalis*, at Macquarie Island during the austral summer. *Marine and Freshwater Research* **53**, 1071-1082.
- Russell, A., Carlson, A., McIlrath, G., Jordan, N. and Clutton-Brock, T. (2004). Adaptive size modification by dominant female meerkats. *Evolution* **58**, 1600-1607.
- Schulz, T. and Bowen, W. (2004). Pinniped lactation strategies: evaluation of data on maternal and offspring life history traits. *Marine Mammal Science* **20**, 86-114.
- Stirling, I. (1970). Observations on the behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Journal of Mammalogy* **51**, 766-777.
- Taylor, R. (1982). New Zealand fur seals at the Bounty Islands. *New Zealand Journal of Marine and Freshwater Research* **16**, 1-9.
- Trillmich, F. and Dellinger, T. (1991). The effects of El Nino on Galapagos pinnipeds. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 66-74. (Springer-Verlag: London)
- Trillmich, F. (1990). The behavioural ecology of maternal effort in fur seals and sea lions. *Behaviour* **114**, 4-19.

- Trillmich, F., Ono, K., Costa, D., DeLong, R., Feldkamp, S., Francis, J., Gentry, R., Heath, C., LeBoeuf, B., Majluf, P. and York, A. (1991). The effects of El Nino on pinniped populations in the Eastern Pacific. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 247-270. (Springer-Verlag: London)
- Trites, A. (1993). Biased estimates of fur seal pup mass: origins and implications. *Journal of Zoology, London* **229**, 515-525.
- Zar, J. (1984). 'Biostatistical analysis.' (Prentice Hall: Englewood Cliffs, New Jersey.)

Appendix:

Raw data of pup behaviour based on individual pups 2004:

Pup ID	Days Observed	Days Mum Present	Days Mum Absent	Mums prop Time Ashore	Mean time nursing	SD	Mean time with mum	SD	Total time with mum	Mean time away from mum	SD
11	63	32	31	0.51	0.07	0.15	0.11	0.16	0.17	0.83	0.28
12	54	26	28	0.48	0.13	0.21	0.10	0.16	0.23	0.77	0.33
13	51	20	31	0.39	0.10	0.17	0.10	0.17	0.20	0.81	0.28
14	48	19	29	0.40	0.04	0.10	0.07	0.14	0.11	0.90	0.18
15	57	27	30	0.47	0.10	0.15	0.14	0.22	0.24	0.77	0.31
16	40	17	23	0.43	0.11	0.16	0.12	0.18	0.23	0.77	0.32
17	37	21	16	0.57	0.15	0.23	0.11	0.18	0.27	0.73	0.31
18	57	18	39	0.32	0.11	0.20	0.10	0.21	0.21	0.79	0.35
20	31	12	19	0.39	0.09	0.14	0.14	0.22	0.23	0.77	0.33
21	52	22	30	0.42	0.10	0.16	0.14	0.22	0.24	0.76	0.35
22	48	23	25	0.48	0.12	0.19	0.12	0.21	0.24	0.77	0.33
23	40	17	23	0.43	0.13	0.21	0.08	0.12	0.21	0.79	0.30
24	59	25	34	0.42	0.09	0.20	0.08	0.16	0.17	0.82	0.32
31	17	9	8	0.53	0.13	0.22	0.21	0.32	0.34	0.66	0.42
32	17	9	8	0.53	0.13	0.20	0.20	0.29	0.33	0.67	0.44
33	27	16	11	0.59	0.17	0.23	0.22	0.27	0.40	0.60	0.41
34	38	13	25	0.34	0.13	0.22	0.09	0.16	0.22	0.78	0.36
35	35	10	25	0.29	0.03	0.07	0.03	0.07	0.06	0.94	0.12
36	26	12	14	0.46	0.08	0.16	0.10	0.19	0.18	0.82	0.31
37	54	16	38	0.30	0.05	0.14	0.07	0.17	0.12	0.88	0.27
38	28	7	21	0.25	0.07	0.19	0.09	0.21	0.16	0.84	0.30
39	42	10	32	0.24	0.04	0.11	0.04	0.10	0.09	0.91	0.19
54	62	31	31	0.50	0.11	0.19	0.20	0.29	0.31	0.69	0.39
55	58	28	30	0.48	0.13	0.20	0.15	0.24	0.28	0.73	0.34
61	47	21	26	0.45	0.10	0.13	0.15	0.24	0.25	0.75	0.34
62	50	23	27	0.46	0.11	0.17	0.16	0.26	0.27	0.73	0.38
63	37	18	19	0.49	0.09	0.13	0.16	0.22	0.25	0.75	0.33
98	32	13	19	0.41	0.08	0.14	0.12	0.21	0.21	0.79	0.30
99	56	31	25	0.55	0.11	0.18	0.16	0.20	0.27	0.74	0.34
100	47	24	23	0.51	0.10	0.14	0.13	0.22	0.22	0.78	0.31
101	48	23	25	0.48	0.14	0.21	0.11	0.18	0.25	0.74	0.33
102	60	19	41	0.32	0.12	0.22	0.10	0.19	0.22	0.78	0.36
103	56	15	41	0.27	0.07	0.17	0.05	0.13	0.12	0.91	0.22
105	14	6	8	0.43	0.16	0.21	0.07	0.11	0.23	0.74	0.33
106	26	8	18	0.31	0.09	0.18	0.12	0.21	0.21	0.80	0.35
107	47	22	25	0.47	0.08	0.14	0.13	0.23	0.21	0.79	0.32
108	64	32	32	0.50	0.13	0.19	0.14	0.23	0.27	0.74	0.34
109	37	20	17	0.54	0.15	0.21	0.13	0.22	0.28	0.74	0.33
113	48	15	33	0.31	0.07	0.15	0.13	0.26	0.19	0.81	0.34
X5	49	22	27	0.45	0.11	0.18	0.12	0.18	0.23	0.77	0.32
X6	58	18	40	0.31	0.09	0.19	0.09	0.16	0.17	0.84	0.29
X7	49	20	29	0.41	0.11	0.21	0.11	0.19	0.22	0.78	0.33
wb	14	5	9	0.36	0.13	0.23	0.08	0.14	0.21	0.79	0.35
mb	17	10	7	0.59	0.24	0.25	0.15	0.17	0.39	0.78	0.39

Raw data of pup behaviour based on individual pups 2005:

Pup ID	Days Observed	Days Mum Present	Days Mum Absent	Proportion of days present	Mean time nursing	SD	Mean time with mum	SD	Total time with mum	Mean time away from mum	SD
1	14	4	10	0.29	0.07	0.12	0.05	0.11	0.11	0.89	0.20
2	20	9	11	0.45	0.10	0.18	0.13	0.22	0.23	0.77	0.35
3	11	5	6	0.45	0.15	0.23	0.12	0.21	0.27	0.73	0.39
4	12	7	5	0.58	0.31	0.37	0.05	0.08	0.36	0.64	0.40
5	16	7	9	0.44	0.16	0.22	0.12	0.19	0.28	0.72	0.36
6	25	14	11	0.56	0.20	0.24	0.16	0.19	0.36	0.64	0.37
7	19	7	12	0.37	0.09	0.15	0.12	0.21	0.21	0.79	0.30
8	14	3	11	0.21	0.10	0.23	0.03	0.07	0.13	0.87	0.29
9	23	7	16	0.30	0.04	0.09	0.05	0.10	0.09	0.91	0.14
10	25	5	20	0.20	0.05	0.14	0.06	0.15	0.12	0.88	0.28
11	8	3	5	0.38	0.09	0.15	0.08	0.16	0.17	0.83	0.30
14	14	3	11	0.21	0.03	0.08	0.02	0.07	0.05	0.95	0.13
15	4	1	3	0.25	0.04	0.08	0.00	0.00	0.04	0.96	0.08
16	6	3	3	0.50	0.21	0.27	0.18	0.30	0.39	0.61	0.49
18	11	4	7	0.36	0.15	0.25	0.09	0.15	0.24	0.76	0.38
19	6	4	2	0.67	0.18	0.19	0.18	0.19	0.36	0.64	0.35
20	16	6	10	0.38	0.12	0.18	0.10	0.23	0.22	0.78	0.36
21	20	8	12	0.40	0.11	0.18	0.06	0.14	0.17	0.83	0.28
22	19	7	12	0.37	0.11	0.17	0.06	0.13	0.17	0.83	0.27
23	14	4	10	0.29	0.10	0.23	0.10	0.27	0.20	0.80	0.38
24	19	7	12	0.37	0.09	0.20	0.10	0.18	0.19	0.76	0.36
25	17	6	11	0.35	0.11	0.20	0.10	0.18	0.21	0.79	0.34
26	10	2	8	0.20	0.02	0.06	0.11	0.26	0.13	0.87	0.32
27	15	7	8	0.47	0.11	0.18	0.17	0.23	0.28	0.72	0.36
28	10	4	6	0.40	0.10	0.13	0.06	0.14	0.16	0.84	0.25
29	20	11	9	0.55	0.15	0.18	0.09	0.19	0.24	0.76	0.28
30	5	2	3	0.40	0.14	0.23	0.24	0.35	0.38	0.62	0.53
31	14	3	11	0.21	0.09	0.19	0.05	0.12	0.14	0.86	0.30
32	15	3	12	0.20	0.09	0.20	0.02	0.08	0.11	0.89	0.24
33	18	9	9	0.50	0.12	0.16	0.09	0.20	0.21	0.79	0.30
34	7	4	3	0.57	0.11	0.13	0.24	0.23	0.34	0.66	0.34
X6	3	1	2	0.33	0.17	0.29	0.03	0.05	0.19	0.81	0.34
X7	2	2	0	1.00	0.00	0.00	0.18	0.13	0.18	0.82	0.13
SS	5	4	1	0.80	0.25	0.25	0.34	0.29	0.59	0.41	0.47

Intermission 2

In the last section we saw in Chapter 4: Maternal attendance, that female attendance patterns reflect the use of a nearby food source. Foraging trip duration was generally short (Table 4), and even in a year of potentially reduced food availability, the longer foraging trip durations were within the range of normal foraging trip lengths reported for *A. forsteri* and other species. Also, the relatively high use of overnight foraging trips suggests that females are able to forage within 20 km from the colony (Table 3). In 2005, when foraging trip duration was increased, shore bout duration was also seen to increase. With the increase in shore bout duration and the increase in proportion of overnight foraging trips exhibited in 2005 females were able to maintain the proportion of time they spent ashore at approximately 35% (Tables 3 and 4).

In Chapter 5: Pup growth, we see more evidence that female attendance patterns are influenced by local parameters and subsequently affect pup growth and condition. Although maternal parameters within a year had little effect on pup growth (Figures 8-9), a females ability to adapt to inter-annual changes in prey availability did affect their pups growth (Figure 4). Female condition and mass at parturition was also related to pup condition and mass (Figure 9), and increased female condition at the onset of the 2004/05 breeding season (Figure 8) was likely to have played a role in the increased rates of pup growth observed that season.

Given that the colony is in stages of exponential growth (Chapter 2), and that a close food source seems to be influencing maternal investment strategies and pup growth (Chapters 4 and 5), then the incidence of mortality and disease would be expected to be low. The following section, will investigate parameters of pup health in two chapters. First, Chapter 6: Mortality, levels and common causes of mortality in the region will be investigated. Then, in Chapter 7: Parasites, I will utilise Ivermectin, an anthelmethic medication, to examine the level of influence intestinal parasites have on pup growth at Ohau Point. Although the anticipation is that seals in the region will be relatively healthy as colony growth and body condition already indicate (Chapter 2 and 5), the heightened proximity between seals and humans in recent years is cause for concern and further monitoring may be warranted.

Chapter 6
Common causes of mortality to New Zealand
fur seals in the Kaikoura region with special
reference to pups and juveniles

Laura J. Boren, Mike Morrissey, Mana Stratton, Padraig J. Duignan, and Neil J.
Gemmell

This chapter will be broken into smaller components for publication.
Entanglement portion accepted by: *Marine Pollution Bulletin*

Chapter 6: Common causes of mortality to New Zealand fur seals in the Kaikoura region with special reference to pups and juveniles

Abstract

Calculating rates of mortality for aquatic species is difficult as it relies on reliably re-sighting individuals, and recovering carcasses. Within pinnipeds, mortality is more easily determined for a single cohort: that of a pup until weaning. In Kaikoura, where the fur seal population has been rapidly growing following re-colonisation, levels and causes of mortality have been investigated through regular checks of the Kaikoura Peninsula and Ohau Point seal colony for dead individuals (2001-2005), post mortems of freshly dead animals (2001-2005), and examination of the Department of Conservation seal related call-out records (1994-2005). Natural causes of death common for pups were emaciation, trauma and infection, while in juveniles and adults; emaciation and parasitic infection were common implications in mortality. While initial pup mortality at Ohau Point was relatively low to age 50 days (3%) and mostly involved emaciation (88.5%), the proximity of human development played a more important role in pup mortality after 50 days of age, with 66.7% of deaths being attributed to car collisions. Other causes of death including train hits, dog attacks and direct human interactions were observed that are unique to areas where humans and seals are in close proximity. In addition, entanglement rates of pinnipeds in Kaikoura are some of the highest reported world-wide (average range: 0.85-2.8%). While seal populations in the Kaikoura region are increasing, there is likely to be a parallel increase in the level of human-influenced mortality observed in future years. Therefore, levels of mortality and causes of death in fur seals in the Kaikoura region will be outlined with special reference to pups and juveniles, and how these types of mortality are likely to affect population dynamics in the future.

Introduction

Comparing population mortality rates over time allows scientists to determine periods of increased population decline and factors that may have contributed to the decline (Estes *et al.* 2003). It also enables the understanding of how climatic patterns and low food availability will affect a population (Soto *et al.* 2004) and how increasing density in established populations will affect its dynamics (Mattlin 1978a; Harcourt 1992). Baseline estimates of mortality are also a key part of modelling complex interactions to determine sustainability of populations undergoing exploitation (Snyder 1976).

Levels of mortality are difficult to determine in aquatic organisms. Rates are typically calculated based on the number of individuals observed dead, through collection of beach-cast carcasses (Estes *et al.* 2003), or mapping of dead individuals observed in a colony (Mattlin 1978b; Soto *et al.* 2004) out of the total population estimate. However, the chance that all deceased animals are found by observers is rare; owing to the colony terrain (Soto *et al.* 2004), accessibility to coastal areas within the population's range (Estes *et al.* 2003), and the fact that animals that died at sea may not always turn up on shore, or in the area being monitored due to the nature of the aquatic environment (Henderson 1984). For some species where intensive carcass recovery has occurred year round, an estimate of carcass recovery rate can be made which enables the calculation of a more accurate population mortality rate (Estes *et al.* 2003). Where this is not possible, the calculated mortality rates are invariably underestimates of the actual mortality.

Within pinnipeds, mortality rates are more easily calculated for pups from birth to weaning as they are dependent upon their mothers and do not leave the colony until after weaning (Mattlin 1978b). Pinnipeds, like other large mammals, have an initial high rate of mortality while the young are still dependent upon their parents, followed by a slower rate of mortality which increases again as animals reach senescence (Snyder 1976; Chapman and Reiss 1992). Thus survival to the age of one year or nutritional independence is often low (Hall *et al.* 2001).

For otariids there have been a range of estimates for pup mortality based on a variety of methods that have included multiple populations for some of the species (Harcourt 1992). Many estimates, however, have only been made for the first few months of life

(0-4) and ranged from as little as 2.7-5.5% (*Arctocrphalus gazella* 0-1 months at Slieper Island) to 30.9-48.7% (*A. australis* 0-1 months in Peru - as summarised in Harcourt 1992). For *Arctocephalus forsteri* on Open Bay Islands, West Coast, New Zealand, a 20% mortality rate was calculated from birth to 50 days through daily mapping of live and dead animals in two study areas (Mattlin 1978b). A 40% mortality rate to 300 days of age was calculated based on the decreasing number of pups seen at the colony on further field trips (Mattlin 1978b).

Pup mortality can be influenced by a number of factors both natural and human-influenced. Some of the more common causes include starvation (Mattlin 1978b) sometimes occurring due to low food availability brought about by environmental changes (Soto *et al.* 2004), increased density and increased female aggression (Harcourt 1992; Majluf 1992), predation (Mattlin 1978b; Harcourt 1993; Bradshaw *et al.* 1998), infection and disease (Duignan 2000a) and parasites (Sepulveda 1998; Spraker *et al.* 2003). Mortality related to humans can include trampling in response to a human disturbance (Mattlin 1978b), entanglement in fishing gear and other marine debris (Donohue *et al.* 2001), incidental by-catch in local fisheries (Shaughnessy *et al.* 2003), and culling (Ambrose 2004).

The *A. forsteri* population in Kaikoura, South Island, New Zealand, is in close proximity to an expanding human population. The town's major industries are eco-tourism, which includes fur seals as a target (Boren 2001); and fisheries (Harris 1994). The largest breeding colony in the region, Ohau Point, is also located adjacent to SH1 – the major North-South highway for the South Island – and is a popular stop off for tourists in transit (Simmons *et al.* 1998). In recent years, the region's expanding tourism industry in parallel with fur seal re-colonisation has raised concerns over the increased potential for zoonotic transfer of disease between fur seals and humans (Hunter *et al.* 1998) and between fur seals and terrestrial mammals (e.g. dogs, possums, livestock, Cooke *et al.* 1999), as well as the potential for increase in human-influenced mortality in the region.

As a result, this study aims to provide a baseline of information regarding the level of mortality of *A. forsteri* in the Kaikoura region, including pup mortality at Ohau Point. This includes determining the major causes of death for fur seals in the region, the

degree of human-influenced mortality and how this might affect population dynamics in the future. Possible sources of error in calculating mortality rates will also be discussed.

Methods

Study sites

Data collected for this study were obtained from areas along the Kaikoura coast (42°15S/173°50E) on the South Island of New Zealand. The Kaikoura township is located at the base of the Kaikoura Peninsula on the north side (Figure 1). Seals can be found along the coast from Oaro to the south up to Kekerengu in the north. Seals breed at three locations within this range: Ohau Point, Lynch's Reef, and Barney's Rock (Figure 1). Seals also haul-out in high numbers either side of Ohau Point, along much of the Kaikoura Peninsula, adjacent to the highway at Barney's Rock, and further south at Haumuri Bluff (Figure 1). Seals frequently haul-out individually and in small numbers elsewhere in this range. State highway 1 and the New Zealand Trans-scenic railway line run adjacent to the coast from Oaro to north of Kekerengu, including alongside the Ohau Point seal colony. Seal numbers in this region have been increasing since nearly being exterminated by the sealing industry in the late 1800's (Wilson 1981). Initially low numbers (200-500) of *A. forsteri* were observed along the Kaikoura coast in the 1950-1960's (Sorenson 1964). In the past fifteen years, numbers have increased from ca. 1200 in 1990 to over 3000 in 2002, and 2005 from the Waiiau River to the south and Clarence River to the north (M. Morrissey, pers. obs).

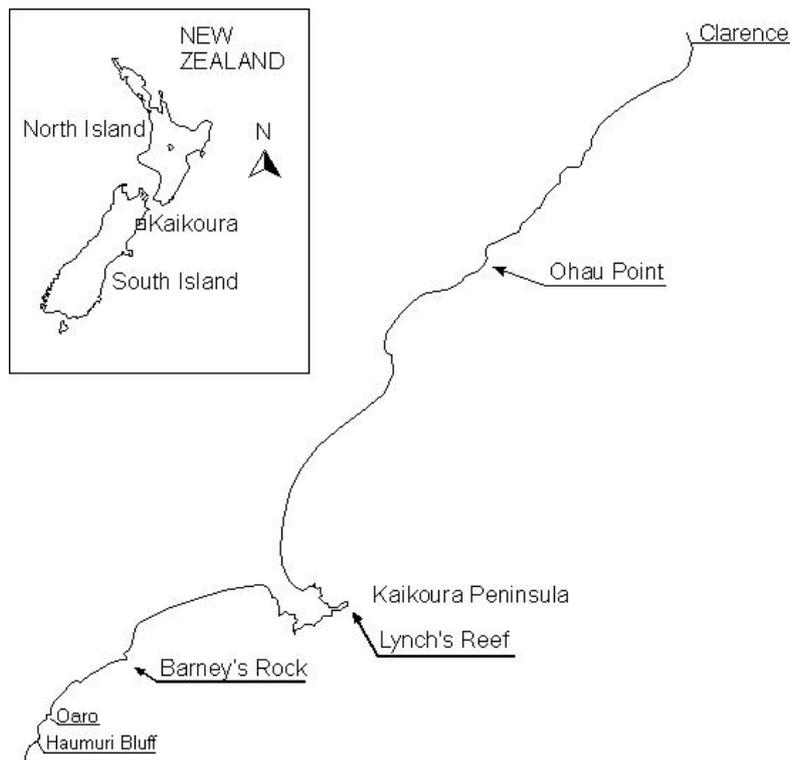


Figure 1: Map of the Kaikoura Coastline showing locations of the three main *A. forsteri* breeding colonies, Ohau Point to the North, Lynch's Reef on the Kaikoura Peninsula, and Barney's Rock to the South. Although seals haul-out elsewhere along the coast, most reports are between Clarence (42 km North of Kaikoura), and Oaro/Haumuri Bluff (16 km to the South).

Review of historical data

Data on seal related callouts has been collected by the Department of Conservation (DOC) Kaikoura field centre staff since 1995. For every call out a form is filled in detailing the incident and follow-up action. The reports are logged over a financial year and summary statistics are calculated. Each callout may involve one or more seals, each with their own outcome. Each seal is counted as an incident. The incidents reported were summarised into the following eleven categories:

- Unknown death
- Entanglement
- Illness/Injury – seal reported sick, injured, not behaving normally, or distressed
- Seal on Road
- Motor vehicle collision
- Wandering – seal reported in an unusual place
- Public harassment – involving humans and seals, seal is “distressed” or death has occurred
- Hit by train
- Dog attack
- Boat strike
- Non-fur seal sighting – sightings involving a leopard or elephant seal

Data from 1995 to 2005 were compiled into a database and analysed for the purpose of assessing time spent on specific call-outs, outcomes of non-fatal callouts, and common causes of mortality in the region (Report for DOC, Rob Suisted, Nov. 2004). These data were summarised to provide historical information on concerns relating to seals in the region and provide an indication of mortality rates in the region.

Sightings of mortalities along the coast

Seal mortalities were recorded opportunistically along the coast during concurrent studies of maternal behaviour and pup condition in the region during the austral summers of 2001/2002, 2002/2003, 2003/2004, and 2004/2005. During the first two seasons, weekly checks of the Kaikoura Peninsula were made and the presence of dead seals was recorded along with carcass condition, age estimate, gender, standard

length and axillary girth, where possible. During the final two seasons effort was focused more at Ohau Point, although, in all four seasons mortalities were recorded from both the Peninsula and Ohau Point breeding colonies.

Post mortems

Freshly dead seals found at Ohau Point or on the Kaikoura Peninsula were brought back to the University of Canterbury, Edward Percival Field Station for post mortem. Here individuals were weighed and measurements were taken of dorsal straight length, axillary girth and sternal blubber depth, where possible. Gender and approximate age of the individual were also recorded. Samples for histological analysis were taken from all major organs, a variety of lymph nodes, salivary glands, and thyroid (See Appendix 1: histological checklist). Brain and eye samples were only collected if head trauma was suspected. Samples were fixed in 10% buffered formalin. Parasites were collected from the gastro-intestinal tracts, rinsed in saline and stored in 70% ethanol (Duignan 2000b). Notes on gross pathology were taken at the time of post mortem to assist in the final diagnosis.

Histology

Tissue samples were prepared into slides, some manually using an Eosin –sigma stain and others at an automated lab using an Eosin-hematoxylin stain (Eroschenko 2005). Samples were then analysed for any signs of disease or abnormalities associated with cause of death.

Data analysis

Blubber depth, state of nutrition and factors relating to death were compared between different age groups using Chi-squared tests of goodness of fit (Dytham 1999). Body condition of pups hit by cars was compared to the colony average by a one-sample one-tail t-test (Zar 1984).

Results

Common report types pertaining to seals on Kaikoura Coast

Based on summary statistics, the number of callouts over the last decade ranged from 44 to 111 callouts per year with an average of 66.5 per year (Table 1). The total number of callouts over the last decade was 665. For analysis, incidents were broken down by calendar year, with 1995 and 2005 only being partial years. The number of incidents for complete years ranged from 57 to 129 incidents per year, with an average of 88.4 incidents per year and a total of 840 for the decade.

Table 1: Number of callouts related to seals in the Kaikoura region per financial year from July 1995 to June 2005 and the number of incidents involving seals in the Kaikoura region per calendar year from 1995-2005. *The calendar years of 1995 and 2005 are not complete years.

Financial year	Number of callouts	Calendar year	Number of incidents
1995-1996	44	1995*	12
1996-1997	111	1996	81
1997-1998	80	1997	128
1998-1999	58	1998	111
1999-2000	58	1999	63
2000-2001	68	2000	68
2001-2002	64	2001	88
2002-2003	57	2002	129
2003-2004	66	2003	71
2004-2005	59	2004	57
		2005*	32
Total	665	Total	840

Five incident types are more common than the rest and are shown in comparison with the remaining categories grouped together as “other” (Figure 2a). Seasonality of the “other” categories, making up 5.1% of the total incidents, is shown in Figure 2b. Unknown death is the most common report (40.2%), and peaks in late winter (Aug) to early spring (Oct) with a small peak in late summer (Feb). Entanglements were the next most commonly reported incident (22.4%), and remained consistent in number through most of the year except for a slight peak in late winter (Aug) and a subsequent decrease in spring (Oct). Illness/Injuries (18.3%) peaks in February and September. Both the number of seals on the road (8.5%), and the number of seals hit by vehicles (5.6%) increase in winter and peak in July. Of the remaining categories, Wandering peaks in July. Public harassment reports occurred year round, but peaked slightly in January, when tourism is highest.

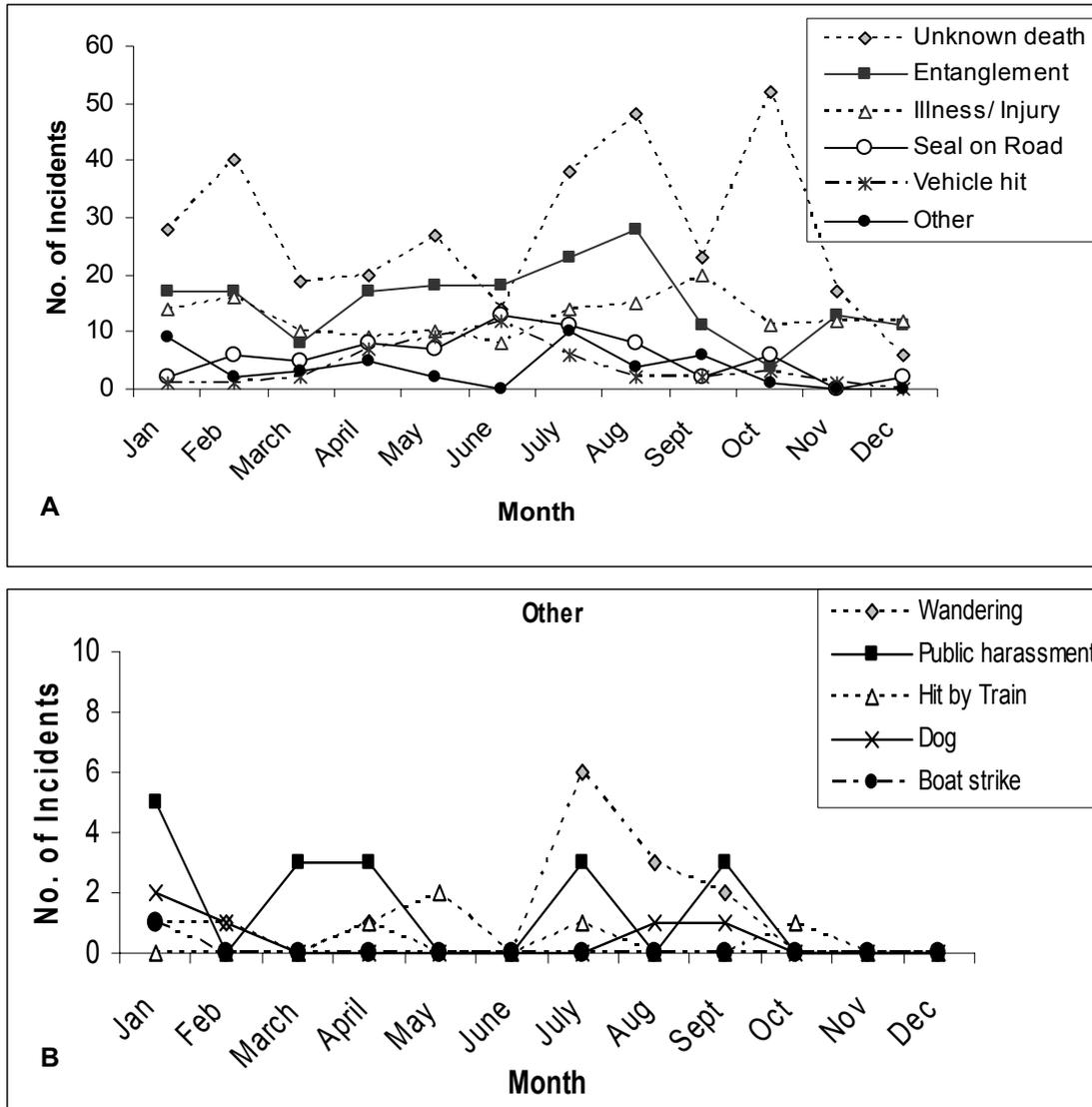


Figure 2: Comparison of the seasonality of the a) most commonly reported incidents relating seals and b) the remaining incident types. As the later incident types are less common, note that the y-axis is displayed on a scale of 10.

Historical common causes of death known versus unknown

Mortalities were associated with a variety of incident types; however, unexplained mortality was the most common reason for a callout. DOC staff were not always able to make it to every location in time to confirm death, and although not common, there were a few cases where a dead seal was reported that was just sleeping. For these reasons confirmed deaths are slightly lower than initially reported and are shown for a comparison in Figure 3. For the years where data is complete (1996-2004), there were on average 36 unexplained deaths reported per year with an average of 34 confirmed, however, two peaks were observed in 1998 and 2002 with 60 and 67 confirmed deaths, respectively.

Gender and age class were not always reported, or not always available depending on state of decomposition, but for 56 carcasses where age class was recorded, 72% were adults. For 28 carcasses where gender was recorded, 77% were males.

Out of 840 incidents recorded in 10 years, approximately 381 resulted in fatality (mean 38.1). Of these, 83% were “unexplained.” The remaining fatalities could be explained, and the majority of these were caused by vehicle hits on the road (68.2% - Figure 4). Ill or injured animals contributed approximately 12.1% to the remaining fatalities, while entanglements only contributed about 6.1%. It is possible that a significant portion of the “unexplained deaths” could have been attributed to illness/injury; however, post mortems were not always feasible due to the condition of the carcass when found.

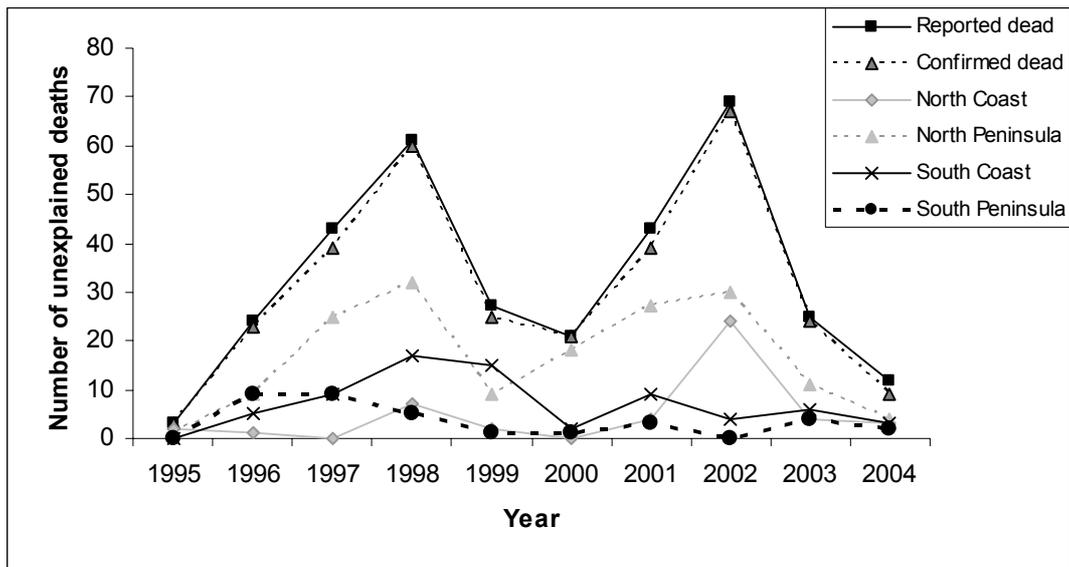


Figure 3: The number of unexplained deaths reported and confirmed over the years in the Kaikoura region, and the locations where these deaths were sighted.

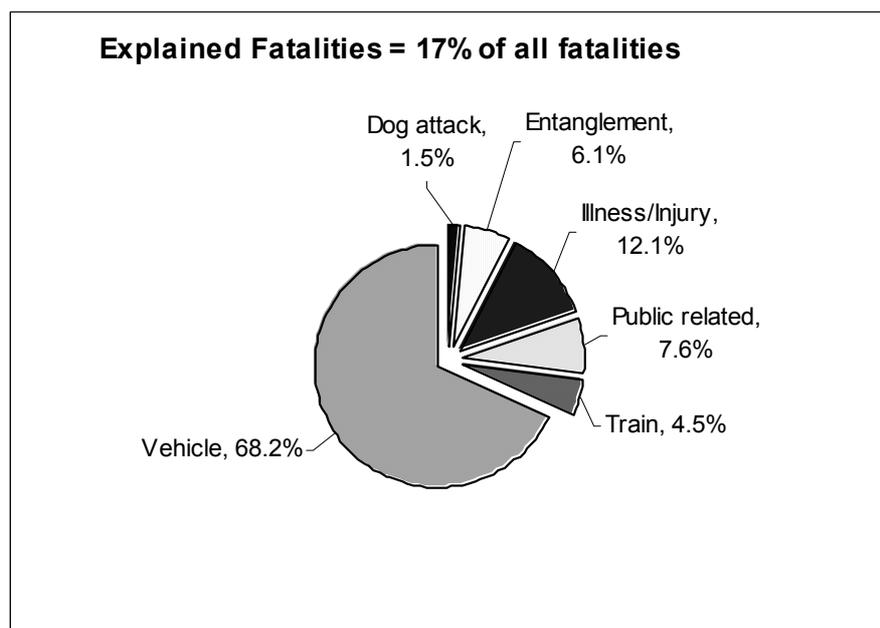


Figure 4: Breakdown of the proportion of explained fatalities in the Kaikoura region. Explained fatalities only make up 17% of the total fatalities reported.

Levels of mortality - general

The average number of fatalities reported based on a decade of call outs was about 38.1 per year (Table 2). This is similar to the number counted within a 3-5 month field season, when actively searching for seals in 2002 and 2003, illustrating that not all mortalities are successfully reported. It is important to note that for 2002 significantly more than 38.1 seals were confirmed dead (81), as this was one of the two peaks in unexplained reported deaths, the other occurring in 1998 when 67 mortalities were reported.

Table 2: Number of dead seals reported by different methods: Average per year based on total number of fatalities recorded in 10 years, Approximate number reported to Department of Conservation staff in a calendar year, and Number sighted during research in approximately 4 month austral summer field seasons.

	Mean total	Calendar year	c. 4 month season
2002	38.1	81	39
2003	38.1	29	41

Similar to the trends found for historical data, males were the most commonly found dead in our survey (Table 3). A high proportion of mortalities were also sub-adults (40.9%) and pups (32.3%). The apparent discrepancies in results for age groups reported to the Department of Conservation and that found in specific searches for dead animals can easily be explained by the experience of the people making the report in categorising the age of a fur seal.

Table 3: Age and Sex classes of dead animals found during searches of the Kaikoura Peninsula, post mortems and seen from the cliffs at Ohau Point. Year 2004 N = 9, is low due to reduced search effort that year. Also, in 2005, the search effort was focused towards Ohau Point rather than the Kaikoura Peninsula.

Year	N	Adult	Subadult	Juvenile	Pre-Weaner	Pup	Male	Female	Unk Gender
2002	39	15.4%	56.4%	15.4%	10.3%	2.6%	53.8%	12.8%	33.3%
2003	41	19.5%	56.1%	2.4%	7.3%	14.6%	68.3%	19.5%	12.2%
2004	9*	11.1%	11.1%	11.1%	0.0%	66.7%	44.4%	55.6%	0.0%
2005	26	0.0%	3.8%	3.8%	0.0%	92.3%	30.8%	23.1%	46.2%
Combined		13.0%	40.9%	7.8%	6.1%	32.2%	53.0%	20.9%	26.1%

Pups

In the final season, 2004/2005, more focus was placed on pup mortality rather than all age/sex classes. In this season more deaths were visible from above the colony than in previous seasons. At least 20 deceased pups ranging between birth and 50 days old were sighted, 18 of which were less than two weeks old. Many of these individuals were small and in poor condition. One individual drowned as the tide came in the day it was born after its mother rejected it for her emaciated yearling. Of the two remaining pups under 50 days old, one was a male presumed to have died from infection after being sighted with a large abscess on his right fore-flipper and in a very lethargic state. He was never sighted again despite his mother being an identifiable female. The other pup was a female and appeared in relatively good condition. However, she was the only instance in all four seasons of a pup less than 2 months of age infected with intestinal parasites. After 50 days of age, very few dead pups were found. Of these, all four were hit by cars. Pup mortality in 2004/05 represents a very small proportion of the total estimated born for that year: 3% (0-50 days old) and less than 1% (>50 days old).

Common causes of death – from post mortems and sightings

Figure 5, shows a breakdown of the blubber depth and state of nutrition of individuals collected for post mortem. The majority of deceased individuals had less than 10mm of sternal blubber depth (57.7%), and were in visibly poor condition. The ratio of emaciated vs. non-emaciated individuals was significantly different for different age groups, with blubber depth being significantly lower for pups less than 50 days old ($\chi^2 = 8.25$, $df = 3$, $p = 0.041$). Table 4 shows factors involved in the cause of death for 46 individuals (currently 27 post-mortems where implications in cause of death is known plus 19 others not sampled but having a discernable cause of death). The factors important in cause of death were significantly different based on age class ($\chi^2 = 71.59$, $df = 24$, $p < 0.001$). Emaciation was the most significant factor causing death in pups less than 50 days old (88.5%) and in juveniles (most aged 1-2 years – 100%). Parasites were also found in all juveniles post-mortemed. For pups aged between 50 days and weaning, vehicles accounted for 66.7% (6/9) of mortalities.

The body condition of emaciated pups was significantly lower than the population average for their cohort (0.05 vs. 0.09 kg/cm at 17 days of age, $t = -13.7$, $df = 15$, $p <$

0.0001; 0.08 vs. 0.14 kg/cm at 11 months, $t = 14.07$, $n = 52$, $p < 0.0001$ - Figure 11) as would be expected, with most blubber depths being less than 10mm (Figure 5; Appendix 3).

Out of all seals post-mortemed there were 31 cases where emaciation played a role in cause of death. Eleven individuals had gastro-intestinal parasites, five had lungworm, one pup had hookworm, and one pup had a fluke in its common bile duct. Two pups had abscessed infections near their fore-flippers, two individuals had abscesses on their livers, one adult had chronic hepatitis and an emaciated 11 month old had severe signs of infection throughout the body. In ten cases trauma was involved and in seven cases the individuals were hit by a car. One subadult male was emaciated and died due to an entanglement (Table 4). Specific details for the individual post-mortems are included in Appendix 3.

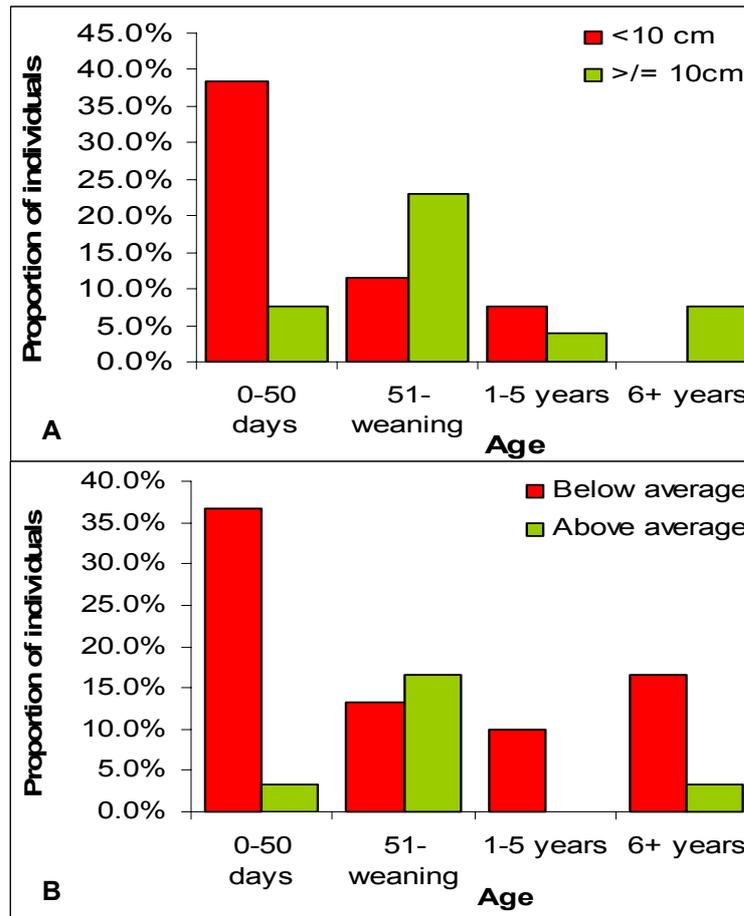


Figure 5: A) Blubber depth and B) Estimated State of nutrition of dead individuals based on age group. Blubber depth is known for n = 26 individual post mortems, and the State of Nutrition is known for n = 30 individual post mortems.

Table 4: Incidental findings related to cause of death are known for n = 46 individuals. Not all underwent necropsy. Sample sizes based on age for this parameter are: 0-50 n = 26; 51-weaning n = 10; 1-5 years n = 4, sub/adult n = 6. For some individuals multiple situations were found, ex: one sub-adult male was emaciated, had GI parasites and lungworm.

Age Group	GI						Infection	Trauma	Car hit	Entangled
	Emaciation	Parasites	Lungworm	Hookworm	Fluke					
0-50 days	88.5%	3.8%	0.0%	3.8%	0.0%	7.7%	11.5%	0.0%	0.0%	
51-weaning	10.0%	0.0%	10.0%	0.0%	3.8%	30.0%	60.0%	60.0%	0.0%	
1-5 years	100.0%	100.0%	25.0%	0.0%	0.0%	0.0%	25.0%	25.0%	0.0%	
6+ years	50.0%	100.0%	50.0%	0.0%	0.0%	33.3%	0.0%	0.0%	16.7%	
Chi-square p =	<0.001									

Human-related concerns – from all combined data

Entanglements

Entanglements are the second most common reason for a callout and require the most in terms of action from DOC staff. A total of 185 entangled seals were reported over the years with an average of 19 per year for the nine years in which the database is complete. In order to calculate entanglement rates for the region one needs to have an accurate population estimate for the region. Full estimates have been carried out sporadically over the years, but are currently not up to date for all the years of interest. Recent estimates for the region and the numbers of entangled seals seen or reported are shown in Figure 6. Entanglement rates have been calculated using the population estimate for the region, and using a population estimate for the Ohau Point seal colony that is calculated by multiplying the pup production for the year by 4.9 (Taylor 1982). Using the regional counts, the rate of entanglement is less than 1% of the population. Although an entanglement rate based on the Ohau population alone is an overestimate, it provides a rough entanglement rate for years in which a regional count is not available. Using this method, the proportion of entangled seals is less than 10% of the population, averaging around 2.84% per annum (Figure 6).

DOC staff responded to approximately 89% of all entanglement callouts. Four potential outcomes were recorded. The first involved the seal being unharmed and managing to free itself or simply having scarring from an old entanglement wound. The other outcomes included: a successful release; unknown because the seal couldn't be caught; or death (Figure 7). Deaths were rare, and there were many successful releases, however, the most common outcome was “unknown.”

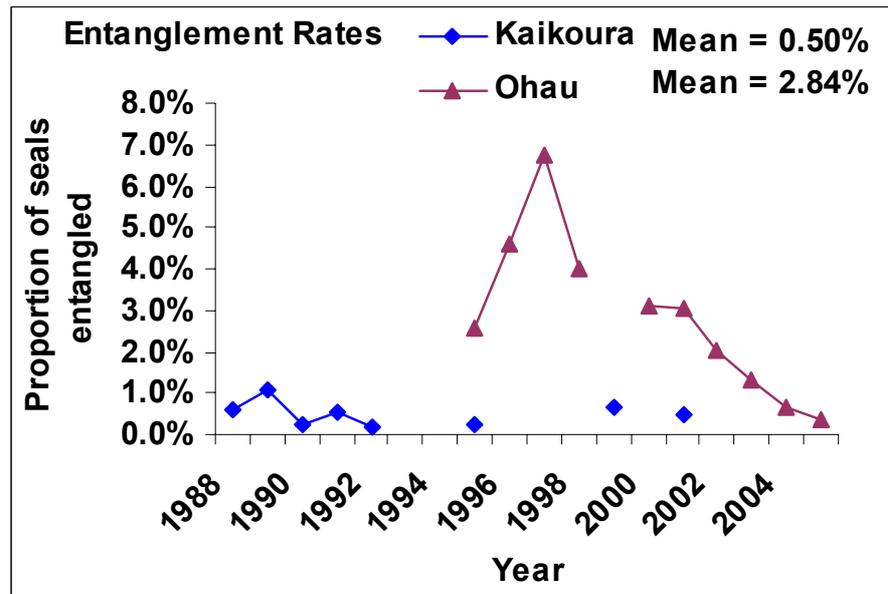


Figure 6: Estimates of rate of entanglement in the Kaikoura region based on regional counts, and pup-based population estimates for Ohau Point. Note the average number entangled per year is based on the nine years where the database is complete (1996-2004). Also, entanglement rates calculated for years leading up to 1996 and 2005 are underestimates as they are not complete years or did not involve the same effort in reporting entangled animals.

There are several different types of debris that have been removed from seals. By far the most commonly seen in the region is green trawling net (Figure 8a). Blue plastic strapping (Blue bands) also make up a reasonable proportion of the entanglement debris. However, the actual contribution of green trawl net and blue bands to the remaining entanglement material is damped out by the “other net” and “other band” categories where not only other colours were included but also generic nets and bands where no colour was reported. Therefore, the proportion of green trawl nets and blue bands are both likely to be slightly higher than the 42 and 16% observed, respectively. Other pieces of debris removed from seals, although only reported in small amounts, included fish hooks, wire, twine, and rubber rings (Figure 8b). Both instances of rubber rings caused deep cuts to the neck.

Very few of the 185 reported entanglements recorded the age class or gender of the animal, however, all age classes have been observed entangled. Without tagging and follow-up information on seal-behaviour it is difficult to monitor the recovery of animals that have been released, especially in cases of non-breeding individuals that

might be in a more transient life stage. Five case studies are included in Appendix 2, that documents re-sighting and recovery of successfully released individuals.

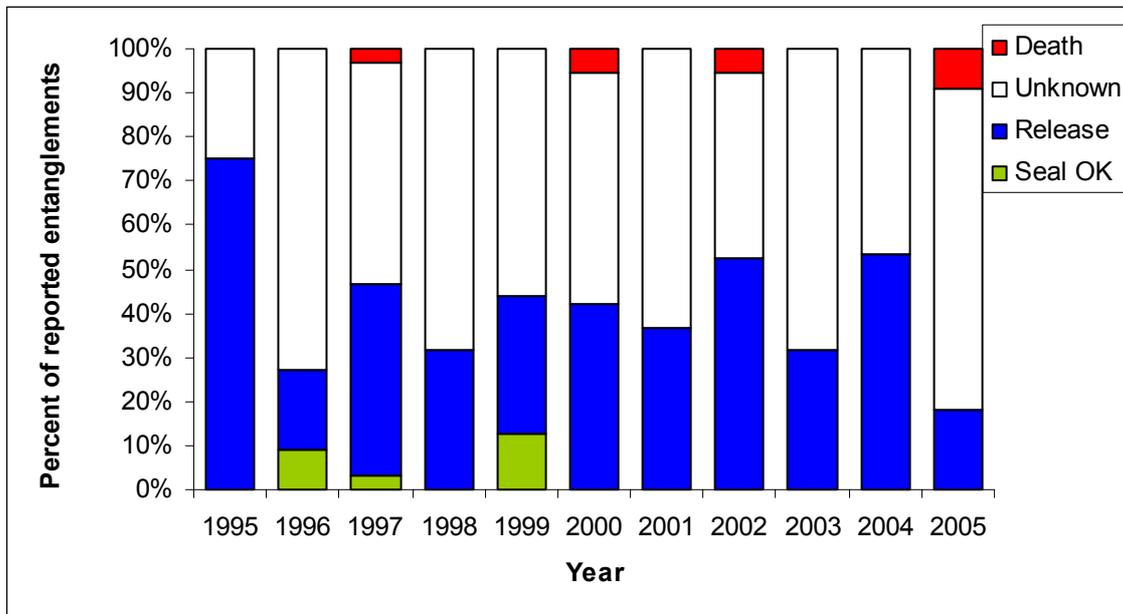


Figure 7: The percentage outcome of reported entangled seals in the Kaikoura region over the last decade.

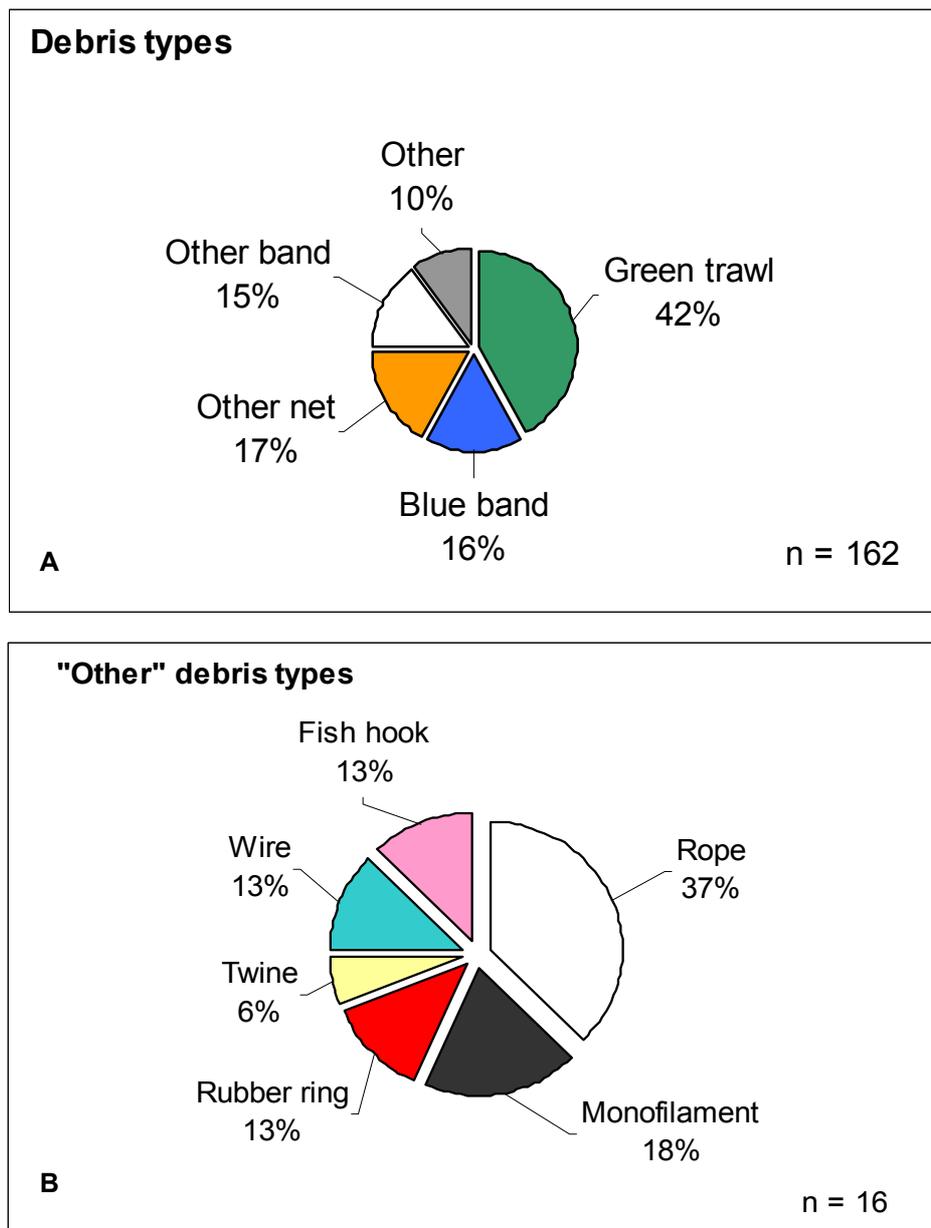


Figure 8: The percentage of different types of debris found on fur seals in the Kaikoura region, A) nets, bands and other entanglement hazards, and B) a breakdown of the other hazards which make up 10% of all debris types.

Human interactions

There were 17 total public related incidents reported in ten years. Although some involved tourists surrounding or approaching seals too closely, these sorts of interactions tend not to get reported unless someone is bitten. Most of the interactions reported here involved jet skis scaring seals, and children throwing rocks at seals (Table 5). In addition, three seals were reported shot: one was still alive following the incident and was euthanized.

In the last decade there have only been five reports of seals being harassed by dogs. Two did not have a severe outcome, one was not investigated, one required euthanasia and one was killed by the dog (Table 6). In three situations DOC staff separated the animals, spoke to the owners or mediated the situation in some way. In one case the dog's owner was fined.

Table 5: Summary of public related incidents involving seals including seals potentially shot in the last ten years.

Seal Status	Death	5
	Normal	7
	Rehab/Release	1
	Unknown	3
Seals shot		
Seals shot	Death	1
	Euthanized	1
	Unknown	1
	Total	3
Action		
Action	No Action	1
	Check only	10
	Mediated	4
	Success	1

Table 6: Summary of known dog and seal interactions reported in ten years.

Seal status	Death	2
	Unknown	3
Action	No Action	1
	Check only	1
	Mediated	3

Road

Road related callouts can take two forms: a seal being on or near the road, or a seal being hit by a vehicle. Both scenarios increase in frequency over the winter months when seas are more rough (Figure 9). Although in many cases the seals on roads eventually move off on their own, or DOC staff move them to a safe place, several seals are killed by vehicles each year. Nearly 40% of the 114 seals reported on the roads were killed. This proportion peaked in 2001 when 70% of road incidents were fatal. Two incidents of seals being on the road involved species other than New Zealand fur seals: one leopard seal and one elephant seal. Although it's less common, seals have also been killed while sleeping on the train tracks; five being reported in the last decade.

Interestingly, in the late 1990's there were many reports of seals on roads along the south coast, but as the years progressed, there were fewer incidents on the south coast and increasingly more on the north coast (Figure 10). When assessing the age classes of animals on roads and those hit by vehicles, it was noticed that more pups were being reported in parallel with the increase of reports occurring on the north coast. Many of these reports were specifically at Ohau Point. The first births at this colony were not recorded until about 1990, and until 1998 pup production remained under 50 per year (Figure 10). Recently, the colony has expanded and produced approximately 590 pups in 2005.

Comparison of body condition for road hits and emaciated pups

Pups that were hit by cars were typically in average or above average body condition for their age group (Figure 11) Two out of three individuals that were able to be measured were in significantly better condition than the population average for their age ($t = -31.74$, $df = 141$, $p = < 0.0001$; $t = -5.84$, $df = 141$, $p < 0.0001$). One

individual weighed 17.5 kg, had a sternal blubber depth of 37 mm, and a condition index of 0.19 kg/cm versus the 0.14 kg/cm average of his age group.

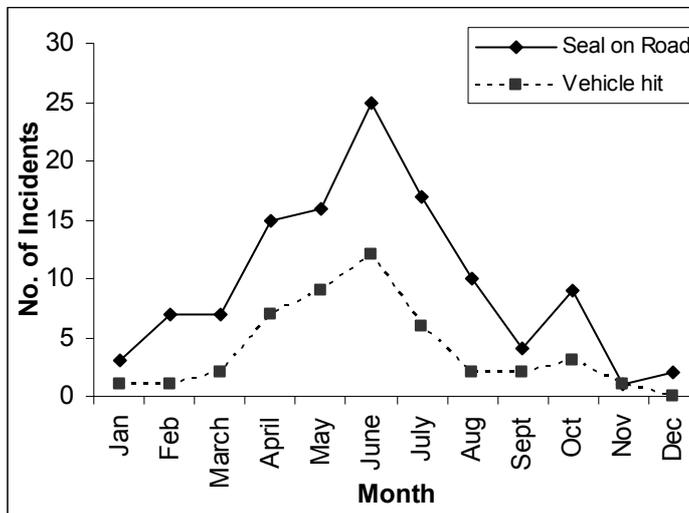


Figure 9: Seasonality of road related reports involving seals.

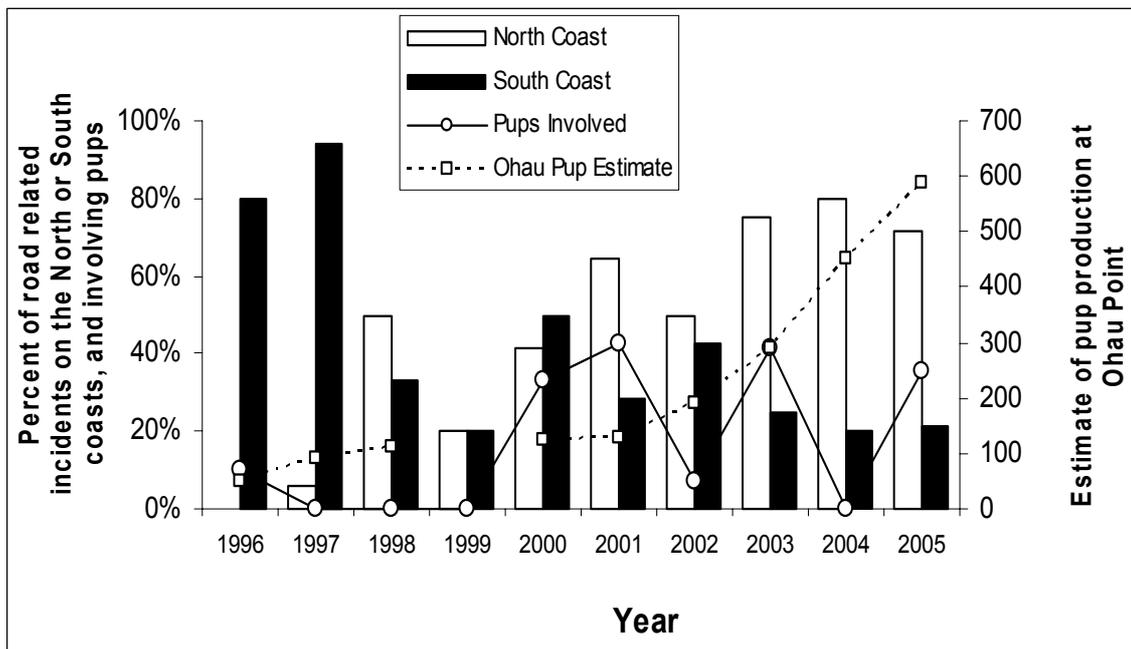


Figure 10: The percent of road related incidents on the north and south coasts and the involvement of pups in road related incidents over the years in comparison with the estimate of pup production at Ohau Point.

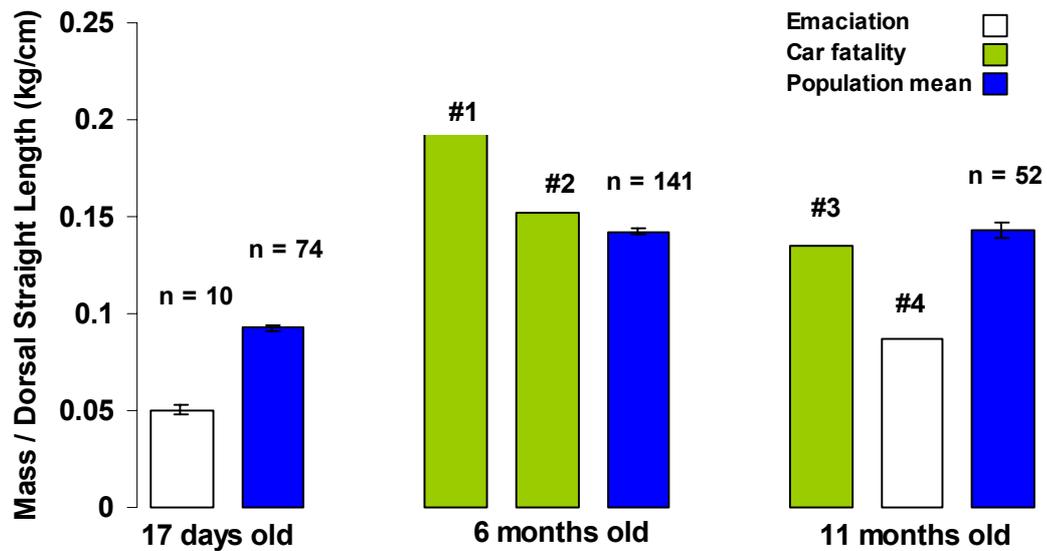


Figure 11: Comparison of body condition between emaciated pups, pups hit by cars and the colony average for that age bracket. Standard errors are included where possible. Individual pups are: #1; male pup ID 4005, #2; male pup unknown, #3; male pup unknown, #4; female pup ID A47.

Discussion

General trends in mortality

All mortality

The data presented show an average of 34-38 dead seals reported each year, with two major increases in 1998 and 2002 (Figure 2). The increase in 1998 corresponds with the reported die-off related to the El Niño Southern Oscillation (Duignan 2000a). In both 1998 and 2002 there was a strong negative Southern Oscillation Index (SOI) indicative of an El Niño event (NIWA 2005; Chapter 5). Reduced pup production and increased mortality was observed for *A. forsteri* pups at other colonies around New Zealand in 1998 (Bradshaw *et al.* 2000) and at Kangaroo Island, South Australia in 2002 (T. Haase, pers. comm.). These years were also the same years that mass mortalities were reported in New Zealand sea lions, *Phocarctos hookeri* (Duignan *et al.* 1998; Wilkinson *et al.* in press). Interestingly, the opposite trend occurred on the West Coast of New Zealand, where pup production was highest in 1998 and 2002 (M. Stratton, pers. comm.). It is likely that within New Zealand, different regions are affected differently by the El Niño Southern Oscillation and further work investigating the causes of mortality during these cyclic events and how different colonies respond to them is recommended.

Pup mortality

The number of dead pups observed through this study was low, and in the 2004/05 season mortality at Ohau Point from birth to 50 days was around 3% of the total number of pups born. This is significantly lower than the 20% reported for this species at Open Bay Islands in the 1970's (Mattlin 1978b), however, other low mortality rates have been reported for *Arctocephaline* species in the first one to four months of life (2.7-5.5% *A. gazella* Slipep Island, 10.2% *A. tropicalis* Prince Edward Island, 13.5% *A. tropicalis* French Antarctic, and 10-15% *Callorhinus ursinus* Eastern Pacific – Summarised in Harcourt 1992). Potential reasons for the low estimate observed at Ohau Point may be related to sources of sampling error and/or density effects on mortality in a relatively young colony and will be discussed in more detail in the following sections.

Potential error

There are potential sources of error within the data that can both result in under and over estimation. Overestimation of mortality is not as likely but may still occur if multiple reports are made for one dead or injured individual. However, the most likely situation is that mortality is underestimated. Areas suitable for seals to haul-out or breed along the Kaikoura Coast extend for >100 km, therefore, the effort required to achieve accurate mortality counts is difficult. Instead, information has been gathered by focusing observations at a few areas and by utilising reports from the public. However, this will inevitably lead to underestimation of the true mortality for the region.

Visibility of carcasses is a key factor in accurate reporting/recording of data. Since the public report the majority of deaths to the Department of Conservation (Report to DOC, Rob Suisted, Nov. 2004), there is a bias in reporting towards what is visible to the public. Most tourist activity in Kaikoura is centred around the north side of the Kaikoura Peninsula (Figure 1), which is near a non-breeding haul-out of mostly male fur seals. As a result many of the reports of dead seals were for this region and involved sub-adult or adult males (77% of carcasses reported as males). The reporting will also peak in spring and summer at the height of tourist activity (Boren 2001). Some reporting may occur by the public north and south of the township, however,

much of the coastline is not readily accessible to the main road, and at Ohau Point, public viewing is limited to the northern and southern most points of the colony. Consequently, there will be a bias in reporting for the time of year, area, gender and age class of seals observed dead that will result in an underestimation of an average regional mortality. The fact that surveys along the peninsula in two summer seasons (2001/02 and 2002/03) resulted in numbers similar to those reported to DOC for the whole calendar (Table 2) year suggests that average mortality is underestimated by DOC records.

While researchers have multiple vantage points above the Ohau Point seal colony, the terrain includes very large boulders and several caves which can obscure carcasses from view, resulting in an underestimate of the number of dead individuals in the colony. A similar situation was reported at Punta San Juan, Peru, where a cave at one end of the study beach reduced the ability to directly count mortalities at that particular beach (Harcourt 1992). Also, Mattlin (1978b) reported a difficulty in estimating numbers of dead individuals as pups aged due to them becoming more active in regions of irregular terrain and poor visibility for the observer. Therefore, the number of dead pups observed is likely to be underestimated.

Since seals hit on roads are going to be more visible than seals washing up at inaccessible parts of the coast, there is likely to be a bias towards reporting these incidents. However, two emerging problems lead to the potential for underestimation of seals on the road, and seals hit by cars. Firstly, seals on the “roadside” are becoming more common, and although the risk of fatality is high, such incidents are not always reported (pers. obs.). Also, people may attempt to move seals or remove carcasses themselves. Some of these get reported but many are missed. A recent example of this involved a tagged individual hit by a car. The tags were cut out and sent to DOC, however, the carcass had been moved. Four other seals were hit by cars within a week of this and it was assumed the tags belonged to one of the pups collected. Upon post mortem, it was possible to tell that the cut tags did not come from the pups collected. Based on information given for the other reported hits, it is highly likely that this individual was another case altogether, where the body was unable to be confirmed.

Both the annual mortality observed in the Kaikoura region and the pup mortality rate at Ohau Point are likely to be underestimates. Despite this, having a baseline of information based on consistent reporting can still show when periods of increased mortality occur, such as that observed in 1998 and 2002.

Natural mortality

Starvation

Starvation or emaciation was found to be the leading cause of death in pups under the age of 50 days (88.5% - Table 4). A similar trend was observed on Open Bay Islands in the late 1970's with 70% of dead pups having virtually no blubber layer (<5 mm - Mattlin 1978b). Starvation is a leading cause of death in many pinniped species (Mattlin 1978b), especially in those that require pups to fast for extended maternal absences for foraging (Guinet *et al.* 1999). This is evident in years of lower food availability where the mass and condition of pups decrease dramatically and leads to increased mortality (Ono *et al.* 1987).

Density effects

Increased density in colonies can also lead to increased mortality as a result of trauma (Harcourt 1992). In the current study the majority of trauma incidents occurred in pups older than 50 days, and were mainly associated with car hits (Table 4), although 11.5% (3/26) of dead pups less than 50 days old did exhibit signs of trauma. One individual had puncture wounds on the side of the neck and severe trauma around the neck and shoulders. Female aggression towards non-filial pups is not uncommon (McNab and Crawley 1995; Carey 1989) and it is possible this pup was thrown into a rock by an adult seal. Increased colony density was found to be a significant factor in the elevated mortality rate observed in *A. australis* in Peru (31-49% in the first month) as pup mortality was strongly correlated with the number of females ashore and female aggression (Harcourt 1992). Due to the low incidence of trauma associated pup deaths at Ohau Point, it is highly likely that population density is not a contributing factor to pup mortality. This may also explain the low overall pup mortality observed at Ohau Point of 3% to 50 days. At the time of Mattlin's (1978a) study, the Open Bay Islands colony was already well established and was estimated to produce 1319 pups in 1975 and 1628 pups in 1976. Ohau Point colony, on the other hand, is still in an exponential stage of re-colonisation (Chapter 2). In 2005

approximately 590 pups were born (Chapter 2). It is possible that the low pup mortality observed here is in part related to the fact that the colony is still growing and densities are not yet high enough to significantly contribute to pup mortality through increased adult aggression and trauma.

Parasites

Marine mammals are hosts to a number of different parasites (Duignan 2000a). Hookworm (*Uncinaria* spp.) has been a significant cause of pup death in many species of pinnipeds (Olsen and Lyons 1965; Chapter 7). In the current study parasites were not commonly found in young pups (<50 days). Only one pup in that age bracket had worms in the intestine (Table 4). This result is consistent with the lack of evidence of hookworm through weight trials of Ivermectin dosed pups (Chapter 7). Once pups reached an age of nutritional independence, the likelihood of finding parasites in deceased animals increased. Gastro-intestinal parasites and stomach ulcers were found in all juvenile, sub-adult and adult seals on post mortem. Cestode larvae were also evident in the blubber of 100% of individuals post-weaning. These larvae do not reach adult stage in pinnipeds and are not likely to be a significant contributor to death (Duignan 2000a; pers. comm.). Lung worm was evident in five individuals: three sub-adults, one juvenile, and one 11 month old pup that had potentially begun to feed independently (Table 4). From these results it appears that in the population's current state parasites are likely to only affect individuals foraging independently, and that hookworm is unlikely to be a significant contributor to pup death.

Disease/Infection

Mass strandings and die-offs in marine mammals are typically attributed to a disease outbreak or infection (Dierauf *et al.* 1981; Borst *et al.* 1986; Duignan 2000a). The increased mortality along the Kaikoura coast in 1998 was potentially a result of toxic algal blooms during the El Niño event of 1997/98 (Duignan 2000a). However, six cases of infection were observed in *A. forsteri* from Ohau Point and three cases were associated with the liver. One adult female showed evidence of chronic hepatitis, while one sub-adult male and one pup also had abscesses on the liver. Of the remaining cases, one 11 month old pup had a severely depleted lymph system and signs of infection throughout the respiratory tract while two individuals exhibited severe infection resulting in abscesses. One was less than 50 days, the other older

(Table 4), and both had abscesses near a fore-flipper. No obvious signs of viral infections were evident in any individuals.

Predation

Predation by shark, orca, and sea lions have commonly been reported for various species of fur seals (Mattlin 1978b; Harcourt 1993; Bradshaw *et al.* 1998), however, predation does not appear to be a major contributing factor in *A. forsteri* mortality in Kaikoura. Only one adult female has been sighted with a potential shark bite (2003/04) and she was seen healed and with a pup in the following season. Although orca do pass Kaikoura (Constantine 1999), they are not in the area for extended periods and have not been sighted in the vicinity of Ohau Point. Sea lion predation is unlikely as they are not commonly found on the Kaikoura coast (Harcourt 2001).

Human influenced mortality

Entanglement

A. forsteri in Kaikoura are commonly sighted ashore entangled in marine debris. Reported entanglement rates are typically minimum estimates as not all entangled animals will be sighted and many may be unable to swim back to shore and die at sea (Henderson 1984). The entanglement rates observed for Kaikoura are some of the highest reported thus far (annual range: 0.16-6.74%). The highest reported was for a population of *Zalophus californianus* near a small fishing village in Los Islotes, Baja California (3.9-7.9%: Harcourt *et al.* 1994). Other reported entanglement rates are: 0.1-0.6% for *A. pusillus* (Shaughnessy 1980), 0.1-0.4% for *A. gazella* (Croxall *et al.* 1990), 0.18-0.85% for *Monachus schauinslandi* (Donohue *et al.* 2001), 0.4% for sub-adult male *Callorhinus ursinus* (Fowler 1987), 1.3% for *Neophoca cinerea* and 0.9% for *A. forsteri* in Australia (Page *et al.* 2004). The debris in which seals become entangled varies a great deal; however, it is typically representative of the local fisheries activities near the species foraging grounds (Page *et al.* 2004). The most common entanglements for fur seals in Kaikoura were trawl nets and packing tape or plastic strapping. This was also the case for *A. forsteri* in Australia (Page *et al.* 2004), *M. schauinslandi* in the Northwestern Hawaiian Islands (trawl net: Donohue *et al.* 2001) and *A. gazella* at Bird Island (packing straps: Croxall *et al.* 1990). Entanglement will not always result in death as sometimes the debris will break, the seal will free itself, or the seal can be caught and released of the entanglement

(Henderson 1984). However, a reasonable proportion of entanglements can cause injury (30% for *A. gazella*: Croxall *et al.* 1990) which may be life threatening (48% Australian pinnipeds: Page *et al.* 2004). Although in the current study few seals were known to have died from entanglements (4/185, Figure 7), many that are released retain deep wounds. The increased entanglement rate observed in the late 1960's in *C. ursinus* (0.4%) was significant enough to affect population dynamics on St. Paul Island through a decrease in pup production as the affected cohorts were of breeding age six years later (Fowler 1987). As a result, even entanglement rates of less than 1% can cause significant mortality within a given cohort, in turn affecting the future reproductive success of the population.

Public Interactions

Public interactions can affect pinniped populations in several ways, although not always causing death. These sorts of interactions can include harassment, dog attacks, trampling and shooting of animals. Harassment as a result of increased tourism encounters has been documented in a variety of marine mammal species (Gales *et al.* 2003), and has been investigated in detail for *A. forsteri* at Kaikoura (Barton *et al.* 1998; Boren *et al.* 2002; Boren, Report to Lincoln University, 2004). Only cases of severe harassment and seal death are likely to be reported to DOC, but harassment does occur on a daily basis. Although only a few situations may directly result in death, consistent interactions may lead to increased stress, which in turn may lead to reduced fitness, loss of muscle mass, and the suppression of the immune system and even reproductive behaviour (Creel 2001).

Trampling was shown to be a cause of death for two pups, which were accidentally killed while researchers were carrying out work at Open Bay Islands (Mattlin 1978b). While Mattlin (1978b) reported that pups do not always appear to be harmed when trampled, and many pups are able to hide or evade larger seals in a stampede, an increase in colony density may affect the level of trampling which is fatal. Although no pups were trampled due to human presence in the Ohau Point colony during the current study, the increasing population size and increasing occurrences of tourists entering the colony (pers. obs.), will also increase the chances of stampedes resulting in fatal trampling.

Dogs have been associated with at least two seal deaths in Kaikoura in the past decade (Table 6), and people have been sighted taking dogs off-lead into the Ohau Point seal colony (pers. obs.). While no seals were injured on these occasions, the potential risk to young pups is high when a dog is in the breeding colony. Also of concern is the potential for zoonotic transfer of disease between dogs, or other land mammals and seals (Cooke *et al.* 1999) as may be the case in Namibia where jackals and wild dogs often come into contact with Cape fur seals (*A. pusillus*) (Gowtage-Sequiera *et al.* 2004)

The most direct human interaction with seals is intentional shooting. This has commonly been reported for several pinniped species in North America (Carretta *et al.* 2001). Although reports of this have been quite low for New Zealand pinnipeds (3 in 10 years in Kaikoura, Table 5), the increasing seal populations around the country are raising concerns with fishermen as to the perceived negative interactions between seals and fisheries. With increased conflict between fisheries and seals in New Zealand, intentional killings may become more widespread. Only recently, three men were charged for shooting seals on the Otago Peninsula (Auckland Herald, 13 June, 2005).

Road

The proximity of a major highway and railroad track to seal colonies and haul-outs along the Kaikoura coast result in a high proportion of road fatalities for *A. forsteri*, an aspect of mortality that is not as common in other populations. Car collisions with pinnipeds are not unheard of, though, as several Northern elephant seals (*Mirounga angustirostris*) have been reported killed in this manner (Hatfield and Rathburn 1999). The stretch of road adjacent to the Ohau Point seal colony is particularly dangerous, and despite crash barriers and fences erected to keep seals off the road, these do not extend the full length of the colony (Report to DOC, Rob Suisted, Nov 2004). In May, 2005, within 1 week, a minimum of five seals were killed on roads around Kaikoura: four near Ohau Point, three of which were 6 month old pups. The same evening that these three were killed, a car lost control and ended up in the south end of Ohau Point seal colony. Further, during heavy storms in autumn of 2002 a section of road over the colony cracked and portions fell into the colony. During both of these severe occurrences few seals were injured, most likely because the noise of

the incident would have caused seals to flee the area. Although seals were not injured directly during these incidents, in 2002 there was an increase in mortality associated with seals trying to get away from rough seas by sleeping on the road or train tracks: 3 of 5 train fatalities occurring in 2002. Of greatest concern is what the effect of road fatalities on healthy pups will be on the future population dynamics. It is usually the bigger/fatter and presumably healthier pups that are sighted furthest from their birth place, some of which traverse over a kilometre through the colony (pers. obs.), and it is unsurprising then that, of the pups hit on the road that were able to be measured, all were in average to above average condition (Figure 11). Male and female pups in above average body condition (Baker and Fowler 1992; Hall *et al.* 2001), or over 9 kg at weaning (Mattlin 1978a), have a higher chance of survival past one year of age. Despite efforts in recent years to keep seals off the road and to warn drivers of the potential hazard, there are still sections of the colony that do not have protection from the road. Recent work has been done to model the effect of fencing by roads on population status of various animal species (Jaeger and Fahrig 2004). It was found that if the species in question exhibited low road avoidance, and there was a moderate to high chance of road mortality, then fencing significantly aided the persistence of the population (Jaeger and Fahrig 2004).

Concern for zoonotic transfer

With the increasing levels of human / seal interactions in the Kaikoura region, there has been increasing concern for the potential of zoonotic transfer of disease between the two. Pulmonary tuberculosis was contracted by a seal trainer in Australia in 1988 and it was the same strain found from post mortem of three fur seals that died two years prior (Thompson *et al.* 1993). Since then, potentially zoonotic tuberculosis (*Mycobacterium* spp.) has been found in wild pinnipeds: *Neophoca cinerea* and *A. forsteri* in Western Australia (Cousins *et al.* 1993); *A. pusillus doriferus* from Tasmania (Woods *et al.* 1995); *A. tropicalis* in Argentina (Bastida *et al.* 1999); and *A. forsteri* on both the North and South Islands of New Zealand (Hunter *et al.* 1998). *Salmonella* is also commonly found in wild pinnipeds (Duignan 2000a) and has the potential to be transferred to humans (Smith *et al.* 1978). In January of 2005 there was at least one case from Open Bay Islands where *Salmonella* was cultured from the abscess of a pup (M. Stratton, pers. comm.). While there was little evidence for such infections from dead seals in the Kaikoura region, or from fecal samples (L. Boren,

unpub. data), the risk may exist in the future if such bacteria are picked up by these colonies since many land mammals in New Zealand both carry tuberculosis and act as a vector for spreading it (Cooke *et al.* 1999). Also of concern is the potential for humans to contract seal finger, a form of blood poisoning that is not well understood, that can be contracted through broken skin and contact with seal fur, oils and debris (Cawthorn 1994).

Conclusion

The current study has shown that pup mortality in the Kaikoura region is relatively low which may be a result of recent re-colonisation and low colony densities. Common causes of death in *A. forsteri* pups are similar to those reported for other populations and other species, with starvation being the leading cause. The low incidence of hookworm, infections, injuries and trauma suggests that disease, predation and density dependent causes of mortality are low. While the incidence of disease is currently low, as the colony grows it may increase, potentially leading to greater risk of zoonotic transfer of disease between seals and humans in the region. Also of concern is the elevated level of death related to human interactions, particularly through entanglement and vehicle collisions. As the seal population continues to grow in parallel with an increasing level of tourism in the region, these trends of human-related mortality may well continue. The fact that two-thirds of pup mortality from 50 days of age to weaning is caused by car collisions, and consistently removes large individuals in good condition from the population, may affect future population dynamics if this trend continues. Fencing extensions along the Ohau Point seal colony and continued monitoring of fur seal mortality and entanglement in the region are recommended as the seal and human populations in the region continue to grow.

References:

- Ambrose, P. (2004). Canadian harp seal hunt. *Marine Pollution Bulletin* **48**, 1014.
- Baker, J. and Fowler, C. (1992). Pup weight and survival of northern fur seals *Callorhinus ursinus*. *Journal of Zoology, London* **227**, 231-238.
- Barton, K. J., Booth, K., Ward, J., Simmons, D. and Fairweather, J. (1998). Tourist and New Zealand fur seal interactions along the Kaikoura Coast. Report to Lincoln University. Tourism, Recreation, Research and Education Centre Report, Report No. 9, Lincoln, New Zealand.
- Bastida, R., Loureiro, J., Quse, V., Bernadelli, A., Rodríguez, D. and Costa, E. (1999). Tuberculosis in a wild Subantarctic fur seal from Argentina. *Journal of Wildlife Diseases* **35**, 796-798.
- Boren, L. J. (2001). Assessing the impact of tourism on New Zealand fur seals (*Arctocephalus forsteri*). MSc. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Boren, L. J., Gemmill, N. J. and Barton, K. J. (2002). Tourist disturbance on New Zealand fur seals, *Arctocephalus forsteri*. *Australian Mammalogy* **24**, 85-96.
- Borst, G., Walvoort, H., Reijnders, P., van der Kamp, J. and Osterhaus, A. (1986). An outbreak of a herpesvirus infection in harbor seals (*Phoca vitulina*). *Journal of Wildlife Diseases* **22**, 1-6.
- Bradshaw, C. J., Lalas, C. and McConkey, S. (1998). New Zealand sea lion predation on New Zealand fur seals. *New Zealand Journal of Marine and Freshwater Research* **32**, 101-104.
- Bradshaw, C. J., Davis, L. S., Lalas, C. and Harcourt, R. G. (2000). Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. *Journal of Zoology, London* **252**, 41-51.
- Carey, P. W. (1989). Behavioural thermoregulation and polygyny in the New Zealand fur seal. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Carretta, J. V., Barlow, J., Forney, K. A., Muto, M. M. and Baker, J. (2001). U.S. Pacific Marine Mammal Stock Assessments: 2001. Report to National Oceanic and Atmospheric Administration. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-317.
- Cawthorn, M. (1994). Seal finger and mycobacterial infection of man from marine mammals: occurrence, infection and treatment. Report to Department of Conservation. Conservation Advisory Science Notes, 102, Wellington, New Zealand.
- Chapman, J. and Reiss, M. (1992). 'Ecology: principles and applications.' (Cambridge University Press: Cambridge.)
- Constantine, R. (1999). Effects of tourism on marine mammals in New Zealand. Report to Department of Conservation. Department of Conservation Science for Conservation, 106, Wellington, New Zealand.
- Cooke, M., Alley, M., Duignan, P. J. and Murray, A. (1999). Tuberculosis in wild and feral animals in New Zealand. *The Infectious Disease Review* **1**, 241-247.
- Cousins, D., Bastida, R., Cataldi, A., Quse, V., Redrobe, S., Dow, S., Duignan, P., Murray, A., Dupont, C., Ahmed, N., Collins, D., Butler, W., Dawson, D., Rodríguez, D., Loureiro, J., Romano, M. I., Alito, A., Zumarraga, M. and

- Bernadelli, A. (2003). Tuberculosis in seals caused by a novel member of the *Mycobacterium tuberculosis* complex: *Mycobacterium pinnipedii* sp. nov. *International Journal of Systematic and Evolutionary Microbiology* **53**, 1305-1314.
- Creel, S. (2001). Social dominance and stress hormones. *Trends in Ecology and Evolution* **16**, 491-497.
- Croxall, J., Rodwell, S. and Boyd, I. (1990). Entanglement in man-made debris of Antarctic fur seals at Bird Island, South Georgia. *Marine Mammal Science* **6**, 221-233.
- Dierauf, L. A., Lowenstine, L. J. and Jerome, C. (1981). Viral hepatitis (*Adenovirus*) in a California sea lion. *JAVMA* **179**, 1194-1197.
- Donohue, M. J., Boland, R. C., Sramek, C. M. and Antonelis, G. A. (2001). Derelict fishing gear in the Northwestern Hawaiian Islands: Diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. *Marine Pollution Bulletin* **42**, 1301-1312.
- Duignan, P. (2000a). Diseases of cetaceans and pinnipeds. In *Marine Wildlife: the Fabian Fay Course for Veterinarians*. Post Graduate Foundation in Veterinary Science, University of Sydney, Proceedings 335 Sea World Nara Resort, Gold Coast, Australia. pp. 419-447.
- Duignan, P. J. (2000b). Marine mammal necropsy techniques and sample collection. In *Marine Wildlife: Fabian Fay Course for Veterinarians*. Post Graduate Foundation in Veterinary Science, University of Sydney, Proceedings 335 Sea World Nara Resort, Gold Coast, Australia. pp. 387-418.
- Duignan, P. J., Hunter, J., Alley, M., Thompson, K., Meers, J., Fenwick, S., Gibbs, N., Gales, N., Childerhouse, S., Garthwaite, I. and Madie, P. (1998). New Zealand sea lion epidemic January-February 1998, preliminary report June 1998.
- Dytham, C. (1999). 'Choosing and using statistics, a biologist's guide.' 1st. (Blackwell Science Ltd.: Oxford.)
- Eroschenko, V. P. (2005). 'DiFiores atlas of histology with functional correlations.' (Lippincott Williams and Wilkins: Philadelphia.)
- Estes, J. A., Hatfield, B. B., Ralls, K. and Ames, J. (2003). Causes of mortality in California sea otters during periods of population growth and decline. *Marine Mammal Science* **19**, 198-216.
- Fowler, C. W. (1987). Marine Debris and Northern fur seals: a case study. *Marine Pollution Bulletin* **18**, 326-335.
- Gales, N., Hindell, M., and Kirkwood, R. (2003) 'Marine Mammals: Fisheries, Tourism and Management Issues.' (CSIRO: Collingwood, VIC, Australia).
- Gowtage-Sequeira, S., Kanellos, T., Chalmers, S., Cleaveland, S., Laurensen, K., and Funk, S. M., (2004) Disease survey of jackals and dogs of the Namibian coast: summary of results, Jackal Project 2004. Report to the Institute of Zoology, Zoological Society of London. Annual Report 2004.
- Guinet, C., Goldsworthy, S. and Robinson, S. (1999). Sex differences in mass loss rate and growth efficiency in Antarctic fur seal (*Arctocephalus gazella*) pups at Macquarie Island. *Behavioural Ecology and Sociobiology* **46**, 157-163.
- Hall, A. J., McConnell, B. J. and Barker, R. J. (2001) Factors affecting first-year survival in grey seals and their implications for life history strategy. *Journal of Animal Ecology* **70**, 138-149.
- Harcourt, R. (1992). Factors affecting early mortality in the South American fur seal (*Arctocephalus australis*) in Peru: density related effects and predation. *Journal of Zoology, London* **226**, 259-270.

- Harcourt, R. G. (1993). Individual variation in predation on fur seals by southern sea lions (*Otaria byronia*) in Peru. *Canadian Journal of Zoology* **71**, 1908-1911.
- Harcourt, R. (2001). Advances in New Zealand mammalogy 1990-2000: Pinnipeds. *Journal of the Royal Society of New Zealand* **31**, 135-160.
- Harcourt, R. G., Auriolos, D. and Sanchez, J. (1994). Entanglement of California sea lions at Los Islotes, Baja California Sur, Mexico. *Marine Mammal Science* **10**, 122-125.
- Harris, J. (1994). 'Tohora: the story of Fyffe House, Kai Koura.' (New Zealand historic places trust: Wellington, New Zealand.)
- Hatfield, B. B. and Rathbun, G. (1999). Interactions between northern elephant seals and vehicles near Point Piedras Blancas, California. *Marine Mammal Science* **15**, 598-600.
- Henderson, J. R. (1984). A review of Hawaiian monk seal entanglements in marine debris. In Workshop on the fate and impact of marine debris. US Department of Commerce, Honolulu, Hawaii. pp. 326-335.
- Hunter, J., Duignan, P. J., Dupont, C., Fray, L., Fenwick, S. and Murray, A. (1998). First report of potentially zoonotic tuberculosis in fur seals in New Zealand. *New Zealand Medical Journal* **111**, 130-131.
- Jaeger and Farhig. (2004). Effects of road fencing on population persistence. *Conservation Biology* **18**, 1651-1657.
- Majluf, P. (1992). Timing of births and juvenile mortality in the South American fur seal in Peru. *Journal of Zoology, London* **227**, 367-383.
- Mattlin, R. (1978a). Population biology, thermoregulation and site preference of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1828) on the Open Bay Islands, New Zealand. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Mattlin, R. (1978b). Pup mortality of the New Zealand fur seal (*Arctocephalus forsteri*). *New Zealand Journal of Ecology* **1**, 138-144.
- McNab, A. and Crawley, M. (1975). Mother and pup behaviour of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson). *Mauri Ora* **3**, 77-88.
- NIWA (2005) The Climate Update. **74**, pp. 4. Wellington, New Zealand.
- Olsen, O. W. and Lyons, E. T. (1965). Life cycle of *Uncinaria lucasi* Stiles, 1901 (Nematoda: Ancylostomatidae) of fur seals, *Callorhinus ursinus* Linn., of the Pribilof Islands, Alaska. *Journal of Parasitology* **51**, 689-700.
- Ono, K., Boness, D. J. and Oftedal, O. (1987). The effect of a natural environmental disturbance on maternal investment and pup behaviour in the California sea lion. *Behavioural Ecology and Sociobiology* **21**, 109-118.
- Page, B., McKenzie, J., McIntosh, R., Baylis, A. M., Morrissey, A., Calvert, N., Haase, T., Berris, M., Dowie, D., Shaughnessy, P. D. and Goldsworthy, S. D. (2004). Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Marine Pollution Bulletin* **49**, 33-42.
- Samuels, A., Bejder, L., Constantine, R. and Heinrich, S. (2003). Swimming with wild-cetaceans, with a special focus on the Southern hemisphere. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 277-303. (CSIRO: Collingwood, VIC, Australia)
- Sepúlveda, M. S. (1998). Hookworms (*Uncinaria* sp.) in Juan Fernandez fur seal pups (*Arctocephalus philippii*) from Alejandro Selkirk Island, Chile. *Journal of Parasitology* **84**, 1305-1306.
- Shaughnessy, P. (1980). Entanglement of Cape fur seals with man-made objects. *Marine Pollution Bulletin* **11**, 332-336.

- Shaughnessy, P., Kirkwood, J., Cawthorn, M., Kemper, C. and Pemberton, D. (2003). Pinnipeds, cetaceans and fisheries in Australia: a review of operational interactions. In 'Marine Mammals: Fisheries, Tourism and Management Issues'. (Eds N. Gales, M. Hindell and J. Kirkwood.) pp. 136-152. (CSIRO: Collingwood, Australia)
- Simmons, D., Horn, C. and Fairweather, J. (1998). Summertime visitors to Kaikoura: characteristics, attractions and activities. Report to Lincoln University. Tourism Research and Education Centre Report, Report No. 3, Lincoln, New Zealand.
- Smith, A. W., Vedros, N. A., Akers, T. G. and Gilmartin, W. G. (1978). Hazards of disease transfer from marine mammals to land mammals: review and recent findings. *JAVMA* **173**, 1131-1133.
- Snyder, R. L. (1976). 'The biology of population growth.' (Croom Helm Ltd.: London.)
- Sorenson, J. (1964) New Zealand seals with special reference to the fur seal. Report to Fisheries Technical Report. Wellington, New Zealand.
- Soto, K. H., Trites, A. and Arias-Schreiber, M. (2004). The effects of prey availability on pup mortality and the timing of birth of South American sea lions (*Otaria flavescens*) in Peru. *Journal of Zoology, London* **264**, 419-428.
- Spraker, T., Lyons, E., Tolliver, S. and Bair, H. (2003). Ascaridoid nematodes and associated lesions in stomachs of subadult male northern fur seals (*Callorhinus ursinus*) on St. Paul Island, Alaska: (1987-1999). *Journal of Veterinary Diagnostic Investigations* **15**, 432-437.
- Taylor, R. (1982). New Zealand fur seals at the Bounty Islands. *New Zealand Journal of Marine and Freshwater Research* **16**, 1-9.
- Thompson, P. J., Cousins, D. V., Gow, B. L., Collins, D. M., Williamson, B. H. and Dagnia, H. T. (1993). Seals, seal trainers and Mycobacterial infection. *American Review of Respiratory Diseases* **147**, 164-167.
- Wilkinson, I., Duignan, P., Grinber, A., Chilvers, B. and Robertson, B. C. (in press). *Klebsiella pneumoniae* epidemics: Possible impact on New Zealand sea lion recruitment.
- Wilson, G. (1981). Distribution and abundance of the New Zealand fur seal, *Arctocephalus forsteri*. Report to Fisheries Research Division. Occasional Publication, No. 20, Wellington, New Zealand.
- Woods, R., Cousins, D. V., Kirkwood, R. and Obendorf, D. L. (1995). Tuberculosis in a wild Australian fur seal (*Arctocephalus pusillus doriferus*) from Tasmania. *Journal of Wildlife Diseases* **31**, 83-86.
- Zar, J. (1984). 'Biostatistical analysis.' (Prentice Hall: Englewood Cliffs, New Jersey.)

Appendix 1:

Tissues taken for histology at post mortem:

Salivary gland
Thyroid
Mandibular Lymph node
Prescapular Lymph node
Axillary Lymph node
Trachea
Esophagus
Bronchi
Lung (several sections)
Thymus
Right atria
Left atria
Right ventricle
Left ventricle
Pulmonary arteries
Pulmonary veins
Vena cava
Aorta
Diaphragm
Liver (several sections)
Gall Bladder
Spleen
Pancreas
Stomach
Small intestine (several sections)
Caecum
Colon
Bladder
Sternal, Renal, Iliac, Gastric and Mesenteric Lymph nodes
Reproductive organs
Right and Left Kidneys
Right and Left adrenal glands
Fat-site

Appendix 2:

Sub-adult male

A sub-adult male has been observed two years in a row with an old entanglement wound. He is reliably identified, and although he is not a dominant male holding a territory is regularly sighted early in the breeding season at the centre point of the colony. His wound is old, fully healed and not very deep, he also appears in good health. The date of his release and debris type are unknown.

Adult female: ID Le

This adult female is an older individual and has been sighted throughout the 2003-2004 breeding season and into the winter. She has an old entanglement wound on her neck, which is more visible from the left side where it began to cut in. The wound is quite old and fully healed. The female appears in good health and in November 2003 gave birth to a male pup tag #3003. ID Le and pup #3003 appeared in good condition throughout the summer, and the pup was consistently heavier than other pups of his year. As for the male above, the date of release and debris type are unknown for this animal.

Pregnant/Lactating adult female: ID Lu

A female with a blue band on her neck was sighted in late October 2003 near the Ohau Point lookout nursing her 10 month old pup. On the 2nd of November, the band was successfully removed, and one hour post handling, the female was observed nursing her pup again. The band was not cutting in deeply, however, both the female and her pup were beginning to lose condition around the pelvis. She continued to nurse her pup through November, then for most of December was not sighted. On December 29th she gave birth to a very small female pup capped "L9". L9 was 3.3 kg at 3 days of age and increased steadily to 6.8 kg at 89 days (3 mo) old. She also increased in body condition from 0.06 kg/cm to 0.09 kg/cm during this time frame. In May, L9 was sighted interacting with other pups at a large tide pool several hundred metres from the site of her birth and appeared in very good condition for her size. In the following season, from November to early December, 2004, Lu was not sighted. On the 23rd of December, 2004, she arrived back on the colony pregnant, and on the 24th of December gave birth to a male pup tagged #4068 for weight trials in the 2004/05 season. The male pup weighed 4.4 kg at 3 days of age and gained weight for each consecutive weight session and was 10.6 kg at 98 days (3.5 mo) of age. During this time his body condition increased from 0.08 kg/cm to 0.13 kg/cm.

Adult female 3: ID Pe

In mid-November, 2003, a small adult female was sighted at the north end of Ohau Point colony with a single strap of green trawl net around her neck. She was very thin and her neck was deformed/bulging on the right hand side where the strap was cutting the deepest. On the 20th of November the piece of net was removed and tetracycline spray was applied to the wound. The female's behaviour was observed an hour post-handling. She was not re-sighted until May 2004 and again in June. She appeared to have put on a lot of weight, and was in much better condition. The wound was mostly healed but was still weeping slightly, blubber or muscle tissue were no longer visible. New digital photos of her were taken in May. During the 2004/05 breeding season, Pe was sighted on numerous occasions during the peak occurrence of copulations (mid-late December) and was consistently in good condition.

Adult female 4: ID Ma

An adult female was sighted in late March 2004 with a blue strap on her neck. She was quite thin, and had a deep wound from the strap. The strap was successfully removed. The female was not seen post-handling but may have still been in the cave she had gone into. In June, 2004, she was re-sighted in much better condition. Her wound was mostly healed and was only weeping slightly. Blubber and muscle tissue were no longer visible. During the 2004/05 breeding season, Ma was also sighted on numerous occasions consistently in good condition.

Appendix 3: Notes and data for 31 post-mortems with W (weight), L (dorsal straight length), G (axillary girth), SBD (sternal blubber depth), SON (visual estimate of state of nutrition), Para (presence or absence of parasites), and VL (presence/location of visible lesions).

Year	Sex	Age	W (kg)	L (cm)	G (cm)	SBD (mm)	SON	Para	VL	Notes
01/02	m	SA	35	137	73	20	4	y	stomach	pretty rotten, tissues autolysed, parasitic gastritis, bcysts present
01/02	m	11 mo	12	89	61	>10	5	n	ax ln	hit by car, jaw smashed, severe trauma, otherwise healthy, stones in stomach
01/02	m	SA	n/a	162	91.5	n	4	y	stomach	many blubber cysts, parasitic gastritis, lung worm
01/02	f	11 mo	7	80	45	0	2	y	stomach	2 blubber cysts, parasitic gastritis 4 stomach ulcers(10x15mm), lungworm, emaciation
01/02	f	1-2 yrs	19	104	69	<5	3	y	stomach	being scavenged, lung worm, parasitic gastritis 6 stomach ulcers (17x52mm a cluster), emaciation
01/02	f	3 mo	10.4	73.5	51.5	8	4	n	ln	outwardly in good condition, severe inflammation, and fluke in common bile duct
02/03	f	SA	23	132	83	n	4	y	ln	50+ b cysts, severe lungworm, parasitic gastritis ~6 ulcers, plus worms in intestine
02/03	f	11m	5.4	79	38	<1	1	y	ln	very emaciated, some b cysts, severe inflammation and depletion of lymph tissue
02/03	f	<1 mo	2.8	61	27.5	0	2	n	n	very emaciated
02/03	m	SA	n	145	71	10	2	y	y	bcysts, severe parasitic gastritis 36 stomach ulcers, stomach discoloured, abscess in liver
02/03	m	1 day	4.4	62.5	35	0	3	n	ax ln	some trauma evident in sub cutis and muscle layer, potentially stillborn, fluid on the lungs
02/03	f	<1 mo	2	51	29.5	0	2	n	n	very emaciated
02/03	f	<1 mo	2.5	53	28	0	2	n	n	very emaciated
03/04	m	SA	n/a	129	75.5	n/a	3	y	stomach	very emaciated
03/04	f	A	47.4	111	90	n	5	y	spleen	blubber cysts, chronic hepatitis, stress
03/04	f	F	4.75	61.5	35	n	n/a	n	n	pup of above female with hepatitis
03/04	m	<1 mo	3.55	63	28.5	0	2	n	n	lungs a bit discoloured but most likely emaciation
03/04	f	2 mo	8.25	68	45.5	30	5	n	n	several strange things post mortem, blood cortisol tested, not excessively stressed
03/04	m	4 mo	11	75.7	53	35	5	n	liver	bacterial infection - had a large abcess under armpit, right side of body
03/04	f	4 mo	10	79	49.5	25	5	y	n	? - need further investigation, pup in apparently good condition
03/04	f	4 mo	8.75	80.5	47.5	25	3	n	n	? - need further investigation, pup in apparently good condition
03/04	m	1.5 yrs	21	105	63.5	25	3	y	stomach	ulceration in stomach, several parasites in stomach and cecum etc. but signs of drowning
04/05	m	1 wk	2.75	62.5	30	0	3	n	n	emaciated
04/05	m	1 mo	3	60	28	0	2	n	n	emaciated, found in pool, trauma in muscle around torso
04/05	m	<2 wk	3.25	58.5	29.5	0	2	n	n	emaciated, bite wound on neck, trauma in region of bite
04/05	f	2 wk	2.75	58.5	26	0	2	n	GI	emaciated
04/05	m	1 wk	2.75	56	28	<1	3	n	n	emaciated
04/05	f	1 mo	5.25	66.5	38.5	15	4	y	liver	hookworm in intestine, no associated heamorrhage, liver had black raised nodules on it (>8), abscesses
04/05	f	1.5 yrs	7.75	80	41	0	3	y	stomach	paras, severe emciation for a juvenile
04/05	m	6 mo	17.5	90	64	37	6	n	n	good condition, trauma, car hit, right shoulder dislocated
04/05	m	6 mo	12	79	57.5	25	5	n	n	good condition, trauma, car hit, jaw smashed

Chapter 7
**Ivermectin as a tool to examine the potential for
intestinal parasites to affect growth in New
Zealand fur seal pups**

Laura J. Boren, B. Louise Chilvers, and Neil J. Gemmell

Proposed journal for submission: *Journal of Parasitology*

Chapter 7: Ivermectin as a tool to examine the potential for intestinal parasites to affect pup growth in New Zealand fur seals

Abstract

Dynamics of populations can be greatly affected by infectious diseases, including parasites. Nematode parasites, especially the intestinal parasitic hookworm (*Uncinaria* spp.), have been observed as a major cause of pup and juvenile mortality in several species. Hookworm has been observed to contribute to pup and juvenile mortality in many pinniped species by impairing growth and condition through haemorrhage and anaemia. In this chapter the growth of *Arctocephalus forsteri* pups treated with the anti-helmenthic drug, Ivermectin, was compared to that of non-treated control pups. This was done to examine the possibility that intestinal parasites were limiting pup growth and contributing to mortality at Ohau Point, Kaikoura. During two breeding seasons; 2004 and 2005, pairs of treated and non-treated pups were weighed on six to ten occasions from birth to four months of age. No significant difference in mass between treated and non-treated pups was observed except during two early weight trials in 2004, where non-treated pups were heavier. No difference was found between the groups in rates of growth, suggesting a low occurrence of intestinal parasites in *A. forsteri* pups at Ohau Point. The lack of observable difference among treated and non-treated pups may be a result of the fact that the colony has not yet reached carrying capacity and that the primarily rock and boulder substrate of the colony may not be conducive to transmission from environmental contamination, thereby limiting the transmission potential within the colony. However, as the colony nears carrying capacity the prevalence of hookworm may increase, and having a better understanding of how hookworm infection affects pup growth and condition may be beneficial for future monitoring of *A. forsteri* colonies.

Introduction

Parasitology in pinnipeds

Marine mammals play host to a number of internal parasites, and although infections range from Protozoans to Helminths, the Helminths tend to be the most common and have the greatest impact on health in pinnipeds (Dailey 2001). Within this group nematodes, trematodes, cestodes and acanthocephalans have the ability to infest several organs including the gastro-intestinal tract, respiratory and circulatory systems, liver, and pancreas (Dailey 2001). A glossary of classifications of parasites and scientific names used in this chapter is included in an Appendix.

Two families of nematode are known to infect the GI tract of pinnipeds; the ancylostomatidae (hookworms – *Uncinaria* spp.) and the anisakidae (large round worms – *Anisakis*, *Contracaecum*, *Psuedoterranova*, and *Phocascaris*). The anisakids can be found in high numbers in pinniped stomachs with minimal effect on the animal; however, larval and adult forms of these round worms have been associated with many clinical complications, including gastric ulceration (Dailey 2001; Duignan 2003).

Of most concern to pup and juvenile pinnipeds are the hookworms, *Uncinaria* spp. (Berón-Vera *et al.* 2004). The life cycle of *Uncinaria lucasi* has been described in great detail for the host *Callorhinus ursinus* (Northern fur seal) (Olsen and Lyons 1965). In adult pinnipeds, the hookworm doesn't fully mature or migrate to the intestine so does not cause mortality, however, this is not the case in pups where it can cause haemorrhagic enteritis and anaemia, which in severe infestations can lead to death (Duignan 2000). Transmission of hookworm to adults and pups can occur from environmental contamination through ingestion or via the skin, in the latter case migrating to the blubber or mammary glands. However, in pups the most common form of hookworm transmission is through milk transfer (Olsen and Lyons 1965; Duignan 2003). Third stage larvae are usually transferred to pups through milk within a short post-partum phase and reach adulthood within about two weeks (Olsen and Lyons 1965). The adult worms and eggs are then expelled from the pups' intestines by the time the host reaches three months of age (Olsen and Lyons 1965). From the eggs, larvae are able to harbour in the soil until picked up by another seal and the cycle repeats (Lyons *et al.* 2001). Hookworm burdens have typically been the highest

in pups that are well-fed in the early stages of their life and thus appear nutritionally healthy (Olsen and Lyons 1965; Sepúlveda 1998; Lyons *et al.* 2001). The life cycle of the hookworm varies somewhat between host species (Lyons *et al.* 2001) and its life cycle in pinnipeds is unique from that of other hookworm (Olsen and Lyons 1965). It is not clear what the impact of a parasitic infection is on the health of pups that do not die as a result of the infestation.

Hookworm-related mortality – uncinariasis: blood loss and enteritis – in pups has been reported in many otariid species including: the California sea lion, *Zalophus californianus* and Northern fur seal, *C. ursinus* (Lyons *et al.* 2000a;b), Steller sea lion, *Eumatopias jubatus* (Lyons 2005), South American sea lion, *Otaria flavescens* (Berón-Vera *et al.* 2004), Juan Fernandez fur seal, *A. philippii* (Sepúlveda 1998) and both species of New Zealand pinnipeds, *A. forsteri* and *Phocarctos hookeri* (Duignan 2003). Historical data recently published have shown that hookworm was reported in *C. ursinus*, *Z. californianus*, *E. jubatus*, and *O. flavescens* from as early as the 1930's (Lyons 2005). Minimal work has been published for some species, primarily *E. jubatus* (Lyons 2005), while much of the reported data come from *C. ursinus* populations (Olsen and Lyons 1965; Lyons *et al.* 2000a;b; Lyons *et al.* 2001; Spraker *et al.* 2003). Most recently, the prevalence of hookworm in *C. ursinus* and *Z. californianus* has been examined and 95% of 20 fur seal pups and 100% of 31 sea lion pups were found to be infected (Lyons *et al.* 2001). A recent study on *O. flavescens* from North Patagonia found that on average 50% of 31 pups found dead were infected with hookworm, the highest prevalence being at the denser beaches and traditional breeding beaches versus the new, less dense breeding areas (Berón-Vera *et al.* 2004). Hookworms were only relatively recently reported in *A. philippii*, since the 1980's and in an investigation from Alejandro Selkirk Island, Chile, 60% of 60 pups were found to be infected (Sepúlveda 1998).

The most commonly reported parasites in the New Zealand fur seal are anasakine nematodes (*Anisakis* etc.), respiratory mites (*Orthohalaracne*), lungworm (*Parafilsroides* spp., and *Otostrongylus* spp.) and hookworm (Duignan 2000). While minimal published data are available on the prevalence of hookworm in New Zealand pinnipeds it has been observed in both *P. hookeri*, and *A. forsteri* (Duignan 2003). The prevalence of hookworm in *P. hookeri* is generally moderate, with less than 10%

of pup deaths having been attributed to hookworm (L. Chilvers and M. Stratton pers. comm.). The prevalence of hookworm in *A. forsteri* has not been well documented. However, in the 2003/04 and 2004/05 austral summer seasons, hookworm was observed in pups at Open Bay Islands, an established colony of *A. forsteri* on the West Coast, with over two-thirds of dead pups examined infected and showing signs of haemorrhage (M. Stratton and H. Best, pers. comm.).

Population dynamics

Any natural population can increase in number and density, until they reach an asymptote near the carrying capacity for their environment (Villem *et al.* 1984). At higher densities physical and biological factors act to limit growth and keep a population at or near carrying capacity. In populations that have been increasing exponentially the most common means of population regulation is within-species competition for physical factors such as space and resources (Villem *et al.* 1984). However, inter-specific biological factors such as predation and pathogens also help control population levels (Villem *et al.* 1984). Understanding how infectious diseases affect populations is critical for conservation of at-risk species in order to determine appropriate management steps for the species in question (Lafferty and Gerber 2002). Typically, populations at low abundance should be the least susceptible to host-specific diseases as it is through crowding and heightened contact that transmission of disease is increased (Villem *et al.* 1984; Lafferty and Gerber 2002). However, regardless of population size, situations that cause increased stress will also increase susceptibility to disease (Kuss *et al.* 1990; Lafferty and Gerber 2002).

Since many countries began to protect their marine mammals, several breeding and non-breeding sites have been re-colonised by a variety of species (Chapter 2). However, it appears that globally some species are doing much better than others, with fur seals rapidly recovering their former range (Lalas and Bradshaw 2001), while many of the sea lion species are still severely endangered (Childerhouse and Gales 1998; Sease and Gudmundson 2002). While the prevalence of pathogens may be increasing in the populations nearing equilibrium (Lyons *et al.* 2001), some of the struggling species are facing setbacks in re-colonisation related to infectious disease (Wilkinson *et al.* in press). For instance, rare species that experienced a severe

population bottleneck may in fact have increased susceptibility to various pathogens (Harwood and Hall 1990).

The New Zealand pinnipeds appear to follow this global trend with the fur seal, *Arctocephalus forsteri*, population steadily increasing, while the main breeding population of the New Zealand sea lion, *P. hookeri*, has faced three mass-mortality events within six years (Duignan *et al.* 1998, Baker 1999, Wilkinson *et al.* in press). However, within *A. forsteri* colonies on the South Island of New Zealand, there are geographical differences in the body condition of pups (Bradshaw *et al.* 2000; Boren 2001; Chapter 2). While these spatial differences in pup condition are primarily related to colony-specific environmental variables that may affect food availability (Bradshaw *et al.* 2000; Chapter 2) they have also been attributed to the density of pups on the colony (Bradshaw *et al.* 2000). As hookworm infection is now becoming more common in fur seals that are successfully re-colonising areas of their former range (Sepúlveda 1998), it is possible that the prevalence of this parasite in *A. forsteri* is likely to be higher in well-established colonies and may contribute to differences in condition and mortality of pups between colonies.

Techniques for exploring parasite loads in a colony

The two most common practices for detecting parasite loads in a population are from egg or parasite counts from faecal samples, and post mortem. Parasite counts from faeces are commonly used in domestic animals to monitor health, as well as to test the efficacy of anti-worming medication (e.g. Horses: Lind *et al.* 2005; cattle: Mertz *et al.* 2005, cats: Humbert-Droz *et al.* 2004). Parasite counts have also been used in wild populations to determine parasite loads in live animals (Vercruysse *et al.* 2003). Although used in both wild and domestic populations, this method tends to be more commonly employed in domestic animals where faecal samples from known individuals are more easily accessible. Many reports of parasites in wild populations come from post mortems of animals found dead, where the organs can be examined in detail (*O. flavegens*: Berón-Vera *et al.* 2004; *C. ursinus*: Spraker *et al.* 2003; *Phoca hispida saimensis*: Sinisalo *et al.* 2003; *A. pusillus pusillus*: Stewardson and Fourie 1998; and New Zealand marine mammals: Duignan 2003).

The post mortem method limits detection of parasites to dead animals and requires collection of carcasses. In some densely populated fur seal colonies the ability to

retrieve fresh carcasses may be limited due to territorial behaviour of adult males. Detecting parasite loads through faeces allows prevalence to be determined for live animals, however, is limited by the sample sizes required, and the ability to acquire samples from known individuals, or known age or gender classes. It also may not always show when an individual is infected, as can be the case in fur seal pups with hookworm when the adult worms have been shed at about three months of age (Dailey 2001; Lyons *et al.* 2001), suggesting that the timing of sample collection is critical in assessing accurately the prevalence of infection within a population. Because much of what is known about *Uncinaria* spp. life cycles comes from examination of faecal samples and dead individuals (Olsen and Lyons 1965; Lyons *et al.* 2001), little is known about the implications of hookworm infection on the health of live animals from wild populations.

More recently, new methods are being employed to infer the presence of intestinal parasites, based on some of the clinical signs of infection; anaemia and loss of body condition (Dailey 2001; Duignan 2003). These methods make use of antihelminthic drugs, including Ivermectin (IVOMEC[®] Merial Ltd.). Ivermectin is from the group of antihelminthic chemicals known as avermectins, and has broad activity against many helminths and arthropods and can be given orally, subcutaneously or as a pour-on (Blood and Studdert 2000). Ivermectin has been used in a number of species for a wide range of purposes: treatment (Yadav *et al.* 2004), examining effect on weight gain (Mertz *et al.* 2005), effect on fecundity (Newey and Thirgood 2004), and resistance to antihelminthics (Hughes *et al.* 2005). Ivermectin has typically been used to treat intestinal parasites in cattle, horses, sheep, pigs, cats and dogs (Steenbergen 2005; Harder *et al.* 2003) but has also been successfully employed to treat heartworm (McCall *et al.* 2004), mange (Strabel *et al.* 2003), lice (Yadav *et al.* 2004), lungworm (Vercuysse *et al.* 2003), and even scabies in humans (Lawrence *et al.* 2004). It has been used successfully as a treatment for *Uncinaria* spp., *Parafilaroides* spp. and *Otostrongylus* spp. in pinnipeds, including *Callorhinus ursinus*, *Mirounga angustirostris*, *Phoca vitulina*, and *Zalophus californianus* (Dailey 2001; Vercuysse *et al.* 2003), and it is currently being trialled as a method to detect hookworm prevalence via its effect on weight gain in *Phocarcetos hookeri* pups (A. Castinel, pers. comm.).

Chapter Aims

The Ohau Point colony is located 26 km north of the Kaikoura township and is a popular tourist stop-off (Boren 2001). As the town relies on the health of its marine mammal populations for the sustainability of its tourism industry, monitoring of colony status and mortality in the region has been ongoing (Bradshaw 1999; Chapters 2 and 6). As this colony has entered a stage of exponential growth (Chapter 2) it provides an opportunity to examine the health of a growing population of *A. forsteri* and ultimately how the prevalence of diseases such as hookworm develops as the colony grows towards carrying capacity. This can also provide a point of comparison with other *A. forsteri* colonies around New Zealand and for *P. hookeri* where hookworm has already been detected.

The goals of this chapter were to assess the potential for intestinal parasites at the Ohau Point *A. forsteri* colony, using a relatively recent approach employing the antihelminth drug Ivermectin (A. Castinel, pers. comm.). We will compare the growth and mass of treatment and non-treatment control pups to ascertain the potential for intestinal parasite presence at the Ohau Point seal colony, and relate the results to the colony's status, future implications of disease at Ohau Point, and the re-colonisation success of the species.

Methods

Study site

This study was conducted at the Ohau Point seal colony, on the east coast of the South Island, New Zealand. The colony has been growing exponentially over the past decade (Chapter 2) and pups are in relatively good condition and exhibit high rates of growth compared with those previously reported for the species (Chapters 2 and 5). The study was conducted over two austral summers, 2003/04 and 2004/05. Pups were born at the end of each year in December while weight sessions were carried out in January and February (the beginning of the new year), so hereafter the seasons will be referred to by the year the pups were weighed in: 2003-04 = 2004, and 2004-05 = 2005.

Identification and number of pups sampled

Each season pups were marked for identification using numbered caps, 3-5 cm diameter. The caps were made of green mesh with yellow numbers (A. Caudron, pers. comm.; Chapter 4; 5). The caps were glued to the pups' backs using a 90 second quick-setting 2-part epoxy (Araldite brand). Later in the season, once pups reached a weight of 6.0-6.5 kg, they were flipper-tagged with four-digit white Allflex brand sheep-tags.

Selection of IVOMEK and control pups

Study pups for IVOMEK and control groups were selected at random from a pool of known-age individuals, less than a week old. Pups of known age were selected where possible, however, if evidence of birth was not observed, age could be estimated for pups based on the presence and state of their umbilicus, the colouration of skin between the hind flipper digits, and the length and condition of the hind-flipper claws. A control pup was selected for each IVOMEK or treatment pup to have a similar birth location, be the same gender, and have approximately the same birth date and birth weight as the treatment pup. Since the set-up for this study was carried out during a larger study on maternal investment and growth rates (Chapters 4 and 5) the selection and initial capping of pups took place over 7 to 14 days. Where possible, the control pup was selected on the same day as the treatment pup to eliminate discrepancies in birth dates and birth weights.

In December 2003, 32 pups were initially selected for the study, and of those 25 pups received all doses therefore 15 male and 10 female pairs were followed for the 2004 season. In December 2004, 18 pups were initially selected, and all but one received all three doses. Two control pups died early in the season presumably due to emaciation, they appeared skinny were rarely observed nursing and their carcasses were unable to be found and retrieved for examination. As a result 15 pairs (8 male, 7 female) were followed for the 2005 season.

Dosing of IVOMEK pups

Based on the life cycle of hookworm, it is recommended that individuals treated with Ivermectin, are dosed at three different times; within five days of age, approximately five days following the first dose, and approximately 15 days following the second

dose (Dailey 2001; Strabel *et al.* 2003; Mylonakis *et al.* 2004). In 2004, pups received their doses on the following schedule: Dose 1) 2-5 Dec, Dose 2) 10-11 Dec, Dose 3) 22-23 Dec. In the following season pups received their doses on a similar schedule: Dose 1) 5-10 Dec, Dose 2) 11-15 Dec, Dose 3) 27-31 Dec. The doses given followed the recommended 200 µg / kg of live weight (Dailey 2001; Vercuysse *et al.* 2003), and were administered subcutaneously with a sterile 20-gauge needle and syringe. The area was swabbed with ethanol prior to giving the injection. Pups receiving the injections were monitored closely during the months: Dec-Jan for any adverse affects.

Weight trials

In 2004 more pups were marked throughout the whole colony (n = 172, Chapter 5) so re-weights were carried out over two days, weather permitting. Re-weights were carried out on the: 4-5/Jan, 16-17/Jan, 28-30/Jan, 12/Feb and 25-26/Mar at approximately 25-37, 38-50, 51-63, 64-76 and 103-119 days of age respectively.

In the following season fewer pups were marked through the colony (n = 64, Chapter 5), and pups for this study were restricted to areas of high re-catch rates, so when weather allowed, re-weights should take only 1 day. Re-weights were carried out on the: 22/Dec, 9-10/Jan, 18/Jan, 30-31/Jan and 1/Apr at approximately 11-20, 31-40, 41-50, 51-60 and 112-120 days of age.

During all dose and weight sessions the specific pups were caught by hand or using a noose, and placed in a bag to be weighed (10 x 0.2 kg Salter spring balance). They were then removed from the bag and restrained on a flat board while dorsal straight length and axillary girth were measured (Chapter 2 and 5). Following this, pups were given doses as required or released. When the pups were under 1 month of age, they were taken back to where they were caught for release.

Post mortem

Where possible, freshly dead pups were collected for post mortem (Chapter 6). If a pup was within 3 months of age the entirety of the intestines were removed, opened down the length of the intestines with scissors and the contents washed and collected into 70% ethanol and the presence of parasites recorded (Sepúlveda 1998).

Data analysis

Mass was compared between a treatment pup and its control partner at each weight session using a Dependent (Paired) Samples t-test (STATISTICA) with a Bonferroni correction to the p-values to account for multiple t-tests (Zar 1984). Growth rates were calculated for each pup and compared between treatments and genders each year using a 2-way ANOVA (STATISTICA). In 2004, growth rates were only calculated to the end of January due to the low number of pups re-caught in April (15 versus 33). Repeated Measures 3-way ANOVAs were used to detect differences in mass between gender, treatment and time.

Results

Raw data

Each season pups were caught on at least 6 occasions and weighed. In 2004 there were only 10 situations (out of 85) where the treatment pup was noticeably heavier than the control pup, 15 times when the control pup was heavier, and approximately 70% of cases showed pups were within 1 kilo of each other (Table 1). On two occasions early in the season, there were significantly more control pups heavier than the treatment pups. But this trend did not persist through the season. In 2005 a similar trend was observed with 60% of cases resulting in the pups being similar in size.

Table 1: Raw data showing the number of pairs in which the: treatment (IVO) pup was at least 1 kilo heavier, the control pup was at least 1 kilo heavier, and when both pups of the pair were within 1 kilo of each other. Stars denote the times that correlated with a significant difference between treatments.

Year	Age	n	IVO ≥ 1 kg heavier	Control ≥ 1 kg heavier	Pair w / i 1 kg
2004	0-5	25p	0	9*	16
	25-37	19p	1	6*	12
	38-50	23p	2	6	15
	51-63	16p	4	2	10
	64-76	3p	1	0	2
	103-119	14p	2	7	5
Totals			10	15	60
2005	0-4	18p	0	2	16
	11-20	11p	2	3	9
	31-40	13p	6	3	4
	41-50	12p	1	5	6
	51-60	14p	2	4	8
	112-120	4p	1	1	2
Totals			12	18	45

Differences in mass between treatments

In 2004 there was little variation in mass within each weight session, although control pups were slightly heavier than treatment pups on the first two occasions (Figure 1). In the first instance this difference was quite marked (5.09 vs. 4.42 kg, $p < 0.0003$), while less significant by the second weight trial (7.88 vs. 7.45, $p = 0.026$, Table 2). On all other occasions there was no significant difference between treatment and control pups, although discrepancies between genders are more evident between the ages of 51-76 days. By 103-119 days of age pups averaged between 10-12 kg.

In 2005 there was very little variation in pup mass prior to age 30 days (Figure 1). After this more variation is evident, however, it was not found to be significant (Table 2), as the control pups' weights ranged between the weights of the treatment males and females. Although pups were slightly lighter at birth in 2005 than the previous year (mean: 4 vs. 5 kg) they still average between 11 and 13 kilos by the age of 112-120 days.

Table 2: Average mass of treatment and control pups at each weight session for each year. The t-statistic for paired samples is shown along with the corresponding p-value. Significant p-values are in bold, Bonferonni correction p-values for 2004 and 2005 were 0.008, and 0.006, respectively. Stars denote a low sample size for that weight trial.

Year	Age (d)	n	IVO (kg)	Control (kg)	t-stat	p-value
2004	0-5	25p	4.42	5.09	4.27	0.0003
	25-37	19p	7.45	7.88	2.42	0.026
	38-50	23p	7.99	8.30	1.49	0.150
	51-63	16p	8.96	8.89	-0.23	0.822
	* 64-76	3p	9.60	9.07	-1.32	0.319
	103-119	14p	11.69	12.34	1.65	0.123
2005	0-4	18p	4.02	4.12	-0.71	0.489
	5-10	17	4.37			
	11-20	11p	5.58	5.47	0.34	0.742
	21-30	17	5.91			
	31-40	13p	7.63	7.33	0.62	0.545
	41-50	12p	7.82	8.49	-1.68	0.120
	51-60	14p	8.58	8.77	-0.47	0.645
	* 112-120	4p	11.74	11.80	3.18	0.974

Despite the apparent discrepancy between genders in 2005 as seen in Figure 1, there were no significant differences in mass between genders in either year (Table 3). There was a significant difference in treatments in 2004 ($p = 0.012$), relating to the control pups being heavier at young ages, however, the overall growth was not significantly different between treatments ($p = 0.145$, Table 4). As one would expect, masses were significantly different over time, with a consistent weight gain with age ($p < 0.0001$ in 2004, and $p < 0.0001$ in 2005).

Differences in rate of growth between treatments

During this study pup growth rates ranged from 56.2 g/day to 89.0 g/day from birth to 120 days of age. Although males tended to grow slightly faster than females, and the treatment females in 2005 exhibited an average growth rate approximately 13 g/day slower than the control females that year none of these differences were significant (Table 4).

Table 3: Results of Repeated Measures 3-way ANOVA comparing pup mass based on gender, treatment and age. Bold p-values are significant. No interactions between variables were observed.

Year		Gender	Treatment	Age
2004	F-stat	1.93	19.46	305.75
	p-value	0.237	0.012	<0.0001
2005	F-stat	0.55	0.02	73.87
	p-value	0.536	0.903	<0.0001

Table 4: Growth rates of male and female treatment and control pups for 2004 and 2005 seasons. Results of a 2-way ANOVA show no significant differences between genders or treatments in either year.

Year	n	Gender	IVO (g / d)	Control (g / d)	F-stat (treat)	p-value	F-stat (gender)	p-value
2004	22	m	63.6	63.5	0.031	0.861	2.233	0.145
	15	f	57.7	56.2				
2005	14	m	89.0	83.3	0.185	0.670	0.402	0.531
	19	f	74.7	87.4				

Results of post mortem

Out of 13 pups aged less than 3 months old available to post mortem, only one was found to be infected with any parasites. The individual was a known pup followed for behaviour and growth studies in 2005 and was found to be infected with hookworm. The pup was a female, and appeared in good condition and had been observed nursing on several occasions. At post mortem she had a sternal blubber depth of 15 mm and no haemorrhage or lesions of the intestines were visible.

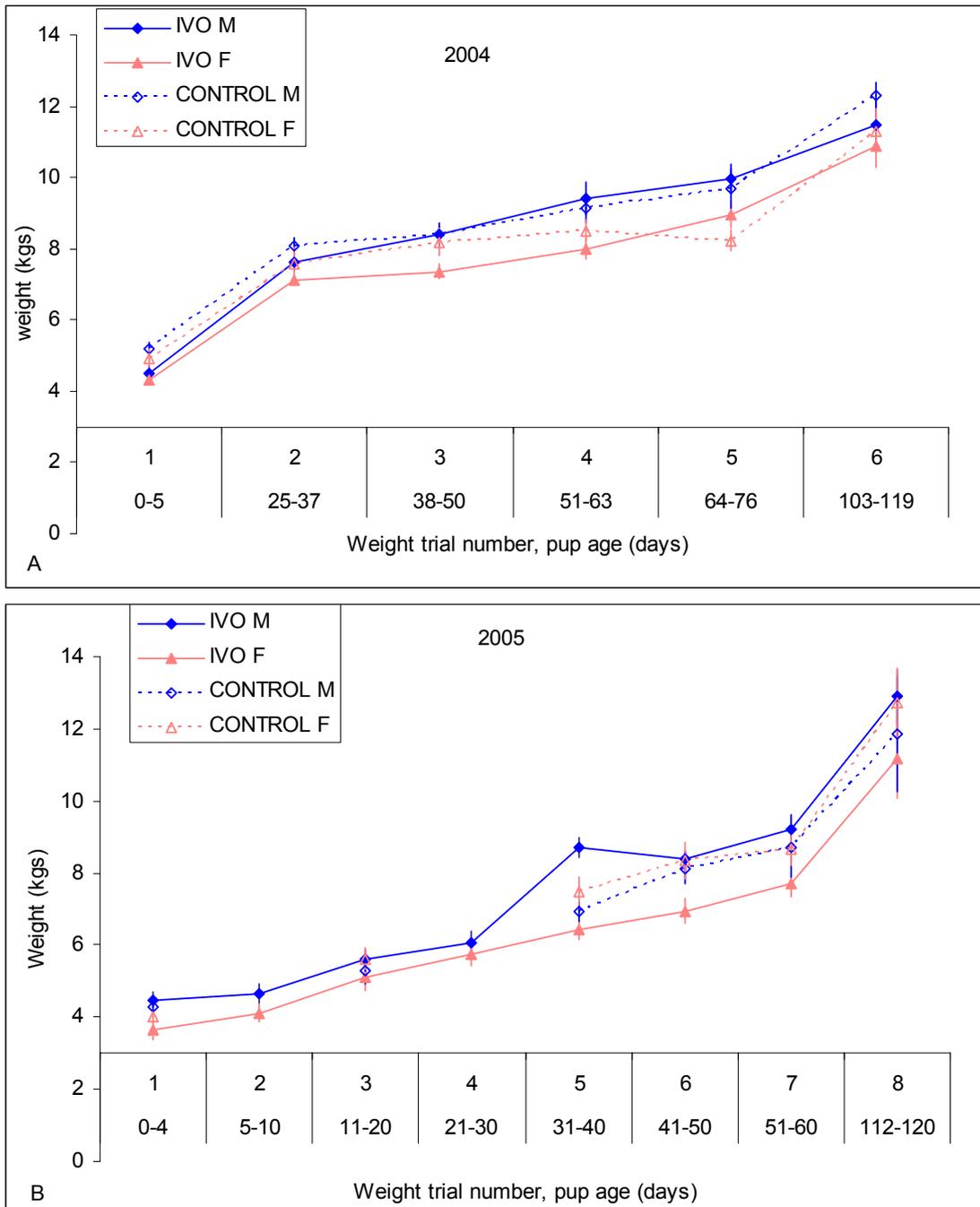


Figure 1: Mass in kilograms of Treatment and Control male and female pups in A) 2004 and B) 2005 from birth to approximately 120 days of age. Error bars show standard errors associated with the measures.

Discussion

Unicaria spp. infection in pinnipeds has commonly been associated with anaemia and haemorrhage in the intestines of pups (Dailey 2001; Duignan 2003), which if severe enough could lead to a decrease in body condition and mortality. In addition, a severe worm burden can also impact an individual's immune response (Duignan *et al.* 1998). In humans, the presence of the helminth *Schistosoma mansoni* has been found to accelerate the progression of HIV-1 (McElroy *et al.* 2005). Likewise in pinnipeds it has been suggested that increased hookworm levels in *P. hookeri* pups have not only affected the pups through poor body condition, but have also impaired their immune system making them more susceptible to bacterial disease (Duignan *et al.* 1998).

The data presented here showed no observable difference between mass and growth rates for treated and non-treated pups of *A. forsteri* at Ohau Point, Kaikoura. Further, the rate of growth observed for both treated (57-89 g/day) and non-treated (56-87 g/day) pups from birth to 120 days were similar to those reported for all pups sampled in 2004 and 2005 (58-109 g/day - Chapter 5). Pup mortality at Ohau Point is relatively low, less than 5% mortality to 50 days of age and post mortem incidence of infection and parasites in young pups has been low (Chapter 6). Also, only one case out of 13 (under 3 months old) was reported of a pup having hookworm, and it was not likely to be the primary cause of death as no haemorrhage or lesions were associated with the presence of the parasites, and the pup was in a reasonable state of condition with a sternal blubber depth of 15 mm. No other intestinal parasites were observed in pups that were still dependent on their mothers (Chapter 6). The findings from the Ivermectin growth study and post-mortems together suggest a low prevalence of hookworm at Ohau Point colony, which may result from a currently reduced susceptibility to parasitic infections due to the colony substrate and low colony densities. Factors related to the life cycle of *Unicnaria* spp. in their pinniped host may also have affected the findings observed in this study.

Treatment of parasite infections with Ivermectin has consistently been shown to improve growth rates in animals, which were naturally infected with various parasites. Gatongi *et al.* (1997) showed increased birth and growth rates in goats and sheep treated for nematode infection with Ivermectin. Similarly, Ivermectin has significantly improved growth rates and body condition of bull and heifer calves in a variety of

studies (Williams *et al.* 1995; Forbes *et al.* 2002; Loyacano *et al.* 2002). However, the unique life cycle of *Uncinaria* spp. in pinniped populations involving transmammary infection of pups may have certain implications on the effect that infection has on pup growth.

While parasites are typically observed in higher densities in animals in poor condition (Gatongi *et al.* 1997), frequently the reverse is true. In *C. ursinus*, *Z. californianus* (Lyons *et al.* 2001) and *A. phillipii* (Sepúlveda 1998) increased worm burdens were significantly positively related to host body condition, in other words, pups with more worms also had greater blubber depth. The explanation for this trend is that if infection is transmammary, then pups need to be feeding at a high rate early in lactation to receive a higher worm burden (Sepúlveda 1998). This hypothesis is supported by a series of detailed experiments on the life-cycle of hookworm in pinniped hosts that indicates that the main source of infection is via the mother's milk, and that the hookworm larva are only in the milk for a short time post-partum (Olsen and Lyons 1965). As the individual at Ohau Point with hookworm was in good condition, it is possible that the absence of mass differences among the control and Ivermectin treated pups was a result of this positive relationship between body condition and worm burden. However, no such positive relationship was found between body condition and worm burden in *O. flavescens*, which also showed evidence of transmammary infection (Berón-Vera *et al.* 2004). Similarly, the majority of *A. forsteri* observed with hookworm infection at Open Bay Islands on the West coast of New Zealand were significantly malnourished, with sternal blubber depths of 0-5 mm (H. Best and M. Stratton, pers. comm.).

As with studying growth rates of pups (Chapter 5) it is important to note for what proportion of the lactation cycle treated and non-treated pups were monitored (Schulz and Bowen 2004), since differences have been observed in hookworm life-cycle between host species (Olsen and Lyons 1965) and these differences could be related to lactation strategies. For example, much of the preliminary work on *Uncinaria* spp. was focused on its life cycle in *C. ursinus* (Olsen and Lyons 1965), which showed that adult worms were shed from pups by the age of 3 months. Further work comparing the biology of hookworms in *Z. californianus* and *C. ursinus* showed that the longevity of the parasite in the sea lion pups was 6-8 months (Lyons *et al.* 2000a).

This difference in longevity could be related to the length of lactation of the two species. *C. ursinus* being a polar species and subject to a pronounced seasonal food supply usually weans pups at approximately 4 months of age (Gentry *et al.* 1986). While the more temperate *Z. californianus* can wean their pups as early as 4-8 months of age, weaning typically takes place 10-12 months of age, and females have even been observed nursing yearlings and 2 year old pups in extreme cases (Ono 1991). In the current study, the individuals were monitored from birth to 120 days (or 4.5 months). Since *A. forsteri* also exhibit longer lactation lengths of between 8-12 months (Schulz and Bowen 2004; Chapter 3) it is possible that potential changes in body condition due to hookworm might not be evident until the pups were closer to weaning. For example, maternal absences become longer in duration as lactation progresses, increase pup fasting time (Harcourt *et al.* 1995) and thus the affect of an infection on body condition may not become evident until a pup is under nutritional stress. Based on the findings that worm burdens are higher in fatter pups due to the transmammmary transmission of hookworms to pups, one would also anticipate burdens to be significantly higher in species with very short lactation durations, (e.g. phocid species, see Chapters 1, 3 and 4), however, *Uncinaria* spp. is relatively uncommon in phocids (Lyons *et al.* 2001). Therefore, further investigation of the life cycle of *Uncinaria* spp. in different pinniped host species is needed to fully understand the implications transmammmary infection will have on pup condition; both during and post infection if the mortality is not the end result.

Another potential reason for the apparently low prevalence of nematodes, including hookworm, at Ohau Point is due to the terrain or substrate of the colony. It has been reported consistently, that the substrate type plays an important role in the transmission of stage three hookworm larvae percutaneously. Silty or sandy areas are more conducive to environmental contamination by the hookworms as seen by the higher prevalence of hookworm infection in *P. hookeri* pups born on sandy beaches, than *A. forsteri* pups born in rocky colonies (Duignan 2003). Similarly, *O. flavescens* have been reported as having intermediate levels of hookworm infestation in comparison with other species due to the substrate type at Punta León (Berón-Vera *et al.* 2004). A study on *C. ursinus* and *Z. californianus* pups in Alaska showed that pups born at sandy rookeries had higher hookworm burdens than those born in less sandy areas (Lyons *et al.* 2000b) while *Eumatopias jubatus*, which inhabits rocky

shores showed minimal hookworm infection (Lyons *et al.* 2003). Transmission of hookworm in species breeding on rocky terrain is limited to transmammary infection and is dependent upon lactating females becoming infected. Differences in rates of transmission between species due to substrate type may account for differences seen in species re-colonisation. Due to the rocky substrate at Ohau point, transmission of hookworm once the colony reaches carrying capacity, may be low initially in comparison with sandy colonies such as Wekakura Point, West Coast, South Island (41°S172.2°E; see Introduction Figure 1) until the parasite densities increase to a point where they are more readily propagated at Ohau Point.

Higher densities of breeding seals also allow for better propagation of hookworm larva (Olsen and Lyons 1965), so a further reason why minimal evidence of hookworm infection may have been recorded at Ohau Point is that the colony is recently re-colonised and has not yet reached a density that is likely to have a major negative impact on survival (Chapter 2; 6). Populations will typically go through a phase of exponential growth while still small and before density-dependent factors begin to influence population regulation (Giesel 1974). Environmental resistance, or biological factors such as competition for resources, predation and disease, which prevent a species from reproducing at its maximum rate, is typically low in populations that are re-colonising, or have just entered a new territory, for example fur seals (Villem *et al.* 1984). Parasites will spread more rapidly if the host is common or spaced closely together (Chapman and Reiss 1984). Therefore, as a population nears carrying capacity density-dependent factors such as: food, space, and predators, will start to regulate the population and keep it at a relatively constant density (Giesel 1974).

Hookworm incidence seems to follow a density-dependent pattern. For example, hookworm prevalence in *O. flavescens* was slightly higher at the traditional breeding areas than the newly colonised beaches (Berón-Vera *et al.* 2004), and hookworm prevalence in *C. ursinus* at St. Paul Island, Alaska has decreased dramatically in the last five decades in parallel with the decreased fur seal population and density there (Lyons *et al.* 2000b). The *A. forsteri* colony at Ohau Point is still growing exponentially (approximately 32% per annum – Chapter 2) and therefore, environmental resistance, including infectious diseases, is likely to be minimal.

However, the high proportion of *A. forsteri* pup mortality observed at a long established colony, Open Bay Islands, West coast, New Zealand, caused by emaciation, hookworm and associated intestinal haemorrhage (66.7% of dead pups examined – H. Best and M. Stratton, pers. comm.) suggests that hookworm can have a major impact on this species when densities and terrain are favourable for infection.

Therefore, while hookworm and other gastro-intestinal nematodes currently do not appear to have a great influence on pup health at Ohau Point, this is not to say that in the future as the colony reaches maturity that it won't play a role in colony dynamics. Although the rocky terrain is not as conducive to transmission of hookworm to adult seals (Duignan 2003), there are areas of the Ohau colony that are more sandy or silty where transmission can occur. Nevertheless, regardless of substrate type, while colony densities at Ohau are low the chance of a seal coming into contact with the larvae remains low. However, with increasing densities, and immigration of breeding seals from other colonies, including ones from colonies in which the parasite is at higher densities, the chance of transmission may increase.

While the results of the weight comparison of treated and non-treated pups at Ohau Point showed little difference in contrast to similar work on other species this suggests either a low incidence of gastro-intestinal nematodes naturally occurring within the colony or that changes in body condition in relation to parasites may not have been evident in the time frame of the current study. Based on the low levels of pup mortality and the low rate of infection observed at Ohau, it is more likely to be the former. The use of Ivermectin should prove useful in the future for monitoring hookworm prevalence at established colonies, or comparing health status between colonies and/or species. As fur seal and other pinniped colonies mature, increased densities of hookworm may have implications on the resilience of a population to increased mortality through other means (e.g. fisheries interactions, El Niño event), and therefore is worthy of further monitoring. However, it is recommended that if such a study design is employed that the study species lactation strategies be taken into consideration, as more information is needed on the affect hookworm has in pinniped species with different lactation strategies.

References:

- Baker, A. (1999). Unusual mortality of the New Zealand sea lion, *Phocarctos hookeri*, Auckland Islands, January-February 1998. Report to Department of Conservation. Wellington, New Zealand.
- Berón-Vera, B., Crespo, E., Raga, J. A. and Pedraza, S. (2004). *Uncinaria hamiltoni* (Nematoda: Ancylostomatidae) in South American sea lions, *Otaria flavescens*, from Northern Patagonia, Argentina. *Journal of Parasitology* **90**, 860-863.
- Blood, D. and Studdert, V. (1999). 'Saunders Comprehensive Veterinary Dictionary.' (W.B. Saunders: London.)
- Boren, L. J. (2001). Assessing the impact of tourism on New Zealand fur seals (*Arctocephalus forsteri*). MSc. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Bradshaw, C. J. (1999). Population dynamics and colonisation modelling of New Zealand fur seals. PhD. Department of Zoology, University of Otago, Dunedin, New Zealand.
- Bradshaw, C. J., Davis, L. S., Lalas, C. and Harcourt, R. G. (2000). Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. *Journal of Zoology, London* **252**, 41-51.
- Chapman, J. and Reiss, M. (1992). 'Ecology: principles and applications.' (Cambridge University Press: Cambridge.)
- Childerhouse, S. and Gales, N. (1998). Historical and modern distribution and abundance of the New Zealand sea lion, *Phocarctos hookeri*. *New Zealand Journal of Zoology* **25**, 1-16.
- Dailey, M. D. (2001). Parasitic Diseases. In 'CRC Handbook of Marine Mammal Medicine 2nd Edition'. (Eds L. A. Dierauf and F. Gulland.) pp. 357-374. (CRC Press: Boca Raton, Florida).
- Duignan, P. (2000). Diseases of cetaceans and pinnipeds. In Marine Wildlife: the Fabian Fay Course for Veterinarians. Post Graduate Foundation in Veterinary Science, University of Sydney, Proceedings 335 Sea World Nara Resort, Gold Coast, Australia. pp. 419-447.
- Duignan, P. (2003). Disease investigations in stranded marine mammals, 1999-2002. Report to Department of Conservation. Department of Conservation Science Internal Series 104, Wellington, New Zealand.
- Duignan, P. J., Hunter, J., Alley, M., Thompson, K., Meers, J., Fenwick, S., Gibbs, N., Gales, N., Childerhouse, S., Garthwaite, I. and Madie, P. (1998). New Zealand sea lion epidemic January-February 1998, preliminary report June 1998.
- Forbes, A., Cutler, K. and Rice, B. (2002). Sub-clinical parasitism in spring-born, beef suckler calves: epidemiology and impact on growth performance during the first grazing season. *Veterinary Parasitology* **104**, 339-344.
- Gatongi, P., Scott, M., Ranjan, S., Gathuma, J., Munyua, W., Cheruiyot, H. and Prichard, R. (1997). Effects of three nematode anthelmintic treatment regimes on flock performance of sheep and goats under extensive management in semi-arid Kenya. *Veterinary Parasitology* **68**, 323-336.
- Gentry, R., Costa, D., Croxall, J., David, J., Davis, R., Kooyman, G., Majluf, P., McCann, T. and Trillmich, F. (1986). Synthesis and conclusions. In 'Fur seals: maternal strategies on land and at sea'. (Eds R. Gentry and G. Kooyman.) pp. 220-264. (Princeton University Press: Princeton, New Jersey).

- Giesel, J. T. (1974). 'The biology and adaptability of natural populations.' (The C.V. Mosby Company: St. Louis).
- Harcourt, R. G., Schulman, A. M., Davis, L. S. and Trillmich, F. (1995). Summer foraging behaviour by lactating female New Zealand fur seals (*Arctocephalus forsteri*) off Otago Peninsula, New Zealand. *Canadian Journal of Zoology* **73**, 678-690.
- Harder, A., Schmitt-Wrede, H., Krucken, J., Marinovski, P., Wunderlich, F., Willson, J., Amliwala, K., Holden-Dye, L. and Walker, R. (2003). Cyclooctadepsipeptides - an antihelmintically active class of compounds exhibiting a novel mode of action. *International Journal of Antimicrobial Agents* **22**, 318-331.
- Harwood, J., and Hall, A. (1990). Mass mortality in marine mammals: its implications for population dynamics. *Trends in Ecology and Evolution* **5**, 254-257.
- Hughes, P., McKenna, P. and Dowling, A. (2005). A survey of the prevalence of emerging macrolytic lactone resistance and benzimidazole resistance in sheep nematodes in the lower North Island of New Zealand. *New Zealand Veterinary Journal* **53**, 87-90.
- Humbert-Droz, E., Buscher, G., Cavalleri, D. and Junquera, R. (2004). Efficacy of milbemycin oxime against fourth-stage larvae and adults of *Ancylostoma tubaeforme* in experimentally infected cats. *Veterinary Record* **154**, 140-143.
- Kuss, F., Graefe, A. and Vaske, J. (1990). Visitor impact management: a review of research. Report to National Parks and Conservation Association. Washington DC.
- Lafferty, K. and Gerber, L. (2002). Good medicine for conservation biology: the intersection of epidemiology and conservation theory. *Conservation Biology* **16**, 593-604.
- Lalas, C. and Bradshaw, C. J. (2001). Folklore and chimerical numbers: review of a millennium of interaction between fur seals and humans in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research* **35**, 477-497.
- Lawrence, G., Leafasia, J., Sheridan, J., Hills, S., Wate, J., Wate, C., Montgomery, J., Pandeya, N. and Purdie, D. (2004). Control of scabies, skin sores and haematuria in children in the Solomon Islands: another role for ivermectin. *Bulletin of the World Health Organization* **83**, 34-42.
- Lind, E., Ugglå, A., Waller, P. and Høglund, J. (2005). Larval development assay for detection of anthelmintic resistance in cyathostomins of Swedish horses. *Veterinary Parasitology* **128**, 261-269.
- Loyacano, A., Williams, J., Gurie, J. and DeRosa, A. (2002). Effect of gastrointestinal nematode and liver fluke infections on weight gain and reproductive performance of beef heifers. *Veterinary Parasitology* **107**, 227-234.
- Lyons, E., DeLong, R., Gulland, F., Melin, S., Tolliver, S. and Spraker, T. (2000a). Comparative biology of *Uncinaria* spp. in the California sea lion (*Zalophus californianus*) and the northern fur seal (*Callorhinus ursinus*) in California. *Journal of Parasitology* **86**, 1348-1352.
- Lyons, E., Spraker, T., Olson, K., Tolliver, S. and Bair, H. (2000b). Prevalence of hookworms (*Uncinaria lucasi*) in northern fur seal (*Callorhinus ursinus*) pups on St. Paul Island, Alaska, USA: 1986-1999. *Comparative Parasitology* **67**, 218-223.
- Lyons, E., Melin, S., DeLong, R., Orr, A., Gulland, F. and Tolliver, S. (2001). Current prevalence of adult *Uncinaria* spp. in northern fur seal (*Callorhinus ursinus*) and California seal lion (*Zalophus californianus*) pups on San Miguel Island, California, with notes on the biology of these hookworms. *Veterinary Parasitology* **97**, 309-318.

- Lyons, E., DeLong, R., Spraker, T., Melin, S. and Tolliver, S. (2003). Observations in 2001 on hookworms (*Uncinaria* spp.) in otariid pinnipeds. *Parasitology Research* **89**, 503-505.
- Lyons, E. (2005). Historical importance of some aspects of research by O. Wilford Olsen on hookworms (*Uncinaria lucasi*) in northern fur seals (*Callorhinus ursinus*) and Steller sea lions (*Eumatopias jubatus*) in 1951 on St. Paul Island, Alaska. *Parasitology Research* **95**, 353-357.
- McCall, J., Guerrero, J., Genchi, C., Kramer, L., Bazzocchi, C., Simon, F. and Martarino, M. (2004). Recent advances in heartworm disease. *Veterinary Parasitology* **125**, 105-130.
- McElroy, M., Elrefaei, M., Jones, N., Ssali, F., Mugenyi, P., Barugahare, B. and Cao, H. (2005). Coinfection with *Schistosoma mansoni* is associated with decreased HIV-specific cytotoxicity and increased IL-10 production. *Journal of Immunology* **174**, 5119-5123.
- Mertz, K., Hildreth, M. and Epperson, W. (2005). Assessment of the effect of gastrointestinal nematode infestation on weight gain in grazing beef cattle. *Journal of the American Veterinary Medical Association* **226**, 779-783.
- Mylonakis, M., Rallis, T., Koutinas, A., Ververidis, H. and Fytianou, A. (2004). A comparison between ethanol-induced chemical ablation and ivermectin plus prednisolone in the treatment of symptomatic esophageal spirocercosis in the dog: a prospective study on 14 natural cases. *Veterinary Parasitology* **120**, 131-138.
- Newey, S. and Thirgood, S. (2004). Parasitic-mediated reduction in fecundity of mountain hares. *Proceedings of the Royal Society B* **271**, S413-S415.
- Olsen, O. W. and Lyons, E. T. (1965). Life cycle of *Uncinaria lucasi* Stiles, 1901 (Nematoda: Ancylostomatidae) of fur seals, *Callorhinus ursinus* Linn., of the Pribilof Islands, Alaska. *Journal of Parasitology* **51**, 689-700.
- Ono, K. (1991). Introductory remarks and the natural history of the California sea lion. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 109-111. (Springer-Verlag: London.)
- Schulz, T. and Bowen, W. (2004). Pinniped lactation strategies: evaluation of data on maternal and offspring life history traits. *Marine Mammal Science* **20**, 86-114.
- Sease, J. and Gudmundson, C. (2002). Aerial and land-based surveys of Steller sea lions (*Eumatopias jubatus*) from the Western Stock in Alaska, June and July 2001 and 2002. Report to National Marine Fisheries Service. Alaska. NOAA Technical Memorandum, NMFS-AFSC-131,
- Sepúlveda, M. S. (1998). Hookworms (*Uncinaria* sp.) in Jaun Fernandez fur seal pups (*Arctocephalus philippii*) from Alejandro Selkirk Island, Chile. *Journal of Parasitology* **84**, 1305-1306.
- Sinisalo, T., Kunasranta, M. and Valtonen, E. (2003). Intestinal helminths of a landlocked ringed seal (*Phoca hispida saimensis*) population in eastern Finland. *Parasitology Research* **91**, 40-45.
- Spraker, T., Lyons, E., Tolliver, S. and Bair, H. (2003). Ascaridoid nematodes and associated lesions in stomachs of subadult male northern fur seals (*Callorhinus ursinus*) on St. Paul Island, Alaska: (1987-1999). *Journal of Veterinary Diagnostic Investigations* **15**, 432-437.
- Steenbergen, V. (2005). Proper use of ivermectin in cats. *Veterinary Technician* **26**, 211-213.
- Stewardson, C. and Fourie, H. (1998). Endoparasites of the Cape fur seal *Arctocephalus pusillus pusillus* from the Eastern Cape coast of South Africa. *Transactions of the Royal Society of South Africa* **53**, 33-51.

- Strabel, D., Schweizer, G., Gansohr, B. and Braun, U. (2003). Treatment with avermectins in two goats with demodicosis. *Schweizer Archiv Fur Tierheilkunde* **145**, 585-587.
- Vercruyse, J., Salomez, A., Ulloa, A., Osterhaus, A., Kuiken, T. and Alvinerie, M. (2003). Efficacy of ivermectin and moxidectin against *Otostrongylus circumlitus* and *Parafilaroides gymnurus* in harbour seals (*Phoca vitulina*). *The Veterinary Record* **152**, 130-134.
- Villee, C. A., Walker, W. F. and Barnes, R. D. (1984). 'General Zoology.' (Saunders College Publishing: New York).
- Wilkinson, I., Duignan, P., Grinber, A., Chilvers, B. and Robertson, B. C. (in press). *Klebsiella pneumoniae* epidemics: Possible impact on New Zealand sea lion recruitment.
- Williams, J., Loyacano, A., Broussard, S. and Coombs, D. (1995). Effect of treatment with an ivermectin sustained-release bolus on productivity of stocker beef calves. *Veterinary Parasitology* **58**, 75-82.
- Yadav, C., Banerjee, P., Kumar, V. and Vatsya, S. (2004). Comparative efficacy of pour-on moxidectin, flumethrin and injectable ivermectin against louse infestation in goats. *Indian Veterinary Journal* **81**, 1325-1326.
- Zar, J. (1984). 'Biostatistical analysis.' (Prentice Hall:Englewood Cliffs, New Jersey.)

Appendix:

List of pinniped species names, parasite classifications and veterinary terms referred to in this chapter. NB. This is not an exhaustive list of all pinniped parasites, nor of all pinnipeds known to harbour various parasites.

Definitions:

Enteritis – inflammation of the intestinal mucosa resulting in a number of clinical signs (e.g. diarrhea, dysentery, electrolyte loss etc.), severe cases may include exfoliated mucosa, and gastric ulceration.

Uncinariasis – the disease caused by *Uncinaria* spp., involving blood loss and enteritis.

Parasite Classifications:

Class:	Protozoans	Helminths
Order:		Nematodes , Trematodes, Cestodes, Acanthocephalans

Gastro-intestinal Nematodes

Families:	Ancylostomatidae	Anisakidae
Genus:	<i>Uncinaria</i> spp. (hookworm)	<i>Anisakis</i> , <i>Contracaecum</i> , <i>Psuedoterranova</i> , and <i>Phocascaris</i>

Respiratory Nematodes (lung worm)

Families:	Filaroididae	Crenosomatidae	Filariidae
Genus:	<i>Parafilaroides</i> spp.	<i>Otostrongylus</i> spp.	<i>Acanthocheilonema</i> spp.

Respiratory mites (ectoparasites)

Genus:	<i>Orthohalaracne</i>
---------------	-----------------------

Definitions summarised from: Blood, D. and Studdert, V. (1999). 'Saunders Comprehensive Veterinary Dictionary.' (W.B. Saunders: London.)

Other species names referred to:**Pinniped host species reported to have *Uncinaria* spp.**

Callorhinus ursinus, Northern fur seal

Zalophus californianus, California sea lion

Eumatopias jubatus, Steller sea lion

Otaria flavescens, South American sea lion

Phocarctos hookeri, New Zealand sea lion

Arctocephalus forsteri, New Zealand fur seal

Arctocephalus philippii, Juan Fernandez fur seal

Mirounga angustirostris, Northern elephant seal

Other species names – pinnipeds

Phoca vitulina, Harbour seal

Phoca hispida saimensis, Lake Saimaa ringed seal

Arctocephalus pusillus pusillus, Cape (South African) fur seal

Other species names – parasites

Schistosoma mansoni - helminth

Chapter 8

General Discussion

Laura J. Boren

Chapter 8: General Discussion

Revisiting the objectives

Worldwide much research has investigated the reproductive biology and behaviour of pinnipeds, including otariids since populations have begun re-colonising after severe exploitation in the fur industry (Gentry and Kooyman 1986; Ono and Trillmich 1991; Reeves *et al.* 1992). In the early 1970's several studies were initiated in New Zealand on the natural history and breeding behaviour of *Arctocephalus forsteri* at Open Bay Islands, West Coast (Stirling 1971; Miller 1971; Crawley and Wilson 1976; Mattlin 1978a). Since then, more knowledge has been gained on the re-colonisation patterns (Taylor *et al.* 1995; Bradshaw 1999; Gales *et al.* 2000; Lalas and Bradshaw 2001), diet (Carey 1992), maternal investment strategies (Harcourt *et al.* 1995; 2001; 2002) and pup growth and behaviour (Goldsworthy 1992; Chilvers *et al.* 1995; Lea and Hindell 1997; Haase 2004) of *A. forsteri* elsewhere in its distribution. While what we know of *A. forsteri* behaviour is growing, little work has been carried out in the Kaikoura region (Carey 1989; Bradshaw 1999), which is now supporting a fur seal population of ca. 6000-7000 (Chapter 6). With increasing tourist numbers (Simmons *et al.* 1998) and the increased potential for human and fur seal interactions (Boren 2001), it is important to focus more work on the population status and breeding biology of *A. forsteri* in this region.

The primary objectives of this thesis were to answer key questions pertaining to the reproductive behaviour, foraging ecology and colony status of *A. forsteri* populations in the Kaikoura region: (1) to assess the status of the Ohau Point breeding colony, and basic population dynamics of fur seals in the Kaikoura region; (2) to determine whether lactating female *A. forsteri* in the vicinity of Kaikoura adopted distinct maternal attendance patterns; (3) to assess pup condition and growth patterns at the Ohau Point colony, and to determine how maternal parameters would affect pup growth; and (4) to assess the current health status of pups in the region through various indices including pup production, condition, intestinal parasite loads and levels of mortality.

In considering these questions, two recurring concepts emerged as being important for the future monitoring and management of the species. Firstly, the presence of a nearby food source plays a key role in shaping the maternal investment strategies observed in

the Kaikoura region. Secondly, and of critical importance, is the proximity of humans to the fur seal populations in Kaikoura in terms of disturbance to breeding seals, human-influenced mortality, and future potential for zoonotic transfer. These two factors play important roles in determining suitable *A. forsteri* habitat (Taylor *et al.* 1995; Bradshaw *et al.* 1999); however, the implications of these on population dynamics and breeding biology are not fully understood. The Ohau Point colony provides a unique opportunity to study a growing colony that is near to human development. It also has desirable environmental qualities that lend it to being a good place for seals to inhabit. As a result, it provides not only a place to monitor changing health and population dynamics in a growing colony, but it also provides a model for monitoring and managing a species targeted by eco-tourism or affected by a growing human population. As the benefits of the close food source may currently outweigh the potential negative impacts of increasing human activity, it is important to understand how these two opposing factors interact to influence *A. forsteri* populations in Kaikoura. I will address each of the primary goals of this thesis in relation to the two central management concepts.

Maternal investment / foraging strategies used by lactating females in the region, and how they may be affected by disturbance

The results presented in Chapter 4 showed that lactating *A. forsteri* were utilising different maternal attendance patterns. These patterns appear to be based primarily on foraging trip duration, and to a certain degree shore bout duration (Chapter 4, Figure 7), however, the number of overnight foraging trips performed played a significant role in categorising the behaviour of VHF monitored females (Chapter 4, Figure 6). A high proportion of females with VHF transmitters (92% and 100%) carried out overnight foraging trips (OFTs) (Chapter 4, Table 3). Inter-annual variation was evident in the foraging trip duration, shore bout duration, the relative importance of overnight foraging trips, and the number of strategies employed (Chapter 4, Tables 3 and 4). While four main attendance patterns were apparent, using behavioural data, the importance of OFTs in defining female patterns suggests that the OFT is important in shaping female attendance patterns in the region.

Food source proximity

Fur seals are central-place foragers whereby lactating females forage at sea and return to land on a regular basis to nurse their offspring (Orlans and Pearson 1979). This travel incurs a cost to the female that needs to be balanced by the energy they gain from a prey patch (Orlans and Pearson 1979; Robinson *et al.* 2002). The foraging behaviour of a predator can therefore provide useful information on prey distribution and how the predator responds to changes in prey distribution (Boyd 1996). The mean duration of foraging trips within a year has been used as a measure of food availability (Lunn *et al.* 1994). For example, *A. gazella* at Bird Island, South Georgia, exhibited significantly longer foraging trips and spent more time foraging in a year of poor food availability relative to good years (Boyd *et al.* 1994). The observed behavioural responses to changes in prey availability represented a 30-50% increase in the cost of foraging due to low prey abundance. For *A. tropicalis* at Amsterdam Island in the sub-Antarctic, foraging trip duration lengthens dramatically within a year (Beauplet *et al.* 2004): females spent an average of 15 days at sea in summer versus 29.1 days in winter. These changes in attendance behaviour are likely to be a result of a high-density colony depleting food patches and causing females to forage as far as 1800 km away (Beauplet *et al.* 2004). At the other extreme, *A. gazella* and *A. tropicalis* at Macquarie Island spend an average of 3.6 and 3.8 days, respectively at sea on extended foraging trips at prey patches approximately 30 and 60 km away (Goldsworthy 1999; Robinson *et al.* 2002).

While fur seals, including *A. forsteri*, are reported to occasionally exhibit short foraging trips of less than 12 hours (Harcourt *et al.* 1995; 2002; Haase 2004), these “mini-foraging bouts” are rare unless the seals are able to exploit a nearby food source (Goldsworthy 1999). Fur seal swimming speeds average around 2 m/s (Boyd *et al.* 1995; Harcourt *et al.* 1995). At this rate it would take approximately 8 hours to travel 60 km. Prey patches less than 20 km from shore could easily be reached in less than 3 hours and could be exploited on an overnight foraging trip. Average overnight foraging trip durations for *A. gazella* and *A. tropicalis* at Macquarie Island were 10.7 and 9.4 hours, respectively (Goldsworthy 1999) and were focused at prey patches within 10 km from the colony (Robinson *et al.* 2002). Since *A. forsteri* females in the current study had slightly longer mean overnight foraging trip durations (14.5 +/- 6.64 hours in 2004; 13.1 +/- 2.91 hours in 2005), they may easily be exploiting prey

patches within 20 km of the colony. The head of the Kaikoura Canyon comes to within 500 m of the shore just south of the Kaikoura township and near Ohau Point the 500-1000 m isobaths can range from between 2-20 km from shore (Jaquet *et al.* 2000; Benoit-Bird *et al.* 2004). The proportion of females exhibiting overnight foraging trips and the frequency with which these trips occurred compared with all types foraging trips (Chapter 4, Table 3), suggest that *A. forsteri* females in Kaikoura are likely to be utilising the Kaikoura Canyon as a food source.

A study on dusky dolphin (*Lagenorhynchus obscurus*) foraging behaviour in Kaikoura, used active-acoustic surveys to determine the vertical migration of the deep scattering layer (DSL) in the Kaikoura Canyon (Benoit-Bird *et al.* 2004). They found the DSL was within 150 m of the surface from 1900 to 0530 hours, and was within 50 m of the surface between 2300 and 0100 hours. *L. obscurus* was observed foraging at the top of the DSL as long as it was within 130 m of the surface.

A. forsteri are also capable divers and although they mainly dive at depths between 10 and 70 m, adult females are capable of maximum depths ranging from 106 to 225 m (Harcourt *et al.* 1995; Harcourt and Davis 1997) while pups aged 6 to 10 months were reported as diving to depths of up to 44 m (Baylis 2003). Fur seals in the Kaikoura region should, therefore, be able to utilise the deep scattering layer of the Kaikoura Canyon as a food source. This is supported by reports that the predominant prey species of *A. forsteri* in the Kaikoura region are *Symbolophorus* spp. (myctophid), arrow squid and octopus, and a very small amount of hoki (Carey 1992). This diet is similar to that of dusky dolphins at Kaikoura (Benoit-Bird *et al.* 2004), and is also similar to the diet of the sister species *A. tropicalis* at colonies located near a deep-sea food source (Goldsworthy *et al.* 1997).

The proximity of such a food source and this colony's use of overnight foraging trips may allow females to adjust their maternal attendance patterns in times of lower food availability. In the current study, females lengthened their extended foraging trip duration, but were able to maintain their proportion of time spent ashore by increasing the proportion of time spent on OFTs, thereby decreasing the number of EFTs and lengthening shore bout durations (Chapter 4, Tables 3 and 4). By increasing the frequency of overnight foraging trips relative to extended foraging trips, females

appear to be able to increase their time spent ashore, and a positive relationship was found between the proportion of OFTs to EFTs and the proportion of time spent onshore. This was also found to be the case in female fur seals at Macquarie Island where a similar relationship was detected (Goldsworthy 1999). Since attendance patterns are indicative of the distribution of prey being exploited, the data presented in Chapter 4 on foraging trip duration and proportion of overnight foraging trips performed indicate that female fur seals in Kaikoura are utilising a reliable food source and that its proximity shapes various aspects of their foraging strategies. The proportion of time female fur seals spend at sea and on shore may have wider implications on the long-term effects disturbance can have on the Kaikoura colonies.

Disturbance

With increasing pinniped-related tourism in the Southern hemisphere and an increasing focus on breeding colonies as a tourist attraction (Kirkwood *et al.* 2003), it is of great importance to understand how human disturbances at a colony might affect female foraging strategies and, consequently, the time they spend provisioning their pups (Boren 2001). Since shore bout durations are typically short for *A. forsteri*, including those at Ohau Point (yearly means: 1.75 and 2.03 days) around 50% of females will be departing for a foraging trip anyway. It would be, therefore, difficult to correlate disturbance within the colony to an increased time spent at sea or a premature departure from the colony. Further, given the proximity of the food source and the relatively short mean duration of maternal absences observed at this colony (4.25 +/- 1.39 days in 2005) even in the face of reduced food availability, a premature departure seems unlikely to be detrimental to pup growth. Of greater concern is the effect that a separation between a mother/pup pair can have on the pup's rate of nutrient uptake during these already short shore bouts.

Previous work on both pinnipeds and hoofed mammals has raised concern about the potential separation of mother/offspring pairs due to a tourist disturbance (*Phoca groenlandica*: Kovacs and Innes 1990; *A. forsteri*: Boren 2001; *Eschrichtius robustus*: Noris *et al.* 1977; African ungulates: Lawick-Goodal and Lawick Goodal 1970). Many species rely on the formation of a mother/offspring bond to reunite after a separation (McNab and Crawley 1975; Phillips and Stirling 2000). A separation after the bond has been established is not as severe as one occurring before hand,

which can lead to permanent separation and starvation of the offspring (Lawick-Goodal and Lawick Goodal 1970). However, in species such as the smaller pinnipeds where females frequently depart to forage, the relatively short time the female spends ashore in her foraging cycle is critical to her pup's survival (Boren 2001).

A. forsteri pups at Cape Foulwind, West Coast, New Zealand, may spend upwards of 30 minutes per hour nursing (Chilvers *et al.* 1995). Barton *et al.* (1998) and Boren (2001) observed recovery times for breeding and non-breeding *A. forsteri*, to be 3-90 minutes and 45 minutes, respectively. In addition to the disruption associated with female recovery time, the average time it took for a mother to reunite with her pup was 10.2 minutes with a maximum of 77 min (Dowell 2005). Therefore, a disturbance in a breeding colony could easily result in separations between mothers and their pups for a minimum of 30-40 minutes, and up to 110 minutes. Given that this minimum separation time is approximately equivalent to the average suckling bout length and minutes per hour spent suckling observed by Chilvers *et al.* (1995), such a separation may greatly reduce the proportion of time pups spend obtaining nutrients. Pups spend about 12% of their time nursing when their mother is ashore (Boren 2001 – *A. forsteri* pup behaviour at Ohau Point; This thesis Chapter 5, Figure 6), which equates to about 80 minutes for a 12 hour period. A 30-minute separation would reduce nursing time by about 38%. This calculation was based on a 12-hour period because little is known about night-time nursing behaviour of fur seal pups, and because the frequency of disturbance is most likely to be highest during summer daylight hours.

Implications of maternal attendance patterns on pup condition and growth

The results presented in Chapter 5 on pup growth suggest that pups in the Kaikoura region experience relatively high rates of growth in comparison to those reported for the species at other sites. At Ohau Point, growth rates for individual pups reached 350 g/day, with average growth rates for the peri-natal period being up to 163.38 g/day (Chapter 5, Table 2). However, pup growth from birth to approximately 116 days of age was significantly lower in 2004 than in 2005 (2004: 66.54 and 58.88 g/day; 2005: 109.54 and 104.05 g/day, Chapter 5, Figures 4 and 5). The high rates of growth observed in 2005 occurred in a year when adult females were at a higher average mass and condition (Chapter 5, Figure 8), despite increased foraging trip duration (Chapter 4, Table 4). Maternal parameters were not found to influence pup size or growth as there was no relationship between maternal foraging trip duration, maternal size and pup size or growth (Chapter 5) and there was no correlation between pup size and pup behaviour. There was a significant relationship between female size and condition with pup size and condition, but not with pup growth (Chapter 5, Figure 9). From this it appears that maternal attendance patterns did not greatly influence pup growth within a season. However, the flexible attendance patterns of *A. forsteri* females' may allow them to exploit a nearby food source, accounting for inter-annual variations in pup growth.

Food Source Proximity

If female attendance patterns are being shaped by a close food source in the Kaikoura region, then these are likely to have an impact on pup production, mortality rates, condition, the timing of weaning, growth and behaviour. Data from Chapters 2, 3, 5 and 6 all lend support to the idea that female *A. forsteri* are foraging in the Kaikoura Canyon, and the accessibility of this highly productive region in turn benefits the pups through increased condition, growth and perhaps future survival.

Pup production at Ohau Point has increased exponentially from first births in 1990 to nearly 600 pups born in December 2004 (Chapter 2). Coupled with this is a low pup mortality rate of approximately 3% from birth to 50 days of age (Chapter 6), versus 20% (Mattlin 1978b). Further, pup mass and condition in the Kaikoura region is consistently higher at approximately 50 days of age than for two Banks Peninsula

colonies, one already established and one experiencing exponential growth (Chapter 2). On the Banks Peninsula, lactating female fur seals may have to travel as far as 100 km to reach the continental slope and adequate foraging grounds (Goring and Henry 1998) versus 2-20 km for Kaikoura seals (Benoit-Bird *et al.* 2004). While no intensive study of fur seal attendance patterns has been undertaken at Banks Peninsula, a study on *A. tropicalis* at the sub-Antarctic Amsterdam Island demonstrated that the distance to the foraging patch was strongly related to the duration of maternal absences (Beauplet *et al.* 2004). Perhaps females at Banks Peninsula colonies spend more time at sea than their Kaikoura counterparts, resulting in increased fasting time for pups and subsequently reduced condition. This is an issue worthy of further study.

The timing of weaning is flexible in temperate species of fur seals (Gentry *et al.* 1986) and typically a longer lactation length is seen in years of poor food availability (Trillmich *et al.* 1991). Such condition dependent variability in weaning was observed at Ohau Point during the 2002-2003 El Niño (NIWA 2005) when pups were weaned at around 347 days of age (Chapter 3). However, all lactation lengths observed at Ohau Point were longer than the 285 days commonly quoted for the species (Schulz and Bowen 2004). This seems contrary to what is typically understood to happen for colonies in years of high prey abundance, where females are able to rear pups to a heavier weight sooner and thus wean them sooner (Haase 2004).

However, at some of those colonies where foraging grounds are 70+ km away (Bradshaw *et al.* 2002; see Introduction, Figure 3), females tend to feed at sea to regain condition for a protracted period of time between weaning and giving birth to their next pup, even in years of high productivity (range observed: 29-60 days: Stirling 1971). If the food source is close and predictable then females might be able to maintain condition throughout the year. Furthermore, after weaning, females in good condition who do not have to travel far to forage would not need as much time at sea to regain condition. As a result, females at Ohau Point could nurse their pups longer with minimal cost to themselves, in turn weaning pups in above average condition with increased chances of survival. Although further research is needed to determine the exact relationship between food source and lactation lengths in Kaikoura, the results of this study may be explained by examining the post-weaning behaviour of *A. gazella* at Macquarie Island. Given the highly seasonal prey

availability throughout much of the *A. gazella* range, lactating females typically leave breeding colonies after weaning their pups, and do not return until the following breeding season (Doidge *et al.* 1986). But, at Macquarie Island they have been observed continuing to haul-out after weaning presumably because of the ability to continue foraging near the colony, which like Kaikoura, is near a pelagic food source (Goldsworthy 1999).

The growth rates observed at Ohau Point over four years were some of the highest reported for *A. forsteri* (Chapter 5). The elevated rates of growth may also be a result of more favourable foraging grounds; however, the more interesting observation was the increased rate of growth for pups observed in 2005 (Chapter 5). Despite El Niño conditions (NIWA 2005), rates of growth were over 40 g/day higher in 2005 than in the previous season. Increased maternal condition at parturition and longer extended foraging trips were thought to be responsible for this (Chapter 5, Figure 8; Chapter 4, Table 4). For example, while it is common for females to lengthen foraging trip durations in response to decreased food availability (Trillmich *et al.* 1991), the mean foraging trip duration observed in 2005 was 4.25 +/- 1.39 days (Chapter 4). This is within the range of normal foraging trip durations exhibited by several species of fur seals under normal conditions: *Callorhinus ursinus* – 5.8 days; *A. gazella* – 4.3 days; *A. australis* – 4.6 days (summarised from Gentry and Kooyman 1986); *A. tropicalis* at Marion Island – 7.0 days (Kirkman *et al.* 2002); *A. forsteri* at Maatsuyker Island 4.6 days (Lea and Hindell 1997) and significantly shorter than winter foraging trips made by *A. tropicalis* at Amsterdam Island (29 days Beuplet *et al.* 2004), and Marion Island (25.5 days Kirkman *et al.* 2002). Consequently, the extended foraging trip durations observed in 2005 are unlikely to be detrimental to pup growth and rather serve as a means to counteract the potential effect of El Niño conditions.

Interestingly, the flexibility shown in female attendance patterns in 2005 allowed females to be onshore and available to their pups for approximately the same amount of time as in the previous year (Chapter 4). This resulted in similar pup behaviour between years (Chapter 5), contrary to the expected reduced pup activity coincidental with an El Niño, or in times of low food availability (Ono *et al.* 1987). This was achieved through an increase in the proportion of overnight foraging trips and the extension of shore bout durations that would only be feasible if females were able to

exploit a nearby food source. This situation has also been observed for *Arctocephalus* spp. on Macquarie Island (Goldsworthy 1999). However, in spite of the flexibility in maternal attendance patterns this close food source provides, if poor conditions persist, as was the case in the 2002-2003 El Niño (Chapters 2, 4 and 5), female condition is likely to decrease substantially resulting in reduced pup growth (Chapter 5). While females may be able to adjust attendance patterns to counteract decreased food availability, the increased use of overnight foraging trips to do so is more costly to females despite the benefits it provides to pups (Goldsworthy 1999). The increased amount of travel to and from a prey patch for overnight trips will eventually reduce female condition and begin to affect foraging efficiency and subsequent pup growth. Thus while pup growth, behaviour, condition, mortality and weaning at Ohau all reflect the ability of fur seal mothers in the region to exploit a nearby food source, they also provide a means to investigate how environmental conditions can affect the dynamics between maternal and pup traits.

Disturbance

Similar to the potential impacts of human disturbance on female attendance patterns discussed above, disturbance is also likely to have a detrimental effect on pup growth as a result of its impact on mother/pup association time. The time a female spends ashore is critical for her pup to acquire enough nutrients to cope with fasting during the following maternal absence (Chilvers *et al.* 1995; Guinet *et al.* 1999). As mentioned earlier, a significant decrease in the proportion of time mothers and pups spend together during short female attendance bouts will likely impact on pup growth. Previous work at Ohau Point has shown that *A. forsteri* pups at this location spent approximately 30.9% of their time involved in mother/pup interactions and may spend as much as 40.0% of that mother/pup association time nursing (Boren 2001). Although as pups get older they spend less time associating with their mother (mean time spent with mother in peri-natal period: 33%, vs. 8% in March (76-110 days old), Chapter 5, Figure 3), a disturbance resulting in the termination of a nursing bout could cause a minimum separation time of 30-40 minutes. The impact of such separations on pup growth will be affected by factors including the pup's present condition since healthier pups may be more resilient to such disturbances (Haase 2004). Given that *A. forsteri* in the region are likely to be exposed to eco-tourism in the long-term, further

work investigating the impact of tourist disturbance on pup growth would be invaluable.

Current colony status and health of pups in the Kaikoura region, specifically in terms of pup production, intestinal parasite loads, and causes of mortality

As defined in Saunders Comprehensive Veterinary Dictionary 2nd Edition (Blood and Studdert 1999), 'Health' is "a state of physical and psychological well being and of productivity including reproduction." By this definition 'health' encompasses a wide range of possibilities and thus, to determine if a population is healthy, certain indices are often employed as a guide (Blood and Studdert 1999). Most obvious examples include food intake and faecal output; although body weight, milk yield, egg yield, quality of fur/wool, and feed conversion efficiency among others are commonly used in a variety of domestic and agricultural species (Blood and Studdert 1999). In wild populations some parameters are more difficult to determine, and may require more invasive investigation methods. In the current study four parameters were utilised to determine the relative health of *A. forsteri* in Kaikoura: pup production, pup condition, the presence of gastro-intestinal parasites in pups, and levels and causes of mortality in pups. Pup condition and survival is closely linked to maternal condition and investment strategies (Chapter 5), so health parameters focused on this most vulnerable cohort, may be indicative of the overall reproductive health of the colony (e.g.. Pup weight - Baker and Fowler 1992).

Fur seal re-colonisation in the Kaikoura region is relatively recent (1990), and pup production estimates from the last sixteen years show that the Ohau Point colony has been increasing at a rate of 32% per annum (Chapter 2). Coupled with this rate of growth, pups at Ohau Point are consistently in better condition compared with other colonies. Despite an average condition index slightly lower than that of Banks Peninsula colonies in 2002, pup condition at Ohau Point improved over the following three seasons while it declined dramatically at both Horseshoe Bay and Te Oka Bay (Chapter 2). Coupled with a high rate of colony growth and the good pup condition observed at Ohau Point, pup mortality at Ohau Point appeared exceptionally low (3% to age 50 days, Chapter 6). A high proportion of the observed early mortality was related to emaciation (88.5%). There were few cases of disease or parasites in Ohau

pups with only one case of hookworm observed out of 13 dead pups examined less than three months of age (Chapter 6). The low incidence of hookworm and other gastro-intestinal parasites observed in pups at Ohau Point was further supported by the lack of observable difference in pup mass between those treated for helminth parasites and their control (Chapter 7). The productivity of the colony and condition of the pups coupled with low mortality and minimal observations of disease and parasites in pups suggests the Ohau Point colony is currently in a good state of health.

Food Source Proximity

The results presented in previous chapters on maternal attendance patterns (Chapter 4), pup growth and condition (Chapter 5), colony growth (Chapter 2) and lactation lengths (Chapter 3) are indicative of a high quality food source (Bester and VanJaarsveld 1997). It stands to reason that this quality food source can support the current healthy status observed in seals in the region. Another key reason for the observed healthy nature of the population in Kaikoura may be related to its recent re-colonisation and low density (Chapter 2). Therefore, as the colony continues to grow, its status may change as well.

At an established colony on the West Coast, Open Bay Islands (OBI), pup production is decreasing (pup production in 1999 and 2000 down 50% from 1992-1998 yearly means: H. Best, pers. comm.). The prevalence of hookworm in pups is increasing (>66.7% of 30 examined during a one-week field trip), and a 40-50% of adult female and pre-breeder seals were observed to be in poor condition with pelvis and ribs visible (2003/04 field season: M. Stratton, pers. comm.). Similarly, pup growth in *A. tropicalis* at Amsterdam Island is reported to be the lowest observed for any otariids (47-56 g/day from birth to 60 days, and 35-55 g/day from 30-230 days - Chambellant *et al.* 2003). It was suggested that the reasons for this low growth rate are that the colony may be at or near carrying capacity, and is subject to density-dependent factors and competition for a consistently low food source (Chambellant *et al.* 2003). It can be expected that similar changes will occur at Ohau Point as the colony grows and the means for population regulation begin to take place (Snyder 1976).

Foraging ground proximity and overlap with fisheries may also influence the health status of a colony. For example, the foraging grounds for female fur seals at Open Bay

Islands appears to overlap with commercial hoki fisheries, resulting in a high incidental by-catch of seals in the fisheries there (Lalas and Bradshaw 2001). Since *A. forsteri* females in Kaikoura are feeding primarily on myctophids (lantern fish) (Carey 1992) in the deep scattering layer of the Kaikoura Canyon (Chapter 3), then the overlap between fur seal foraging grounds and fisheries in Kaikoura and subsequent mortality due to incidental by-catch should be minimal. Also, since pup condition reflects food availability (Bradshaw *et al.* 2002) but is also affected by pup density within the colony (Bradshaw *et al.* 2000), the benefits provided by a reliable and close food source may also influence the carrying capacity the colony is able to maintain. Therefore, the location of foraging grounds relative to a given population is likely to shape not only foraging behaviour of the species in question (Boyd 1996), but will also influence both directly (through density-dependent interactions) and indirectly (through fisheries interactions) the health or status of the colony (Lalas and Bradshaw 2001; Bradshaw *et al.* 2002). Baseline information on local population dynamics will be crucial for the management of key populations.

Disturbance

Given the complexity of interactions between a population and its environment, it is difficult to determine the long-term effects of disturbance on a population. While it may be difficult to assess relationships between human activity and fur seal productivity in the Kaikoura region (Boren 2001), certain issues became apparent during the course of this study. The fact that Ohau Point is a young colony means that colony densities remain low (1.41 to 6.56 pups/100m²) compared to those of more established colonies (14.34 to 16.53 pups/100m² - Bradshaw *et al.* 2000). In addition, *A. forsteri* in the region are in relatively good condition and may be more resilient to stress brought about by interactions with humans (Kuss *et al.* 1990). However, since increased density can lead to increases in competition for resources, stressful conspecific interactions, and facilitate the spread of disease, one can expect to see a concurrent decrease in individual fitness and condition as population density increases (Villem *et al.* 1984). Consequently, as the Ohau Point colony continues to grow and reach carrying capacity, the health of the colony may decrease and become less resilient to outside disturbances. With this, levels of disease may increase. While a normal process in population growth and regulation (Snyder 1976; Chapman and

Reiss 1992), the greatest concern for this region is related to the close contact between fur seals and humans.

Fur seals in Kaikoura are a popular target of the eco-tourism industry due to the high predictability associated with when and where they can be found ashore (Boren 2001). They are targeted by independent tourists and commercial ventures and can be viewed from land, and sea (kayak, motor-boat and snorkelling options – Kirkwood *et al.* 2003). If levels of various diseases increase in the region, there is a risk of transfer from seals to humans and from humans to seals through these close interactions. Tuberculosis (*Mycobacterium tuberculosis*) and *Salmonella*, have been reported in seals and are zoonotic (Smith *et al.* 1978; Thompson *et al.* 1993). These diseases can be contracted through contact with saliva, oil, fur, and faecal matter, and additionally tuberculosis can be transferred through breath (Cawthorn 1994; Tryland 2000). Seal bites can also become severely infected with an acute form of blood poisoning known as “seal finger” if not treated properly (Cawthorn 1994; Tryland 2000). The incidence of seal bites that get reported remain relatively low given the amount of contact between seals and humans in the region (8 reported bites in the first 8 years of seal tourism –Tim Hanbury-Weber, MD, pers. comm.; one per year, M. Morrissey, pers. comm.).

Also of concern for the region is the potential increase for human related seal mortality. Car collisions, entanglements, dog attacks and intentional killings function differently than natural mortality in a population, which tends to remove weaker individuals (Snyder 1976). Instead, these human related mortality events often remove strong, healthy individuals, and in the case of car collisions, tends to affect a high proportion of very healthy and active pups (Chapter 6). Removal of a high proportion of healthy individuals is likely to reduce the overall health of the colony, and removal of a high proportion of one age cohort can influence population dynamics by reducing reproductive output when the affected cohort reaches breeding age (Chapman and Reiss 1992). Similar results were found with entanglement mortality in *Callorhinus ursinus* being closely linked with decreased pup production (Fowler 1987). Due to the increasing level of human activity in the region, and an increasing population of *A. forsteri*, continued monitoring of health indices including mortality are recommended and discussed in more detail in the following section.

Further research and/or recommendations for management

The results of this thesis reveal areas where future research and monitoring for management purposes would be beneficial. While much of the work suggests that females are foraging in the Kaikoura canyon, further work to verify foraging locations and diet is advised. The utilisation of satellite tags and time-depth-recorders would allow the determination of *A. forsteri* foraging areas in the Kaikoura Canyon as well as assessment of dive activity during the foraging trips (Harcourt and Davis 1997). Diet analysis from identification of hard parts in regurgitates and faecal samples can be used to verify if *A. forsteri* are feeding on myctophids in the deep scattering layer (Fea and Harcourt 1997). Since annual abundance of myctophids is unknown, trawls to assess their availability in years of variable conditions (Guinet *et al.* 2001) would be beneficial to determine the link between local conditions and *A. forsteri* foraging behaviour. Also, collection of myctophids to analyse energy content (Tierney *et al.* 2002) would enhance the understanding of the relationship between fur seal diet and body condition in the region. Such information on diet would also help confirm the level of interaction between *A. forsteri* and local fisheries. This, coupled with information on female body condition through the period of lactation would aid in determining the relationship between the food source and the lengthened lactation periods observed at Ohau Point. New research has found that dive characteristics uploaded from Satellite Relayed Data Loggers can provide accurate indices of buoyancy in order to monitor the body condition of free-ranging Southern elephant seals (*Mirounga leonina* – Biuw *et al.* 2003). If such technology were applied to other pinnipeds, it would provide a less invasive method for tracking adult female body condition over the course of lactation because multiple captures of several individuals would not be required. Detailed information on maternal investment and reproductive strategies employed at a colony level is important for management purposes since differences observed between colonies will affect how populations respond to changes in their environment (Chapter 2) and, thus, how they will respond to human-influenced changes.

With an increasing fur seal population in the region, further monitoring of mortality in the region is recommended. The relatively recent re-establishment of the Ohau Point colony provides an opportunity to study changing population dynamics as the colony

becomes more established. As the colony grows, collection of information on the level of maternal aggression and density dependent mortality (Harcourt 1992) is recommended, along with further monitoring of the prevalence of parasites. Comparisons with already established colonies such as Open Bay Islands on the West coast would also be beneficial to predict changes that are likely to occur at Ohau. As the level of human and fur seal interactions increase, an assessment of the presence of diseases such as *Salmonella*, (*Mycobacterium*) tuberculosis and *Brucellosis* within the Kaikoura *A. forsteri* population is critical due to the zoonotic potential of these diseases (Smith *et al.* 1978; Thompson *et al.* 1993; Duignan 2000).

Finally, further work on the implications of disturbance on mother-pup separation times and pup growth is recommended. Since a disturbance may result in a minimum separation time of approximately 30 minutes, and this has the potential to reduce the amount of time a pup spends nursing during a maternal shore bout, it is critical to understand the physiological implications such a separation may have on pup health. It is especially crucial as the Kaikoura population of *A. forsteri* continues to increase and pupping areas expand into regions of higher human accessibility and activity, including on the Kaikoura Peninsula (Boren 2001; pers. obs.). Further work incorporating (1) behavioural observations of mothers and pups after reuniting, and at night, and (2) pup growth is advised. In order to minimise colony disturbance for such a project, a combination of old and new technologies could be employed to remotely weigh pups via weighing stations in areas of high pup traffic (Trillmich 1986) and the utilisation of electronic radio frequency stock identification tags (Allflex NZ Ltd.).

With a better understanding of the dynamics of fur seal populations in Kaikoura and the potential risks associated with increased human and seal interactions, better education and management decisions can be made to mitigate these risks. Site improvement recommendations include an extension of fencing along the Ohau Point seal colony and in other high risk areas to help deter seals from coming onto the road. Up to date interpretive signs explaining the implications of close contact with seals, the potential for seals to be on the road, and the risks of man-made debris on marine animals are advised.

Summary

The data presented in this thesis have provided valuable information on the reproductive behaviour and population dynamics of *A. forsteri* in Kaikoura. They also provide a baseline on the status of the colony early in the development of pinniped targeted eco-tourism in Kaikoura, as well as providing a point of comparison for other colonies. The population in question is unique in that the same coastal terrain and food source location that make the Kaikoura coast a suitable habitat for seals also makes it a desirable tourist location. The colony is currently healthy, with low incidence of mortality, disease and parasite burdens in pups. The proximity of the Kaikoura Canyon and the ability of female fur seals to exploit a nearby food source may mitigate potential negative effects of environmental fluctuations with minimal cost to female body condition and pup growth. Pup condition is consistently high in the region, and the typically increased lactation lengths may increase the survival rates of pups. Despite the benefits this region provides to a growing colony, the likelihood of increased pressure on the population through greater numbers of human interactions in the region is also inevitable. Rates of entanglement in the region are relatively high, as is the proportion of pup mortality associated with car collisions. Accordingly, further monitoring of the Ohau Point colony as it reaches carrying capacity is recommended. Local factors, namely the proximity of a pelagic food source and the level of human activity in the region have vast implications on the reproductive biology of *A. forsteri*. Understanding what the site-specific factors are that influence a population and how they affect the species in question can be used to make predictions and comparisons about how populations will respond to various pressures in order to adequately manage the species.

References:

- Baker, J. and Fowler, C. (1992). Pup weight and survival of northern fur seals *Callorhinus ursinus*. *Journal of Zoology, London* **227**, 231-238.
- Barton, K. J., Booth, K., Ward, J., Simmons, D. and Fairweather, J. (1998). Tourist and New Zealand fur seal interactions along the Kaikoura Coast. Report to Lincoln University. Tourism, Recreation, Research and Education Centre Report, Report No. 9, Lincoln, New Zealand
- Baylis, A. M. (2003). The ontogeny of dive behaviour in New Zealand fur seal pups (*Arctocephalus forsteri*). Postgraduate diploma in Zoology. Department of Zoology, LaTrobe University, Victoria, Australia.
- Beauplet, G., Dubroca, L., Guinet, C., Chereil, Y., Dabin, W., Gagner, C. and Hindell, M. (2004). Foraging ecology of subantarctic fur seals *Arctocephalus tropicalis*

- breeding on Amsterdam Island: seasonal changes in relation to maternal characteristics and pup growth. *Marine Ecology Progress Series* **273**, 211-225.
- Benoit-Bird, K., Würsig, B. and McFadden, C. (2004). Dusky dolphin (*Lagenorhynchus obscurus*) foraging in two different habitats: active acoustic detection of dolphins and their prey. *Marine Mammal Science* **20**, 215-231.
- Bester, M. and VanJaarsveld, A. (1997). Growth in the subantarctic fur seal *Arctocephalus tropicalis* pups as a possible indicator of offshore food availability. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds M. Hindell and C. Kemper.) pp. 88-91. (Surrey Beatty & Sons, Chipping Norton: Australia)
- Biuw, M., McConnell, B., Bradshaw, C. J., Burton, H. and Fedak, M. (2003). Blubber and buoyancy: monitoring the body condition of free-ranging seals using simple dive characteristics. *Journal of Experimental Biology* **206**, 3405-3423.
- Blood, D. and Studdert, V. (1999). 'Saunders Comprehensive Veterinary Dictionary.' (W.B. Saunders: London.)
- Boren, L. J. (2001). Assessing the impact of tourism on New Zealand fur seals (*Arctocephalus forsteri*). MSc. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Boyd, I. (1996). Temporal scales of foraging in a marine predator. *Ecology* **77**, 426-434.
- Boyd, I., Arnould, J., Barton, T. and Croxall, J. (1994). Foraging behaviour of Antarctic fur seals during periods of contrasting prey abundance. *Journal of Animal Ecology* **63**, 703-713.
- Boyd, I., Reid, K. and Bevan, R. (1995). Swimming speed and allocation of time during the dive cycle in Antarctic fur seals. *Animal Behaviour* **50**, 769-784.
- Bradshaw, C. J. (1999). Population dynamics and colonisation modelling of New Zealand fur seals. PhD. Department of Zoology, University of Otago, Dunedin, New Zealand.
- Bradshaw, C. J., Thompson, C. M., Davis, L. S. and Lalas, C. (1999). Pup density related to terrestrial habitat use by New Zealand fur seals. *Canadian Journal of Zoology* **77**, 1579-1586.
- Bradshaw, C. J., Davis, L. S., Lalas, C. and Harcourt, R. G. (2000). Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. *Journal of Zoology, London* **252**, 41-51.
- Bradshaw, C. J., Davis, L., Purvis, M., Zhou, Q. and Benwell, G. (2002). Using artificial neural networks to model the suitability of coastline for breeding by New Zealand fur seals (*Arctocephalus forsteri*). *Ecological Modelling* **148**, 111-131.
- Carey, P. W. (1989). Behavioural thermoregulation and polygyny in the New Zealand fur seal. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Carey, P. W. (1992). Fish prey species of the New Zealand fur seal (*Arctocephalus forsteri* Lesson). Report to Department of Conservation. Science and Research Internal Report, No. 115, Wellington, New Zealand.
- Cawthorn, M. (1994). Seal finger and mycobacterial infection of man from marine mammals: occurrence, infection and treatment. Report to Department of Conservation. Conservation Advisory Science Notes, 102, Wellington, New Zealand.
- Chambellant, M., Beauplet, G., Guinet, C. and Georges, J. (2003). Long-term evaluation of pup growth and preweaning survival rates in subAntarctic fur seals,

- Arctocephalus tropicalis*, on Amsterdam Island. *Canadian Journal of Zoology* **81**, 1222-1232.
- Chapman, J. and Reiss, M. (1992). 'Ecology: principles and applications.' (Cambridge University Press: Cambridge.)
- Chilvers, B., Wilson, K. and Hickling, G. (1995). Suckling behaviours and growth rates of New Zealand fur seal, *Arctocephalus forsteri*, at Cape Foulwind, New Zealand. *New Zealand Journal of Zoology* **22**, 263-270.
- Crawley, M. and Wilson, G. (1976). The natural history and behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). *Tuatara* **22**, 1-29.
- Doidge, D., McCann, T. and Croxall, J. (1986). Attendance behaviour of Antarctic fur seals. In 'Fur seals: maternal strategies on land and at sea'. (Eds R. Gentry and G. Kooyman.) pp. 102-114. (Princeton University Press: Princeton, New Jersey)
- Dowell, S. (2005). Mother-Pup recognition behaviour, pup vocal signatures and allosuckling in the New Zealand fur seal, *Arctocephalus forsteri*. MSc thesis. School of Biological Sciences, University of Canterbury, Christchurch, New Zealand.
- Fea, N. and Harcourt, R. G. (1997). Assessing the use of faecal and regurgitate analysis as a means of determining the diet of New Zealand fur seals. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds M. Hindell and C. Kemper.) pp. (Surrey Beatty & Sons, Chipping Norton: Australia).
- Fowler, C. W. (1987). Marine Debris and Northern fur seals: a case study. *Marine Pollution Bulletin* **18**, 326-335.
- Gales, N., Haberley, B. and Collins, P. (2000). Changes in the abundance of New Zealand fur seals, *Arctocephalus forsteri*, in Western Australia. *Wildlife Research* **27**, 165-168.
- Gentry, R. and Kooyman, G. (1986). 'Fur seals: maternal strategies on land and at sea.' (Princeton University Press: Princeton, New Jersey.)
- Gentry, R., Costa, D., Croxall, J., David, J., Davis, R., Kooyman, G., Majluf, P., McCann, T. and Trillmich, F. (1986). Synthesis and conclusions. In 'Fur seals: maternal strategies on land and at sea'. (Eds R. Gentry and G. Kooyman.) pp. 220-264. (Princeton University Press: Princeton, New Jersey)
- Goldsworthy, S. (1992). Maternal care in three species of fur seal, *Arctocephalus* spp. at Macquarie Island. PhD thesis. Monash University, Melbourne.
- Goldsworthy, S. (1999). Maternal Attendance behaviour of sympatrically breeding Antarctic and Subantarctic fur seals, *Arctocephalus* spp., at Macquarie Island. *Polar Biology* **21**, 316-325.
- Goldsworthy, S., Hindell, M. and Crowley, H. (1997). Diet and diving behaviour of sympatric fur seals *Arctocephalus gazella* and *Arctocephalus tropicalis* at Macquarie Island. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: status, ecology and medicine'. (Eds M. Hindell and C. Kemper.) pp. 151-163. (Surrey Beatty & Sons, Chipping Norton: Australia.)
- Goring, D. G. and Henry, R. F. (1998). Short period (1-4 h) sea level fluctuations on the Canterbury coast, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **32**, 119-134.
- Guinet, C., Goldsworthy, S. and Robinson, S. (1999). Sex differences in mass loss rate and growth efficiency in Antarctic fur seal (*Arctocephalus gazella*) pups at Macquarie Island. *Behavioural Ecology and Sociobiology* **46**, 157-163.
- Guinet, C., Dubroca, L., Lea, M.-A., Goldsworthy, S., Cherel, Y., Duhamel, G., Bonadonna, F. and Donnay, J.-P. (2001). Spatial distribution of foraging in female Antarctic fur seals *Arctocephalus gazella* in relation to oceanographic variables: a

- scale-dependent approach using geographic information systems. *Marine Ecology Progress Series* **219**, 251-264.
- Haase, T. (2004). The determinants of weaning in the New Zealand fur seal. Unpublished PhD. Department of Zoology, School of Life Sciences, La Trobe University, Victoria, Australia.
- Harcourt, R. (1992). Factors affecting early mortality in the South American fur seal (*Arctocephalus australis*) in Peru: density related effects and predation. *Journal of Zoology, London* **226**, 259-270.
- Harcourt, R. and Davis, L. (1997). The use of satellite telemetry to determine fur seal foraging areas. In 'Marine Mammal Research in the Southern Hemisphere Volume 1: Status, Ecology and Medicine'. (Eds M. Hindell and C. Kemper.) pp. 137-142. (Surrey Beatty & Sons, Chipping Norton: Australia.)
- Harcourt, R. G., Bradshaw, C. J. and Davis, L. (2001). Summer foraging behaviour of a generalist predator, the New Zealand fur seal (*Arctocephalus forsteri*). *Wildlife Research* **28**, 599-606.
- Harcourt, R. G., Bradshaw, C. J., Dickson, K. and Davis, L. S. (2002). Foraging ecology of a generalist predator, the female New Zealand fur seal. *Marine Ecology Progress Series* **227**, 11-24.
- Harcourt, R. G., Schulman, A. M., Davis, L. S. and Trillmich, F. (1995). Summer foraging behaviour by lactating female New Zealand fur seals (*Arctocephalus forsteri*) off Otago Peninsula, New Zealand. *Canadian Journal of Zoology* **73**, 678-690.
- Jaquet, N., Dawson, S. and Slooten, E. (2000). Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: foraging implications. *Canadian Journal of Zoology* **78**, 407-419.
- Kirkman, S., Bester, M., Hofmeyr, G., Pistorius, P. and Makhado, A. (2002). Pup growth and maternal attendance patterns in Subantarctic fur seals. *African Zoology* **37**, 13-19.
- Kirkwood, R., Boren, L., Shaughnessy, P., Szteren, D., Mawson, P., Huckstadt, L., Hofmeyr, G., Oosthuizen, H., Schiavini, A., Campagna, C. and Berris, M. (2003). Pinniped-focused tourism in the Southern hemisphere: a review of the industry. In 'Marine Mammals: fisheries, tourism, and management issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 257-276. (CSIRO: Collingwood, VIC, Australia)
- Kovacs, K. M. and Innes, S. (1990). The impact of tourism on harp seals (*Phoca groenlandica*) in the Gulf of St. Lawrence, Canada. *Applied Animal Behaviour Science* **26**, 15-26.
- Kuss, F., Graefe, A. and Vaske, J. (1990). Visitor impact management: a review of research. Report to National Parks and Conservation Association. Washington DC. Vol. 1.
- Lalas, C. and Bradshaw, C. J. (2001). Folklore and chimerical numbers: review of a millennium of interaction between fur seals and humans in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research* **35**, 477-497.
- Lawick-Goodal, H. v. and Lawick-Goodal, J. v. (1970). 'Innocent Killers.' (Collins Ltd.: London.)
- Lea, M.-A. and Hindell, M. (1997). Pup growth and maternal care in New Zealand fur seals, *Arctocephalus forsteri*, at Maatsuyker Island, Tasmania. *Wildlife Research* **24**, 307-318.
- Lunn, N., Boyd, I. and Croxall, J. (1994). Reproductive-performance of female Antarctic fur seals - the influence of age, breeding experience, environmental variation and individual quality. *Journal of Animal Ecology* **63**, 827-840.

- Mattlin, R. (1978a). Population biology, thermoregulation and site preference of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson 1828) on the Open Bay Islands, New Zealand. Unpublished PhD. Department of Zoology, University of Canterbury, Christchurch, New Zealand.
- Mattlin, R. (1978b). Pup mortality of the New Zealand fur seal (*Arctocephalus forsteri*). *New Zealand Journal of Ecology* **1**, 138-144.
- McNab, A. and Crawley, M. (1975). Mother and pup behaviour of the New Zealand fur seal, *Arctocephalus forsteri* (Lesson). *Mauri Ora* **3**, 77-88.
- Miller, E. (1971). Social and thermoregulatory behaviour of the New Zealand fur seal. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
- NIWA (2005) The Climate Update. **74**, pp. 4. Wellington, New Zealand.
- Noris, K., Goodman, R., Villa-Ramirez, B. and Hobbs, L. (1977). Behaviour of California gray whale (*Eschrichtius robustus*) in the South Baja, California, Mexico. *Fisheries Bulletin* **75**, 159-172.
- Ono, K., Boness, D. J. and Oftedal, O. (1987). The effect of a natural environmental disturbance on maternal investment and pup behaviour in the California sea lion. *Behavioural Ecology and Sociobiology* **21**, 109-118.
- Ono, K. and Trillmich, F. (1991). 'Pinnipeds and El Niño, responses to environmental stress.' (Springer-Verlag: London.)
- Orians, G. and Pearson, N. (1979). On the theory of central place foraging. In 'Analysis of Ecological Systems'. (Eds D. Horn, E. Stairs and R. Mitchell.) pp. 155-77. (Ohio State University Press: Columbus, Ohio, USA)
- Phillips, A. and Stirling, I. (2000). Vocal individuality in mother and pup South American fur seals, *Arctocephalus australis*. *Marine Mammal Science* **16**, 359-616.
- Reeves, R. R., Stewart, B. and Leatherwood, S. (1992). 'The Sierra Club Handbook of Seals and Sirenians.' (Sierra Club Books: San Francisco, California.)
- Robinson, S., Goldsworthy, S., vandenHoff, J. and Hindell, M. (2002). The foraging ecology of two sympatric fur seal species, *Arctocephalus gazella* and *Arctocephalus tropicalis*, at Macquarie Island during the austral summer. *Marine and Freshwater Research* **53**, 1071-1082.
- Schulz, T. and Bowen, W. (2004). Pinniped lactation strategies: evaluation of data on maternal and offspring life history traits. *Marine Mammal Science* **20**, 86-114.
- Simmons, D., Horn, C. and Fairweather, J. (1998). Summertime visitors to Kaikoura: characteristics, attractions and activities. Report to Lincoln University. Tourism Research and Education Centre Report, Report No. 3. Lincoln, New Zealand.
- Smith, A. W., Vedros, N. A., Akers, T. G. and Gilmartin, W. G. (1978). Hazards of disease transfer from marine mammals to land mammals: review and recent findings. *JAVMA* **173**, 1131-1133.
- Snyder, R. L. (1976). 'The biology of population growth.' (Croom Helm Ltd.: London.)
- Stirling, I. (1971). Studies on the behaviour of the South Australian fur seal, *Arctocephalus forsteri* (Lesson) II. adult females and pups. *Australian Journal of Zoology* **19**, 267-273.
- Taylor, R., Barton, K., Wilson, P., Thomas, B. and Karl, B. (1995). Population status and breeding of New Zealand fur seals (*Arctocephalus forsteri*) in the Nelson-northern Marlborough region 1991-94. *New Zealand Journal of Marine and Freshwater Research* **29**, 223-234.
- Thompson, P. J., Cousins, D. V., Gow, B. L., Collins, D. M., Williamson, B. H. and Dagnia, H. T. (1993). Seals, seal trainers and Mycobacterial infection. *American Review of Respiratory Diseases* **147**, 164-167.

- Tierney, M., Hindell, M. and Goldsworthy, S. (2002). Energy content of mesopelagic fish from Macquarie Island. *Antarctic Science* **14**, 225-230.
- Trillmich, F. (1986). Attendance behaviour of Galapagos fur seals. In 'Fur seals: maternal strategies on land and at sea'. (Eds R. Gentry and G. Kooyman.) pp. 168-185. (Princeton University Press: Princeton, New Jersey).
- Trillmich, F., Ono, K., Costa, D., DeLong, R., Feldkamp, S., Francis, J., Gentry, R., Heath, C., LeBoeuf, B., Majluf, P. and York, A. (1991). The effects of El Nino on pinniped populations in the Eastern Pacific. In 'Pinnipeds and El Nino, responses to environmental stress'. (Eds K. Ono and F. Trillmich.) pp. 247-270. (Springer-Verlag: London)
- Tryland, M. (2000). Zoonoses of arctic marine mammals. *Infectious Disease Review* **2**, 55-64.
- Villee, C. A., Walker, W. F. and Barnes, R. D. (1984). 'General Zoology.' (Saunders College Publishing: New York.)

Acknowledgements

Many people have helped make this thesis possible on a number of levels. Because I have so many people to thank I have tried to break this process into the major areas of support. My sincere apologies if I have forgotten to name anyone. The groups and names that follow are not in any specific order.

Logistics

Many thanks to University staff and technicians who have helped in a variety of ways; from answering questions, helping to find and organize gear, building things and helping me with histology slides: Nicole Lauren-Manuera, Joanne Burke, Jan MacKenzie, Graeme Bull, Bruce Lingard, Gavin Robinson, Linda Morris, and Nick Etheridge.

Special thanks also to Jack Van Berkel for group logistics, mapping and sea temperature data.

Thanks also to Nicki Hutchison for her hospitality and allowing us access to Horseshoe Bay by land. And thank you to Gene Harper for showing me the Te Oka Bay seals and setting me up with access there. Thanks to Alistair Hutt and Robin Burleigh of DOC Akaroa for your assistance in setting me up with Nicky and Gerald for the Banks Peninsula colonies.

Field assistants

Okay...this is where I am bound to miss some people. I have many field assistants, without whom this work would not have been possible. Some helped for a day, a week, a month, some for a whole season and others for all four (MIRT – Minority International Research Training crew listed first followed by colleagues within the main crew sections for each year):

2001/2002 –

The main crew: Kimmy, Jodi, Jose, Melissa, Karin, Ewart, Tanya, Bridget, Michelle, Chris and Abi

Extra helpers: Shelley, Maxine, Heather, Aaron, Bruce, Louise, Victoria, Norman & Jo, Sharyn & Jason, Spencer, Mark (Shark), Sabine, Kathryn, Paul, and Patrice.

2002/2003 –

The main crew: Andrew, Maria, Art, Nicole, Michelle, Sacha, Bridget, Mel, Cathy & Tanguy, Chris and Abi

Extra helpers: Christina, Bridget, Brian, Robert

2003/2004 –

The main crew: Genevieve, Catherine, Oli, John & Leona, Mel, Sacha, Chris and Abi

Extra helpers: Lauren, Margee, Warrick, Sleiman, Ryan, Merrin, David, Bridget, Tracy, Misty, Mark (Shark), and most of Canterbury's Marine Ecology Research Group (MERG) – Kim, Katie, Mark, Robyn, Stacie and Sheba.

2004/2005 –

The main crew: Christina, Rachel, Sandra, Sacha and Chris.

Extra helpers: Katrina, Canterbury University's Molecular Ecology Lab – Maureen, Glenda, Manu and Ange, again the MERG group – Kim, Katie, Anneke, Stacie, Robyn and Sheba, and both dads this time – Robert and David.

Specific advice

Thanks to all of the following for advice from email correspondence to devoting your time and expertise on stats, histology, pathology, microbiology, and carrying out post-mortems: Ian Wilkinson, Hugh Best, Simon Childerhouse, Rob Harcourt, Simon Goldsworthy, Corey Bradshaw, Rochelle Constantine, Charles Littnan, Mike Hickford, Jennifer Brown, Raphael Didham, Bruce Robertson, Bernd Würsig, Joanne Connolly, Pdraig Duignan, Nadine Gibbs, Mana Stratton, and Gareth Jones.

Advisory committee

I have had a wonderful group of advisors encompassing a wide area of expertise thank you all very much: Abi Caudron, Louise Chilvers, Jim Briskie, Robert Jackson.... And of course...

A huge thank you to my senior advisor, Neil Gemmell and his wife, Tamsin Brasher for all of their support through the last six years (the MSc too). Thank you for riding with me through all the ups and downs that a thesis can bring, always inspiring me, believing in me, and for everything you've taught me. I wouldn't have made it here without you.

Funding / Permit support

I have had financial assistance from a variety of organisations that have helped make this research possible:

Canterbury of University Doctoral Scholarship

Whale and Dolphin Adoption Project Funding grants

Minority International Research Training – for finances and field assistant. Thank you, Leo Ortiz, for your huge contribution towards completing this work and to seeing it presented at conferences, as well as some great advice. Thank you, Michelle Wainstein, for your help in selecting field assistants. Thank you both for supporting this project and not only making it possible, but providing me with the ability to acquire more skills than the typical PhD would allow.

Within this section I would like to thank the numerous people from the Department of Conservation that have supported my research in many different ways: Jan White, Ian Wilkinson, Hugh Best, Alistair Hutt, Robin Burleigh, Helen McConnell, Nadine Gibbs, Simon Childerhouse, Rob Suisted and Andrew Baxter.

Of course I cannot forget the Kaikoura field centre staff – Mike, Dave, Keith and Faith! Thanks for your advice, field support, logistical support, gear, putting pups in the freezer, information on historical seal counts, and all the historical mortality data.

Friends & Colleagues –

During the course of this project I have had the wonderful opportunity to work with a number of post-doctoral researchers, fellow PhD and MSc students. Many of whom have become not only mentors and colleagues but also close friends. Thank you all for your help, support, friendship, and in some situations accommodation in Christchurch, Fairlie, Wellington and Palmerston North for lab work.

Abigail Caudron (& Sleiman), Cathy Debier & Tanguy de Tillese, Michelle Wainstein (& Django), Sacha Dowell, Sandra Negro, Melinda Fowler, Tanya Blakely (& Mark), Bridget Keenan (& Brent and flatties – who never minded when Bridget forgot to mention I was coming to stay), Mark Botting, Patrice Irvine, Ximena Nelson, Katrina Hale, Mana Stratton, Nadine Gibbs, Debra Curson, and Ashley & Sylvia James.

Plus all who read chapters of my thesis: My advisors, Chris, Dad, Robyn, Mark, Mel, Anneke, Stacie, Mike, Mana and Bridget.

Family

I seem to have acquired families as I went through this process....

The Keenan Family – Bridget, Brian, Diane, Ursula, and all the animals!

Thank you for opening your home and your hearts, you made getting the Banks Peninsula work done so much easier and so pleasant. Thank you for your interest in the seals and the project and for sharing a bit of Kiwiana with all of our international field assistants. And when things didn't go entirely to plan, thank you for your down-to-earth views that helped me keep things in perspective.

The Muller Family –

Thank you for always being there and always making me feel so much a part of your family. Thank you for your constant support, cutting out pictures and articles from the Herald for me...and David, thanks for helping with field work; fending off males and helping restrain pups when you thought you were coming to Kaikoura for a weeks holiday!

The Boren Family –

Thanks to my parents that sent me over to NZ to study, and then followed me out here! Thanks for always believing in me and for your unconditional support. Dad, thanks for your help in the field, retrieving VHF's, restraining pups, and helping the chain-gang getting pups out of Sacha's cave.

Chris – How do I thank you for everything without writing 100 pages? Thank you for standing by me through thick and thin, for your assistance in the field **EVERY** season (including my MSc), for being a rock when I really needed something to lean on, and brainstorming with me on our daily walks as I was writing up! Thank you for all of your love and support through the years and for always understanding. I love you!

Last, but certainly not least – I couldn't have done it without such an amazing and inspiring study species. Fur seals rule!

Mother, Mother Ocean
I've heard you call.
I wanted to sail upon your waters
Since I was three feet tall.
You've seen it all,
You've seen it all.

I've watched the men who sail you
Switch from sail to steam.
And in your belly, you hold the TREASURES
Few have ever seen.
Most of them Dream.

Most of them Dream.

- *Jimmy Buffett*

