

**THE LIFE HISTORY CHARACTERS, REPRODUCTIVE  
CONSTRAINTS AND FORAGING STRATEGIES OF A  
NERITIC SEABIRD, THE CRESTED TERN**

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A thesis submitted in complete fulfilment of the requirements for the Doctor of Philosophy

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October 2009

## **Thesis declaration**

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## Publications

The following publications resulted from research undertaken during candidature and are presented in this thesis with the publisher's permission:

### *Papers*

\* McLeay, L.J., Page, B., Goldsworthy, S.D., Ward, T.M., Paton, D.C., Waterman, M. and Murray, M.D. (2009) Demographic and morphological responses to prey depletion in a crested tern *Sterna bergii* population: Can fish mortality events highlight performance indicators for fisheries management? *ICES Journal of Marine Science*, **66**, 237-247. Oxford University Press ([www.oxfordjournals.org](http://www.oxfordjournals.org)).

\* McLeay, L.J., Page, B., Goldsworthy, S.D., Ward, T.M., and Paton, D.C. (2009) Size matters: variation in the diet of chick and adult crested terns. *Marine Biology*, **156**, 1765-1780. Springer/Kluwer Academic Publishers, Springer Science and Business Media ([www.springeronline.com](http://www.springeronline.com))

McLeay, L.J., Page, B., Goldsworthy, S.D., Paton, D.C. and Ward, T.M (in review) Keeping it in the family: provisioning strategies and the consequences of adult condition on reproductive timing and fitness in crested terns. *Behavioural Ecology*

McLeay, L.J., Page, B., Goldsworthy, S.D., Paton, D.C., Teixeira, C., Ward, T.M. and Burch, P. (in review) Foraging behaviour and habitat use of a short-ranging seabird, the crested tern. *Marine Ecology Progress Series*

### *Reports*

McLeay, L.J., Page, B., Goldsworthy, S.D., Ward, T.M. (2008) Are signals of prey variability present in the demographic characteristics of crested tern (*Sterna bergii*) populations in South Australia? Final Report to the South Australian Wildlife Conservation Fund. Project No 0256. SARDI Research Report Series No 312, Publication No F2008/000964, 15p.

McLeay, L.J. (2009) The flight of the crested tern: quantifying the foraging behaviour of crested terns *Sterna bergii* in South Australia. Final Report to the Nature Foundation of South Australia Inc. SARDI Research Report Series, Publication No F2009/000127-1, 10p.

## Frontispiece

“Science, like all creative activity, is exploration, gambling and adventure. It does not lend itself very well to neat blueprints, detailed road maps, and central planning. Perhaps that's why it's fun” (Simon, 1964).

*and* .....in the words of George Box “All models are wrong, some are useful”



Adult crested tern from Troubridge Island (Photo provided courtesy of Mr Todd Kemper)

## Abstract

This thesis examines the functional relationships between the diet, foraging behaviour and life history traits of crested tern populations in South Australia between 2004 and 2008. Diet analyses indicated that crested terns are a generalist predator on surface-schooling fishes. Clupeiform fish (Australian anchovy *Engraulis australis*, sardine *Sardinops sagax*) comprised a large component of the diet of crested terns. Ontogenetic differences in prey size indicated that adults selected small prey for their chicks during early provisioning but increased the size and rate of prey delivered throughout the breeding season as chicks grew. Adults also selected higher quality prey for their chicks compared to what they consumed themselves. Chick and adult diets may have reflected spatial differences in the species composition of prey assemblages near colonies and a North-South gradient in prey size. I also investigated the provisioning patterns of crested terns and how reproductive timing and adult body condition affect the growth and survival of crested tern chicks. Provisioning rates were related to the daily mass change of chicks, and chick growth was correlated with asymptotic mass, suggesting that prey availability and adult foraging proficiency influences fledgling size. Parental 'quality' affected reproductive performance. Adults with good body condition hatched chicks earlier and early breeding was positively related to hatchling mass, fledgling condition and chick survival. Adults aged <7 years had significantly poorer body condition and hatched their chicks later compared to adults  $\geq 7$  years. However, adult body condition also varied within cohorts, indicating that reproductive performance is affected by phenotypic differences in parental quality. Consequently, the growth of crested tern populations may be most sensitive to the foraging behaviour and reproductive output of high quality adults  $\geq 7$  years old. Disease-related mortality events in 1995 and 1998, which killed  $\sim 70\%$  of adult sardine *Sardinops sagax* biomass, provided an opportunity to assess whether crested tern populations were affected by decreases in prey abundance. Age-specific information collected from adults indicated that chicks reared during poor prey conditions caused by the first sardine mortality event in 1995 exhibited lower rates of recruitment to the breeding colony. Females from cohorts reared <1 year after the end of each sardine mortality event also had smaller morphology compared to other age classes indicating that chick growth was reduced during periods of low sardine abundance. Analyses of foraging behaviour using GPS indicated that adults generally commuted to foraging grounds <40 km from the colony where they accessed prey from warm, shallow, near-surface waters that were relatively high in Chl-*a* ( $> 0.5 \text{ mg}\cdot\text{m}^{-3}$ ). Intra-specific variations in foraging behaviour reflected either prior knowledge of where prey aggregations exist, distinctions in individual niche use driven by the types or sizes

of prey available, and/or alternate behavioural states (self feeding and provisioning). The restricted foraging range of crested terns while breeding may make them sensitive to competition with fisheries that operate within their foraging range. Diet and demographic information collected from crested tern populations may provide ecological performance indicators to enhance conservation strategies for crested tern populations and augment current fisheries management approaches.

## Acknowledgements

It seems appropriate to submit a thesis relating to animal life history strategies and population ecology during the 200<sup>th</sup> anniversary of Charles Darwin's birth. As all who are involved with wildlife research would know, scientific collaboration is much more than the sum of its parts. A countless number of people assisted in bringing this work to fruition. Simon Goldsworthy, Tim Ward and David Paton showed tremendous enthusiasm as supervisors of my research. Thanks to you all for our numerous chats, giving me the free reign to take the research where I wanted and pulling me back to reality when it was required.

Special thanks go to Brad Page, my surrogate co-supervisor. I was always more interested in the prey than the predator before I started this research. You introduced me to the field of apex predator research, and there may be no turning back. I will always remember our first field trip to sunny Point Pearce and your near 'Yabbie' award for our lack of a judgement. Thanks to the Narungga lads for their help in a dicey situation; what goes on tour stays on tour! Brad, your enthusiasm for my research was inspirational throughout my study. I am truly grateful for your help with developing analyses and scientific argument, and for our chats about central place foraging, life history theory and parenthood; that of seabirds and our own.

Sincere thanks to my family and friends, a lot of you who helped me on offshore islands in the heat of a South Australian summer among tern vomit, guano, flies and lice. Although doing a PhD is one of the most rewarding experiences, it can leave less time for other more social activities and I thank you all for your friendship, support and patience with me during times when I was bunkered down writing up.

Thanks to the band of volunteers who accompanied me in the field over the long summer breeding seasons. There were some long trying days catching birds or waiting for them to return to their nests with their newly attached 'bling', and your hard work and enthusiasm are greatly appreciated. The following people assisted research in the summers listed:

2004/05: Derek Hamer, Annelise Wiebkin, Simon Goldsworthy and Brad Page

2005/06: Annelise Wiebkin, Al Baylis, Adam Newman, Paul Rogers, Leslie McLeay, Jane McKenzie, Brad Page, Rupert Mayo and Alex Ivey

2006/07: Leslie McLeay, Graeme McLeay, Hamish McLeay, Mignon McLeay, Gemma French, Jason Nichols, Todd Kemper and Cindy Platt

2007/08: Ken Jones, Rebecca Sheldon, Amity Alexander, Penne Coleman, JJ Brits, Barry Hetherington, Jan Hetherington, Angela Pestell, and Kerry Daly

2008/09: Tom Kaethner, Graeme McLeay and Jenny Bicknell

I thank Max Waterman (AO) and his band of volunteers for kick starting this project in the 1960's through an intensive chick banding program at Troubridge Island and other South Australian colonies. Over 35 000 chicks have now been banded at Troubridge Island alone. This colony now provides a wealth of potential data from which to explore age-related demographic processes and ecological relationships for a long-lived seabird. Long term banding data are rare for seabird populations and without Max's efforts many of the analyses in this thesis could not have been achieved. I also thank Mitchell 'Durno' Murray (deceased) for our frequent chats about crested terns and for his early enthusiasm towards my research.

The analyses undertaken in this thesis could not have happened without 'significant' statistical advice. I thank Paul Burch, Paul Rogers, Brad Page and Damian Fordham for their assistance with number crunching and advice in developing models. I also thank Jason Tanner and Carlos Teixeira for providing habitat and environmental data relevant to Chapter 5. SARDI Aquatic Sciences provided data relating to sardine spawning biomass estimates and commercial sardine landings provided in Chapter 2. I am also grateful to Annelise Wiebkin, Mike Steer and Wetjens Dimmlich for data and/or prey regressions used in Chapter 3.

Special thanks go to Suzanne Bennett our SARDI librarian for putting me onto the latest search engines and collecting the most obscure references when I needed them. I am also indebted to Jason Tanner, Paul Rogers, Peter Fairweather, Scoresby Shepherd, Stephen Mayfield, Luke Einoder, Annelise Wiebkin, Peter Shaughnessy and anonymous referees for providing useful comments on previous versions of chapters included in this thesis.

This study was principally supported through the Australian Government's Fisheries Research and Development Corporation (FRDC) Grants Scheme (PN 2005/031 - Establishing ecosystem-based management for the South Australian pilchard fishery: developing ecological performance indicators and reference points to assess the need for ecological allocations), co-funded by the South Australian Sardine Fishery. I also received financial support from the South Australian Department for Environment and Heritage through the Wildlife Conservation Fund, and the Nature Foundation of South Australia who provided financial



assistance for the purchase of GPS units. All diet sampling and bird handling procedures were carried out under South Australian scientific research permit A24684 and approved by Primary Industries and Resources South Australia (PIRSA) and University of Adelaide Animal Ethics Committees. Banding was undertaken under the Australian Bird and Bat banding scheme (ABBBS) banding authority 2695.

Finally to my partner Mignon and daughter Bonnie. Your love and support was a rock solid foundation throughout this research and helped me make it to the end. Thanks for sharing the ups and downs that are part and parcel of such a large project. Let the good times roll babes!

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