

Why does Chytridiomycosis drive some frog populations to extinction
and not others? The effects of interspecific variation in host
behaviour.

A thesis submitted by
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in December 2006

for the degree of Doctor of Philosophy
in the School of Marine and Tropical Biology
James Cook University

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STATEMENT OF THE CONTRIBUTION OF OTHERS

This thesis was co-supervised by Ross Alford and Lin Schwarzkopf, but also received valuable input from a number of people. Ross Alford contributed in the form of advice on ideas, experimental design, statistical support, editorial assistance, and funded the majority of project costs. Lin Schwarzkopf provided useful comments and editorial assistance on the thesis. Richard Speare, Robert Puschendorf, Robert Jehle, Jérôme Pellet, Lee Skerratt, Andrea Phillott, Bryan Windmiller and Ruth Campbell provided editorial assistance for individual chapters. PCR diagnostic tests for *Batrachochytrium dendrobatidis* were performed by Ruth Campbell at the School of Veterinary and Biomedical Sciences, and Alex Hyatt at the Australian Animal Health Laboratory at CSIRO.

Throughout the thesis, I was supported by an Australian Postgraduate Award. Project costs were funded by the Australian Government Department of Environment and Heritage, the US National Science Foundation Integrated Research Challenges in Environmental Biology grant DEB-0213851, the Australian Geographic Society, the Society for the Study of Amphibian and Reptiles, the Peter Rankin Trust Fund for Herpetology and the School of Marine and Tropical Biology at James Cook University.

Thirty-six volunteers assisted for approximately five and a half months in the field; the names of which are listed in the acknowledgements.

ACKNOWLEDGEMENTS

Thank you to my supervisor Ross Alford, I am proud to have learnt from such a great mind, and to Lin Schwarzkopf, who gave me much valuable, honest advice.

I couldn't have carried out (or lived through) such difficult fieldwork without my volunteers, many of whom became my closest friends. There's nothing that bonds people more than getting stung by an entire nest-full of wasps, fracturing bones, falling off waterfalls or into the deepest parts of the stream head-first, getting bitten by a myriad of ants, leeches, march flies and clouds of mosquitoes, getting tangled in wait-a-while, crawling through prickly thickets on your hands and knees with a six-pronged antenna and counting 'beeps' for hours on end. To Jason Schaffer, Valentine Hemingway, Hugh McGregor, Brady Roberts, Britta Hartmann, Jennifer Parsons, Tim Atwood, Sara Bell, Scott Brady, Elizabeth Booth, Philip Bowles, Alex Castle, Alicia Crawley, Blanche Danastas, Leanne Ezzy, Matthew French, Tamsyn Garby, Lori Grassgreen, Michael Harrison, Thomas Holmes, Lorraine Ketzler, Jaime Kay, Ainslie Langdon, Ben Lester, Braydon Maloney, Rachel Mellor, Ian Milne, Alex Noheda-Garcia, Dean Richards, Kathryn Rose, Fletcher Sewall, Darrel Steely, Benedicte Eftevand, Mirza Kusriini, Cassandra Retchless, Eivind Baste Undheim, and Chip Blackburn, I am eternally grateful.

Thank you also to Richard Speare, Robert Puschendorf, Robert Jehle, Jérôme Pellet, Lee Skerratt, Andrea Phillott, Bryan Windmiller and Ruth Campbell provided editorial assistance for individual chapters, and Ruth Campbell and Alex Hyatt for their PCR expertise.

I was fortunate to have some fantastic accommodation during my field trips. Thank you to Rhodney Dodds and all at Kareeya Hydro Power Station for allowing us stay in the "tea-room" at Tully Gorge, and to all at Babinda State Motel for making us feel like home. Special thanks also to Nick at Babinda 'pub', a true friend.

This research was supported by funding from the Australian Geographic Society, the Society for the Study of Amphibian and Reptiles, the Peter Rankin Trust Fund for Herpetology, the Australian Government Department of Environment and Heritage, and from US National Science Foundation Integrated Research Challenges in Environmental Biology grant DEB-0213851, and was carried out under Scientific Purposes Permits issued by the Queensland Parks and Wildlife Service (WISP01715204 and WITK01715604) as approved by the James Cook University Animal Care and Ethics Committee (A863 and A955).

Thanks to all my friends for putting up with me, particularly during my "solitary-confinement-with-laptop" days. Thank you to Robert Puschendorf.

Finally, thank you to my parents, Tandy and Helen, who have encouraged and supported my scientific pursuits from the onset. Without their love and support I would not be where I am now.

ABSTRACT

Infectious diseases currently pose a great threat to global biodiversity. One of the most alarming wildlife disease to date is chytridiomycosis, a fatal disease of amphibians caused by the pathogen *Batrachochytrium dendrobatidis*. Chytridiomycosis has been implicated in mass mortalities, population declines, and local and global extinctions of many species of amphibians around the world. However, while some species have been severely affected by the disease, other, sympatric species remain unaffected. One reason why some species decline from chytridiomycosis and others do not may be interspecific differences in behaviour, which may affect the probabilities of acquiring and succumbing to infections. Host behaviour can either facilitate or hinder pathogen transmission, and transmission rates in the field are likely to vary among species according the frequency of factors such as physical contact between frogs, contact with infected water, and contact with environmental substrates that may serve as reservoirs. Similarly, the thermal and hydric environments experienced by frogs can strongly affect their susceptibility to chytridiomycosis, so some interspecific differences in the effects of the disease may also be caused by differences in microenvironment use among species.

I examined the potential effects of behaviour on the susceptibility of different host species to declines caused by chytridiomycosis by tracking three species of stream-breeding frogs in northern Queensland, Australia. The species historically co-occurred at many sites in the Wet Tropics, but high elevation (> 400 m) populations of two species declined to differing degrees in association with outbreaks of chytridiomycosis in recent decades, while low elevation populations remained apparently unaffected. The waterfall frog *Litoria nannotis*, declined to local extinction at all known high elevation sites. All studied populations of the green-eyed tree frog *Litoria genimaculata* at high elevation sites declined to low numbers and then recovered. The third species, the stoney creek frog *Litoria lesueuri*, is not known to have experienced population declines even at high elevations.

I used radio telemetry and harmonic direction finding to track frogs at five sites. Surveys lasted 16 days and were conducted in both the cool/dry season and the warm/wet season. The location of each frog was determined once during the day and once at night over the duration of the survey period. At each location, I recorded contact with other frogs, stream water, and other environmental substrates, its three-dimensional position, movement, habitat type, and body temperature. Retreat sites of *L. lesueuri* and *L. nannotis* were also sampled for *B. dendrobatidis*. Harmonic direction finding obtained fewer fixes on frogs but measures of movement and habitat use did not differ significantly between techniques. In total, 117 frogs were tracked: 28 *L. nannotis*, 27 *L. genimaculata* and 62 *L. lesueuri*. Frequency of contact with other frogs and with water was highest in *L. nannotis*, intermediate in *L. genimaculata*, and lowest in *L. lesueuri*. Environmental substrate use differed among species, and *B. dendrobatidis* was not detected at retreat sites. Movement and habitat use also

differed significantly among species. *Litoria lesueuri* moved more frequently and greater distances and was often located away from streams, moving between intact rainforest and highly disturbed environments. *Litoria genimaculata* moved less frequently and shorter distances, and was more restricted to stream environments, occasionally moved large distances along and between streams, but was never located outside of intact rainforest. *Litoria nannotis* remained in streams during the day, did not move large distances along or move between streams, and was always located within intact rainforest.

In addition to tracking data, I designed, tested, and deployed novel physical models to record the thermal conditions experienced by frogs, regardless of cutaneous resistance to water-loss. These models were placed in species-specific diurnal retreat sites; providing profiles integrated over time of the thermal and hydric regimes of the microenvironments experienced by each species.

Microenvironmental conditions experienced by frogs differed markedly among species and seasons. Retreat sites of the most susceptible species, *L. nannotis*, were almost always within the thermal optimum and never above the thermal tolerance of *B. dendrobatidis*, while retreat sites of the least susceptible species, *L. lesueuri*, were commonly above the thermal optimum and thermal tolerance of *B. dendrobatidis*. Hydric conditions were most suitable for *B. dendrobatidis* growth at *L. nannotis* retreat sites.

Species-specific differences in behaviour are therefore likely to have large implications for the susceptibility of species to decline due to chytridiomycosis. This thesis provides the first empirical confirmation that species-specific differences in behaviour are likely to affect the susceptibility in nature of amphibians to chytridiomycosis. The behaviour of the species most susceptible to *B. dendrobatidis* related declines was the most favourable for the transmission, growth and development of *B. dendrobatidis*, while the behaviour of the species least susceptible to *B. dendrobatidis* related declines had the least favourable for its transmission, growth and development. Species-specific differences in the behaviour of frogs in the field may also explain why infected individuals of some species experience rapid mortality in the laboratory, yet are able to carry infections for extended periods in the field. Temporal and spatial variation in microenvironments available to and used by frogs may also explain variation in infection prevalence and host mortality. Information on amphibian behaviour and microenvironmental use may be useful in evaluating the susceptibility to declines caused by chytridiomycosis in species that presently occur in areas without *B. dendrobatidis*.

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