“Hunting between the air and the water: the Australasian gannet (*Morus serrator*)”

A thesis presented in partial fulfilment of the requirements for
the degree of Doctor of Philosophy in Ecology
at Massey University, Auckland, New Zealand

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2012

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

DEDICATION

To my mother Lidia Capuska

To the memory of my father, Emilio Machovsky

To the best possible family I could ever dream of

To my FRIENDS… even some widespread around the world, you are always in my heart

FRONTISPIECE

Australasian gannets (*Morus serrator*) are highly specialised amphibious predators capable of coping with the optical and physiological demands of rapidly transitioning between the air and water interface. Photo cover of Proceedings of the Royal Society B: Biological Sciences 2012, 279 (1745), courtesy of David Raubenheimer.

ABSTRACT

Australasian gannets (*Morus serrator*) are the second rarest member of the seabird group Sulidae. Among the three species of gannets worldwide, they are the only species that regularly breeds in southeastern Australia and New Zealand. Like all gannets, *M*. *serrator* face considerable challenges in foraging, relying on sparsely and patchily distributed pelagic prey, which move in a 3D environment. Whereas most predators are specialise hunters in one media, gannets have to hunt within a complex air-water interface. The aim of the present thesis is to examine the hunting strategies of Australasian gannets, with particular emphasis on how these birds use both aerial and aquatic adaptations to locate and capture prey.

The acquisition of information concerning food sources was analysed using GPS data loggers, field observations and high resolution video footage. I tested the hypothesis that gannets obtain information of food resources from their partners using bill fencing as referential signals analogous to the waggle dance in honeybees (*Apis mellifera*) (Chapter 2). Results did not support this hypothesis but suggested that Australasian gannets use a combination of strategies, probably including memory that facilitates their return to locations where prey was previously captured (Chapter 3) and local enhancement to locate active feeding sites (Chapter 2).

The impact of intraspecific competition for local resources was studied between large (Cape Kidnappers, 7,300 breeding pairs) and small (Farewell Spit, 3,900 breeding pairs) colonies in New Zealand using GPS data loggers (Chapter 3). Results indicated that gannets from the larger colony invested more in foraging (greater foraging times and foraging distances). This is consistent with previous studies of other gannet species, suggesting that *M*. *serrator* experience intraspecific competition for food when living in large colonies.

Pelagic prey are able to evade predation by descending to depths beyond the reach of diving birds. Among the adaptations evolved by gannets for dealing with this challenge is plunge-diving, where the bird uses gravity in the aerial phase of the hunt to gain speed and momentum for descending into the water column. I conducted a fine scaled analysis using videography of the aerial and aquatic phases of this highly specialised hunting strategy. Analysis of the aerial phase (Chapter 4) showed that the initiation of plunge dives are synchronised among members of foraging groups,

suggesting a form of group-level behaviour in which gannets might benefit from the sensory experiences (prey detection) of conspecifics. The analysis also showed that gannets adapt the aerial phase of their dives in presence vs. absence of heterospecific predators. In the aquatic phase (Chapter 5), gannets perform short and shallow V-shaped dives and long and deep U-shaped dives in pursuit of pelagic fish and squid. My findings revealed that gannets adjusted their dive shape in relation to the depth of their prey rather than prey type, as previously hypothesised. Although the maximum number of prey captured per dive by the gannets was higher than previously reported, reaching up to five fish in a single U-shaped dive, the results presented herein suggest that the two dive profiles were equally profitable.

To examine the role of underwater vision in prey capture, I used underwater video footage, photokeratometry and infrared video photorefraction (Chapter 6). Analysis of video footage confirmed that there are two distinct phases in the underwater component of plunge dives in Australasian gannets, an initial phase in which the bird is propelled through the water column by the momentum of the plunge (M phase) and a phase in which it is actively propelled by wing flapping (WF phase). The highest prey capture rate was observed during the WF phase, a result that suggests the use of vision in underwater prey pursuit. I therefore used photokeratometry and video photorefraction to test whether gannets are able to adapt optically in the transition from aerial to aquatic media. My measurements showed that underwater visual accommodation in the gannets was attained within 2 - 3 frames (80 - 120 ms) of submergence, a remarkably short timescale in relation to the optics of most vertebrate eyes.

The preceding chapters demonstrate some highly effective behavioural and sensory capacities used by gannets in foraging. In Chapter 7 I demonstrate evidence of fatal injuries due to collision between conspecifics in plunge-diving Australasian and Cape gannets (*M. capensis*). The analysis also revealed a case of attempted underwater kleptoparasitism, in which a diving bird targeted a previously captured fish in the beak of another gannet. This novel observation suggests a further challenge for hunting gannets, namely to retain prey following the capture.

ACKNOWLEDGEMENTS

It's been a big journey….yes indeed. In the mid-1980s I remember reading an interview of some famous person and they were asking him about his favourite things and particularly about his dreams. Mimicking the interview, I wrote down my favourite things (I remember there were 2 or 3) and the list of dreams I had at that point in time. Believe it or not, one of those was to become a "marine biologist". Here I am 25 years later writing the last pages of my PhD thesis. A lot of water has passed under the bridge… I lost my hair in the process… and to my own amazement, I now speak and write in a different language and I am immersed in a different culture. Nothing can express the joy and pride I feel being able to tick the last dream of that list: 'Become a doctor in science"

"Dreams are not negotiable…they are little treasures in your soul… don't waste them, just enjoy the adventure of making them real."

Gabriel E. Machovsky-Capuska

Zig Ziglar said, "Success occurs when opportunity meets preparation." The success of the achievement of this dream reflects the support of several people. Special thanks to Karen and Sabrina Machovsky, Cristina Negri, Laura Plana and Lilia Sevillano for their hours invested in the development of my bilingual skills. Many thanks to Adrian Voycovich and family, Dr. Simon Thrush, Dr. Judi Hewitt, Dr. Drew Lohrer and the members of the Benthic Ecology Group at NIWA-Hamilton for the opportunity to work with all of you during my early years in New Zealand.

An additional thesis can be written about the people who have unconditionally trusted and supported me in all circumstances. All my gratitude goes to Prof. David Raubenheimer for being an amazing mentor during these years. Through your “open door policy” I have learned several keys to grow and develop my scientific career. Your constant encouragement and the possibility to learn from your personal experience made me the kind of researcher that I am now.

My gratitude is also extended to my co-supervisor Prof. Mark Hauber, for the opportunity to volunteer in his gannet project, for recommending me to David as a PhD candidate and for his constant feedback on improving my manuscripts. Exceptional thanks go to Prof. Gadi Katzir, for our fieldwork and “being on the same page”, for his support and for trusting my innovative ideas. In this highly competitive scientific community, collaborations are the key for success. It has also been a real pleasure to collaborate and learn from Prof. Leon Huynen (Australia), Prof. Bernd Würsig and Dr. Robin Vaughn-Hirshorn (Texas A&M University, USA), Prof. Howard Howland (Cornell University, USA), Dr. Eric Libby and Dr. Karen Stockin (Massey University), Rob Schuckard, David Melville, Pete Gaze and Willie Cook (New Zealand Ornithological Society) and Danny Boulton (Sea Safaris).

Special thanks to my collaborators for helping me to improve early drafts of manuscripts and chapters for the thesis. Karen Stockin and Sarah Dwyer, thank you for your patience with the final proof-reading of the thesis.

This PhD research project would not be possible without the help of so many people. Numerous research assistants volunteered their time during this study (in no particular order): Belinda Bompani, Gaby Beans, Eric Libby, Ticiana Fettermann, Sonja Clements, Idan Shapira, Fabio Piccinato, Gabriela de Tezanos Pinto, Anne-Sophie Boyer, Laureline Meynier, Laura van Zonneveld, Antonio Jalilian, Gary

Greyling, Tina Greenawalt, Emmanuelle Martínez, Karen and Sabrina Machovsky, Stephanie Ismar, Joffre Jouma'a, Anna De Plaa and Julia Melville for assistance in the field. I would also like to highlight the support of Massey University staff from various departments who have assisted with logistics and administration issues during this research project. In particular, Muharram Khoussainova, Vesna Davidovic-Alexander, Antonio Jalilian, Sri Nagappan, Arno Vacher, Gerhard Saayman, Eddie Rodgers, Paul Thornton and Little Jennifer. To the entire Maori liaison team at Massey University, Albany Campus led by Donald Ripia for their advice with Iwi consultations. To all the Iwi from different geographic areas for their support on the DoC research permits.

This research was funded by the Institute of Natural Sciences at Massey University Doctoral Scholarship. Research aspects of this work were funded by Massey University Research Fund; National Geographic Waitt Fund; Massey University International Visitors Research Fund; the Australasian Society of the Study of Animal Behaviour Student Grant; and the Israeli Academy of Sciences. I would also like to highlight the support received from the Department of Conservation (Nelson and Napier Conservancies) for the permission to use the ranger's house during fieldworks, Cape Kidnappers and Ocean Beach Wildlife Preserve, Cape Kidnappers landowners and farm managers that kindly gave admission to their property, Ampro Sales Limited ®, Gift Watch ®, Seal Line ®, Dolphin Explorer for providing the filming platform, Paddy Gillooly of Farewell Spit Ecotours for providing transport to Farewell Spit and the Ecology and Conservation Group at Massey University for providing some field equipment. We thank Danny Boulton and Earth-touch© for loaning some underwater video footage to us.

Mega "abrazo" to all my NZ friends (in no particular order), Adrian Voycovich and family, Eric Libby, Karen Stockin and Mike Corbett, Gabriela Tezanos Pinto and Danny Pauls, Laureline Meynier and "Miguelito" Boulic, Monika Merriman, Sarah Dwyer and Emmanuelle Martinez. For Sarah and Manue, a million thanks for all the good moments spent together at the office and in the field and for those ones that will come. Eric Libby and Karen Stockin, you have been amazing with me and huge thanks for your unconditional support. Additional thanks extended to my colleagues from the different research groups in Building 5 and 86: Nutritional Ecology, Coastal-Marine, Human-Wildlife Interaction and Conservation Ecology.

Final thanks to my wife Karen Machovsky for her constant enthusiasm and support throughout the whole project. I basically found in her the best partner in life and I couldn't do it without her, TAM ADMV "TE AMO MUCHO AMOR DE MI VIDA".

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LIST OF ABBREVIATIONS

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kg	Kilograms
cm	Centimetres
ca.	Approximately
S	South
e.g.	For example
3D	Three dimensional

Chapter 2

E	East
BF	Bill fencing
GPS	Global Positioning System
g	Grams
s	Seconds
h	Hours
mm	Millimetres
CK	Cape Kidnappers
Km	Kilometres
m	Meters
MDC	Maximum distance from the colony
FPL	Foraging path length
TAC	Time away from the colony
S	Speed
CT	Couple time
BF/CT	Bill fencing/ Couple time ratio
BT	Bill touches
C	Pearson correlation coefficient
P	Statistic p value
2D	Two dimensional
DD	Direct departure

LC	Landing near conspecific
S	Splashdown
ICH	Information Centre Hypothesis
GMC	Gabriel Machovsky-Capuska
INS	Institute of Natural Sciences

Chapter 3

FS	Farewell Spit
FT	Flying time
RT	Resting time
SD	Standard deviation
vs.	Versus
SW	southwest
NE	northeast
M	Male
F	Female

Chapter 4

ms	Milliseconds

Chapter 5

MSFA	Multi-species-feeding-associations

Chapter 6

M	Momentum phase of the dive
WF	Wing flapping phase of the dive
D	Defocus measure in dioptres
IR	Infra-Red
F	Dioptric power of a cornea
E	Eccentricity of the light source
A	Distance of the camera to the eye
DF	Dark fraction in the pupil and
R	Pupil radius

LED	Light Emitting Diode
CCD	Charge-Coupled Device camera
p	Pages

Chapter 7

G-G	Gannets colliding with gannets
G-SWH	Gannets colliding with sharks, whales and/or humans
G2M	Gannet found floating dead in the water on the 2nd May
G17M	Gannet found floating dead in the water on the 17th May

Chapter 8

UV	Ultraviolet

GLOSARY

Emmetropia: the situation where parallel rays are focused exactly on the retina and vision is perfect (Chapter 6, Zadnik et al. 2004)

Fundus: the portion of the interior of the eyeball around the posterior pole, visible through the ophthalmoscope (Chapter 6, Jones et al. 2007)

Hyperopia: also called far sightedness, refers to the situation where near objects are seen with difficulty compared to distant objects. Far sightedness is the result of the visual image being focused behind the retina rather than directly on it (Chapter 6, Donahue and Baker 2005).

Local Enhancement: foragers may indirectly locate food patches by observing the foraging behaviour of conspecifics and/or heterospecifics predators (Chapter 2, Thorpe 1963). Once the food source has been located, predators can increase their information on the prey by observing its behaviour as well as that of other predators that are foraging in the area (Chapter 4, Schaller 1963).

Myopia: the state of refraction in which parallel rays of light are brought to focus in front of the retina of a resting eye. Also called near sightedness (Chapter 6, Saw et al. 1996).

Visual accommodation: The ability to focus the eye to see objects sharply at varying distances (Chapter 6, Thewissen and Nummela 2008).

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