Safeguarding the northern quoll. Can we mitigate cane toad impacts through conditioned taste aversion?

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Abstract

Australia has the world's worst record of mammal extinctions. Changes to fire regimes, habitat loss and the impacts of invasive species are causal agents; but controlling invaders across landscapes is difficult. In northern Australia, the spread of toxic cane toads (*Rhinella marina*) has caused population declines of the northern quoll *(Dasyurus hallucatus*), a marsupial predator that dies from toad poisoning. Traditional methods have failed to halt the toad invasion, so we need new methods to reduce their impact.

In this thesis, I critically examined whether conditioned taste aversion (CTA) could reduce the impacts of cane toads on northern quolls. Trials on captive quolls confirmed that quolls fed toad meat infused with an emetic (of a substance causing vomiting) subsequently refused to attack live toads. This raised the question of whether we could use CTA *in situ* to train wild quolls to avoid cane toads. This thesis addresses that gap. Firstly, I analysed mark-recapture data to estimate quoll demographic parameters and used a population viability model to determine whether CTA could prevent quoll population extinction. The success of CTA in reducing the probability of extinction was strongly influenced by the baiting design and requires that a high proportion of the population can be trained prior to toad invasion. In addition, cultural transmission of food preferences from mothers to offspring is necessary for CTA to be a successful long-term mitigation strategy.

I developed a bait suitable for field deployment and demonstrated that captive quolls that ingested toad baits generalised their aversion to toads, and that wild quolls readily consumed baits. Importantly, bait uptake by non-target species was negligible. Next, using a BACI design, I carried out a replicated field experiment to determine whether baiting could mitigate the impact of toads. Surprisingly, at control and experimental sites, quoll populations went extinct following toad invasion. To understand this failure, I then determined the optimum level of bait deployment needed to reach my target species. I aimed to improve baiting design outcomes by employing a model that optimised the delivery of CTA, while accounting for the fact that some animals in the population could not be CTA trained.

Overall, my thesis highlights the challenges of implementing a novel technology in complex ecological systems and demonstrates the need for evidence-based data to guide decision makers. In a world experiencing rapid rates of mammalian extinction, novel conservation strategies such as CTA may help us mitigate threatened populations against the serious impacts of invasive species.

Certificate of Original Authorship

I, Naomi Indigo declare that this thesis is submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy in the School of Life Sciences, Faculty of Science, at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualification at any other academic institution. This research was supported by an Australian Government Research Training Program.

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Preface

The main body of this thesis consists of 5 chapters, including four data chapters that I have, or intend to, submit to journals. I have therefore formatted each chapter according to the guidelines of the individual journals. This has caused some minor formatting differences between chapters and some unavoidable repetition in the species description, experimental methods and background information in some of the chapters.

At the beginning of each chapter, I have acknowledged all authors involved, in the same order as they appear in the manuscripts. In all the chapters, I am listed as the first author and was primarily responsible for conceiving, designing and implementing the research and writing the manuscripts.

Approvals and Funding

The study was conducted under Wildlife Conservation Regulation 17 (Permit number: SFO10584), the University of Technology Sydney Animal Care and Ethics Committee (Protocol: 2012-432A), University of Melbourne Animal Ethics Committee (Protocol: 1413369.2) and Department of Parks and Wildlife Animal Ethics Committee (Protocol: AEC 2016_50 and Protocol 2013_37) and AVPMA Permit number: PER82262. Funding was provided by Australian Wildlife Conservancy supporters, the Australian Research Council (LP150100722 and FT160100198 (to Ben Phillips and Jonathon Webb), The Holsworth Wildlife Research Endowment (to Naomi Indigo), The Australian Wildlife Society- Wildlife

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Chapter contributions

Chapter 2

Indigo, N., J. Smith, J. Webb, and BL. Phillips (2019) Cultural and genetic transmission of a conditioned taste aversion lesson can interact to prevent extinction: Cane toads and northern quolls in Australia. Manuscript in preparation for peer-review.

Indigo N Conceived and developed ideas, conducted data analysis and wrote manuscript.

*Smith J D*eveloped ideas, coordinated field-experiments, and assisted with manuscript preparation.

Webb JK Assisted in development of ideas, analysis and manuscript preparation.

Phillips BL developed ideas and contributed to experimental design, contributed to analysis, writing of the model and manuscript preparation.

Chapter 3

Indigo, N., J. Smith, J. Webb, and BL. Phillips (2018) Not such silly sausages: Evidence suggests northern quolls exhibit aversion to toads after training with toad sausages. Published by *Austral Ecology* on 8th Febuary 2018.

Indigo N Conceived and developed ideas, executed field experiments, conducted data analysis and wrote manuscript.

Smith J Developed ideas, assisted with coordination of data collection and assisted with manuscript preparation.

Webb JK Developed ideas and assisted with manuscript preparation.

Phillips BL Developed ideas, contributed to experimental design, data analysis and manuscript preparation.

<u>Chapter 4</u>

Indigo. N, J. Smith, E.Kelly, J. Webb and B.L. Phillips (2019) Unpleasant surprises: a full field trial of a promising conservation action suggests it will not work. Manuscript in preparation for peer-review.

Indigo N Conceived and developed ideas, executed data analysis, writing of model, experiments and wrote manuscript.

Kelly, E Conceived and developed ideas, executed data analysis, experiments and wrote manuscript presented in the appendix.

*Smith J D*eveloped ideas, assisted with coordination and collection of data in the field, and assisted with manuscript preparation.

*Webb JK D*eveloped ideas and assisted with manuscript preparation.

Phillips BL developed ideas, contributed to experimental design, conceived and wrote data analysis model and assisted with manuscript preparation.

<u>Chapter 5</u>

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Indigo N Conceived and developed ideas, executed data analysis, field-experiments and wrote manuscript.

*Smith J D*eveloped ideas, assisted with coordination and collection of data in the field, and assisted with manuscript preparation.

*Webb JK D*eveloped ideas and assisted with manuscript preparation.

Phillips BL developed ideas, contributed to experimental design, conceived and wrote data analysis model and assisted with manuscript preparation.

Explanation of Terms

Conditioned taste aversion is the process whereby an animal associates the taste or smell of food with adverse gastrointestinal effects (such as malaise or emesis) post-ingestion, and subsequently avoids consuming that food (Garcia, Kimeldorf et al. 1955, Baker, Ellwood et al. 2005).

Referent food is the food item (prey) which an animal becomes averse to.

Bait is a mimic of the referent food paired with a noxious compound or CTA agent (Cohn and MacPhail 1996).

CTA agent is a toxic compound that evokes an adverse post-ingestion effect such as malaise or emesis. CTA agents are required to create a conditioned aversion to an odour or taste of a referent food (Baker et al. 2005, Cagnacci, Massei et al. 2005).

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