Controlling invasive predators at a national scale.

Anthony Davidson

February 2019

Table of Contents

[Overview 2](#_Toc40427822)

[This thesis generates: 2](#_Toc40427823)

[Introduction 2](#_Toc40427824)

[Reproducible framework 3](#_Toc40427825)

[[Davidson2020-Reproducibility] 3](#_Toc40427826)

[Literature review 3](#_Toc40427827)

[[Davidson2020-Invasive species database] 3](#_Toc40427828)

[Case studies 4](#_Toc40427829)

[Beech Forests 4](#_Toc40427830)

[[Davidson2020-Beech-forests] 4](#_Toc40427831)

[Mixed Podocarp forests 4](#_Toc40427832)

[[Davidson2020-MPD-forests] 4](#_Toc40427833)

[Discussion 4](#_Toc40427834)

[[Davidson2020-PFNZ2050] 5](#_Toc40427835)

Throughout my candatiture I have developed my thesis while simulationously writing a series of computationally reproducible pipelines (packages and repostories; 3) that faciliate the sound curation, analysis and communication of datasets collected for large-scale pest control programs *[Davidson2020-Reproducibility; Invasive species database]* 6. I use this framework to address the “unexpected” outcomes of predator removal in two case studies *[Davidson2020-Beech-forests\* 5.1; \*MPD-forests]* 5.2. I fit different state-space models to account for the underlying demographic processes of increased complexity. I use New Zealand PFNZ 2050 “appollo shot” to demostrate the applicability of this reproducible method to support citizen science and community driven predator control *[Davidson2020-PFNZ2050]* 6.

# Overview

The overarching aim of this PhD is to examine the role of predation, competition and resource flow in regulating invasive mammal populations in NZ forests.

I have done this by constructing ecological models that describe the population dynamics of interacting invasive species in New Zealand forests. I will use the understanding derived from these models to predict the effects of management manipulations and reduce the likelihood of unanticipated outcomes. Aligning this ecological research with good research practice that insures the results are reproducible and replicate by allowing open access to statistical code and analysis.

This research can then be used support other forecasting models to estimate the likely effects of species removals on the objectives set by the government of New Zealand under “Predator Free New Zealand 2050. In this thesis I will use observed data to build ecosystem models that allow researchers to directly quantify the interactions among invasive species (Peng 2015).

## This thesis generates:

* A reproducible and scalable research database for invasive mammals in NZ.
* Advanced in ecological models that incorperate both the theoretical models and observational data (King 2012).
* Interactive tools to develop understanding and application of Bayesian Hierarichal Models for conservation managers and citizen researchers alike.

# Introduction

Invasive species are regarded to have large impacts native species globally (Doherty et al. 2016). Meta-analysis highlight the unexpected impacts of not monitoring and account for dynamic changes in both species interactions and enviromental changes (Tompkins and Veltman 2006; Caut, Angulo, and Courchamp 2009). Under these conditions, repeatabilty and computational reproducibility are vital aspects to the development of this research (Buerkle and Mercer 2019).

# Reproducible framework

This chapter creates a workflow that allows the ability to access and use the invasive species database in a reproducable way. I take the exisiting research analysis to build a reproducible research synthesis database of the theoretical relationships proposed in over 100 years of conservation research in NZ (e.g.  (Ruscoe, Goldsmith, and Choquenot 2001; Ruscoe et al. 2005; Tompkins and Veltman 2006; Holland et al. 2015; King 1983).

## [Davidson2020-Reproducibility]

**Title:** *Dealing with Reproducibility: Why and how to make a reproducible workflow for invasive species research in New Zealand*

**Abstract:** Science is currently undergoing a “Reproducibility crisis” (Baker and Penny 2016) but the tools and methods to ilimate certian aspects of this crisis with respect to computating software and platforms used to conduct this research. I apply novel reproduciblity measures throughout this thesis to replicate theoretical processes and fit observed data to these models to provide a framework that can account for dynamic changes in observd outcomes of predator control.

**Status:** Frameworks working…need to write up.

**NOTE:** This is already part of a standard literature review and if this does not get any further than that it is a bonus.

# Literature review

I estimate the effects of predator control from these models but addionationally provide a reproducible workflow in systems with and without stoat control, varying control methods and differences in resources flow between these systems (Chapter Four).

## [Davidson2020-Invasive species database]

**Title:** *A database (DB) for invasive species in New Zealand (NZ)*

**Abstract:** Creating a database of research to understand the current knowledge of observation and/or population level demographics of New Zealand invasive species.

**Status:** Developing off Walker et al 2019. Using dataspice package to create baseline dataset including Clarke et al 2019 experimental design.

**NOTE:** This is already part of a standard literature review and if this does not get any further than that it is a bonus.

# Case studies

I then apply a Bayesian modelling framework to two case studies, incorperating increased complexity from beech forests (Chapter Two) t mixed forest dynamics (Chapter Three) in NZ forests. Each case study consists of high quality CR datasets. The CR study design allows me to encorperate both the proposed ecological processes (e.g. predation) know to drive populations and the observation error (e.g. estimating population size) from the research synthesis.

## Beech Forests

Compare the importance of bottom-up and top-down processes in regulating invasive species in New Zealand forests.

### [Davidson2020-Beech-forests]

**Title:** Merky forests. What can we expect from stoat control in NZ forests? - Food vs. Predation.

**Status:** [1st draft with Richard](https://www.dropbox.com/s/m5hte0n2vyl1dt2/Davidson_2019_BeechForest_19022019.docx?dl=0)

**Abstract:** This research paper clarifies the discrepancy between two previous modelling papers; both suggesting that mesopredator release of rodents is possible in New Zealand forest systems and; several field studies that have presented limited but conflicting support for increases in mouse abundance following pest control. We used an experimental design to test the differences between the two publications and found that there is no evidence to suggest mice will become more abundant after predator removal. Additional options and WR guidelines can be found here.

## Mixed Podocarp forests

A more complex set of interacting invasive species.

### [Davidson2020-MPD-forests]

**Title:** Merky forests. What can we expect from stoat control in NZ forests? - Food vs. Predation.

**Status:** [Analysis underway](https://www.dropbox.com/s/fm57ns1jndmkmq1/Davidson_2019_mpd_manuscript.docx?dl=0)

# Discussion

The computationally reproducible framework I create and apply in this thesis are a key aspect of achieving PFNZ2050. I explain why this is and apply these new reproduciblity measures to replicate theoretical processes and visualise new data to account for dynamic changes in observd outcomes of predator control. This chapter puts my thesis in the context of global control programs.

## [Davidson2020-PFNZ2050]

**Title:** *Dealing with Reproducibility for invasive species research in New Zealand*

**Abstract:** Science is currently undergoing a “Reproducibility crisis” (Baker and Penny 2016). During the past four years this movement has developed tools and methods to ilimate certian aspects of this crisis with respect to computating software and platforms. The New Zealand goverment also released the PFNZ 2050 innitive in 2016 (cite). Much debate and discussion has come about (“Predator Free 2050: A flawed conservation policy displaces higher priorities and better, evidence‐based alternatives” 2018). Resources and man-power are driven by communities for New Zealands predator-free NZ 2050 to achieve targets. If these predator targets are not repeatable, it will not be possible to scale control to a national, human-inhabited enviroment due to the exessive unexpected outcomes are likely.

**Status:** Frameworks working…need to write up.

**NOTE:** This may not become a publication before I submit thesis however, there could be a good opportunity to extend this paper here: (Peng 2015) with my work as a five year check/advancements… *This could be added to a database as an intervention?*

# References

Baker, Monya, and Dan Penny. 2016. “Is there a reproducibility crisis?” *Nature* 533 (7604): 452–54. <https://doi.org/10.1038/533452A>.

Buerkle, Alex, and Jason Mercer. 2019. “Computational Biology.” [www.uwyo.edu/buerkle/compbiouwyo.instructure.com](file:///C:\PhD\phd-thesis\_book\www.uwyo.edu\buerkle\compbiouwyo.instructure.com).

Caut, S, Elena Angulo, and Franck Courchamp. 2009. “Avoiding surprise effects on Surprise Island: Alien species control in a multitrophic level perspective.” *Biological Invasions* 11 (7): 1689–1703. <https://doi.org/10.1007/s10530-008-9397-9>.

Doherty, Tim S., Alistair S. Glen, Dale G. Nimmo, Euan G. Ritchie, and Chris R. Dickman. 2016. “Invasive predators and global biodiversity loss.” *Proceedings of the National Academy of Sciences of the United States of America* 113 (40): 11261–5. <https://doi.org/10.1073/pnas.1602480113>.

Holland, E Penelope, Alex James, Wendy A Ruscoe, Roger P Pech, Andrea E Byrom, and E Byrom. 2015. “Climate-based models for pulsed resources improve predictability of consumer population dynamics: outbreaks of house mice in forest ecosystems.” *PloS One*, 1–16. <https://doi.org/10.1371/journal.pone.0119139>.

King, Carolyn M. 1983. “The Relationships between Beech (Nothofagus Sp.) Seedfall and Populations of Mice (Mus musculus), and the Demographic and Dietary Responses of Stoats ( Mustela erminea ), in Three New Zealand Forests.” *Journal of Animal Ecology* 52 (1): 141–66.

King, R. 2012. “A review of Bayesian state-space modelling of capture-recapture-recovery data.” *Interface Focus* 2 (2): 190–204. <https://doi.org/10.1098/rsfs.2011.0078>.

Peng, Roger. 2015. “The reproducibility crisis in science: A statistical counterattack.” *Significance* 12 (3): 30–32. <https://doi.org/10.1111/j.1740-9713.2015.00827.x>.

“Predator Free 2050: A flawed conservation policy displaces higher priorities and better, evidence‐based alternatives.” 2018. *Conservation Letters* 11 (6): e12593. <https://doi.org/10.1111/conl.12593>.

Ruscoe, Wendy A, Joseph S Elkinton, David Choquenot, and Robert B Allen. 2005. “Predation of beech seed by mice: Effects of numerical and functional responses.” *Journal of Animal Ecology* 74 (6): 1005–19. <https://doi.org/10.1111/j.1365-2656.2005.00998.x>.

Ruscoe, Wendy A, Ruth Goldsmith, and David Choquenot. 2001. “A comparison of population estimates and abundance indices for house mice inhabiting beech forests in New Zealand.” *Wildlife Research* 28: 173–78.

Tompkins, Daniel M, and Clare J Veltman. 2006. “Unexpected consequences of vertebrate pest control: Predictions from a four-species community model.” *Ecological Applications* 16 (3): 1050–61.