Alien vertebrate risk assessment and invasion pathway modelling

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Abstract

Alien species are a key driver of the ongoing biodiversity crisis. Changing patterns in the number and identity of transported alien species, and recent changes in the importance of different pathways for transporting alien species (e.g., recent decline in the role of acclimatisation societies vs. the increase in importance of the pet trade), means that there is a novel pool of alien species available for introduction. There is a pressing need to evaluate the biosecurity risks posed by these emergent alien species and their pathways. In this thesis, I focussed on unravelling the patterns and processes driving the transport, introduction, and establishment of novel vertebrate taxa (e.g., alien amphibians, reptiles, and fishes) in Australia and the world. Complementarily, I have also developed approaches to support the implementation of early detection activities for emergent alien reptile species.

My results have highlighted the large number of new alien vertebrates being transported around the world, and particularly in Australia. The wildlife trade transports a substantial portion of all alien vertebrates, whereas unintentional pathways (i.e., stowaways) move fewer numbers of alien vertebrates (in terms of species transported). My research found that propagule number, the minimum number of release events of an alien species, is the main predictor of establishment success of self-sustaining reproductive alien populations. My global analysis of the relationship between the trade in Nearctic pet turtles and their establishment success revealed the complexities associated with managing novel pathways. The probability of introduction of a turtle species in a country (release or escape into the recipient environment) relates to the number of turtles imported, whereas the probability of establishment was associated with propagule numbers (number of releases) but not the number of individuals imported. My research on the establishment of alien fishes in Australia demonstrated substantial modern changes in the importance of transport pathways, with the recent rise of the ornamental fish trade as the key source of new alien species. These shifts in the importance of pathways for alien fish transport have also altered the processes governing the establishment success of alien fishes in Australia.

The prevention of the establishment of new alien species is the best course for managing their potential impacts. However, even the best of prevention strategies cannot realistically aspire to be perfect. In order to be successful at preventing new alien species, it is important to implement early detection systems. I have developed and evaluated a quantitative approach for the early detection of alien reptiles on Christmas Island. The results

indicate that large surveying efforts have to be conducted to ensure the absence of new alien reptiles with confidence.

Drawing from the results of my research, I conclude with some suggestions to improve preventive management strategies for alien species. Particularly, I argue in favour of incorporating economic considerations in prevention strategies (e.g., the benefits of early detection activities vs. delayed intervention and eradication), conducting further research into the importance and drivers of different transport pathways, and examining potential management alternatives to species-based risk assessments.

Thesis Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

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I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship (International Postgraduate Research Scholarship /Australian Postgraduate Award).

Pablo García Díaz

Christchurch, June 2017

Acknowledgements

Thus, if my intellectual creativity and mental instability were logically linked
as reflecting the upside and downside of the same genetic and developmental trajectory,
then I best see them together
Robert Trivers, an introductory comment to the chapter *Parent-offspring conflict* in his book
Natural selection and social theory

Aw, you can come up with statistics to prove anything, Kent.
Forty percent of all people know that
Homer Simpson in *Homer the Vigilante*

If we believe there's even a one percent chance that he is our enemy,
we have to take it as an absolute certainty
Bruce Wayne conducts a risk assessment on Superman in
Batman v Superman: Dawn of Justice

I am sucker for rare, threatened, and cryptic vertebrates, and I used to think that studying those species was the most complicated and challenging task in conservation biology. I was wrong. Working on preventing alien species for almost four years has proven to be way more complex than any other thing I have done so far. Amongst other factors, I will highlight two particularly challenging: the pervasive presence of uncertainties (which, I have always been taught are a bad thing but now I understand they are not necessarily so); and the need for using advanced quantitative methods for extracting information from all the noise in the data (you don't learn about this in your undergraduate years). The research presented in this thesis is the result of a process that, overall and in hindsight, has been really rewarding. Especially, my current grasp of how to construct and fit my own models for ecological systems was the main goal that I was pursuing when I decided to move to Adelaide. It took a hell lot of effort to learn new quantitative approaches, but it was worthwhile (or so I choose to think). I have to admit that I'm slightly disappointed in the

Australian fauna, not nearly as dangerous as they like to boast – four years co-habiting with venomous spiders, and chasing highly dangerous elapids and yet I'm still alive.

My PhD candidature has been sometimes tedious and I won't be able to submit my thesis if not for the support, help, and interest of a number of amazing people. I want to thank the support and help of my family, Dolores Diaz, Porfirio Garcia and Jorge Garcia. This work would not have been possible without the support, guidance and mentorship of my supervisors, who often went well beyond the call of duty. Thank you very much, Phill Cassey, Josh Ross, and Andrew Woolnough - it's been fun and I hope you have enjoyed as much as I have. I am very aware of my stubbornness and perhaps even strong character, I acknowledge your efforts in supervising me. J. Virtue was an excellent supervisor during my industry placement with Biosecurity South Australia.

The nature of my research implied compiling and curating data from a range of sources. A lot of people have collaborated providing data for my research, the list would be very long, but I do remember all of you. Nonetheless, I would like to make a special mention to M. Hutchinson, P. Bird, T. Wittmann, E. Smee, T. Prowse, the Office of Law Enforcement (United States Fish and Wildlife Service), and the Department of Agriculture and Water Resources (Australian Government) for their important contribution supporting my data-collection and curation efforts.

C. Ayres, M. Vall-llosera, M. Lurgi, K. Wells, D. Ramsey, V. Arevalo, T. Prowse, T. Buckmaster, S. Delean, M. Christy, and J. Virtue also deserve a special shoot out for their genuine interest in my work (including discussing my research with me), which has improved my work quite a lot. Also, thanks for your friendship and interest in going birdwatching and 'snaking' with me. The research presented in Chapter 6 (surveillance for detecting alien reptiles in Christmas Island), was a bit complex in several dimensions - it would not have been possible without the collaboration and support provided by the all the staff of the Christmas Island National Park, the Christmas Island Natural Resource Management Board, and the Department of Agriculture and Water Resources (Indian Ocean). The research on Christmas Island was conducted under permit number '*CIN_2015_5'* (Christmas Island National Park, Director of National Parks, Australian Government) and a '*Licence to undertake research activities on regulated crown land*'. The research was approved by the University of Adelaide Animal Ethics Committee (approval number '*S-2014-155*'). I want to acknowledge all my co-authors, listed in each chapter, the research presented here has been possible thanks to your collaboration. Thanks to all my colleagues and friends in Australia and Spain for making the process of a PhD candidature a bit less painful.

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In preparing this final version of my PhD thesis, I want to acknowledge the revisions of the two examiners, Dr Robert Reed and an anonymous examiner. Their comments and suggestions helped me improve this thesis.

Repeating the words in the Thesis Declaration, just in case, I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship (International Postgraduate Research Scholarship /Australian Postgraduate Award). Part of the research presented here used computing services provided by eRSA to the Invasion Ecology Group (University of Adelaide).

Concluding this section - to cold, nice Aussie beer! Outstanding mention to Coopers Pale Ale, Little Creatures, and Fat Yak Pacific Ale, for their role in inspiring me, my ideas, and my writing. (This statement is not, by any means, an admission of alcoholism)