Epidemiology of Chytridiomycosis in Rainforest Stream Tadpoles

A thesis submitted by

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This thesis was co-supervised by Prof. Ross Alford and Dr. Lee Skerratt, but received valuable input from a number of other people. Ross Alford and Lee Skerratt contributed in the form of ideas, experimental design, editorial assistance, statistical advice and provided the majority of funding. Dr. Bryan Windmiller, Robert Puschendorf, Jamie Voyles and anonymous reviewers provided useful advice and suggestions on individual chapters. Dr. Stephen Garland and Ruth Campbell at the School of Public Health and Tropical Medicine, JCU and Veronica Olsen and Dr. Alex Hyatt at the Australian Animal Health Laboratory, CSIRO performed most of the diagnostic PCR tests for *Batrachochytrium dendrobatidis* and contributed experimental design and sampling advice. Bryan Windmiller provided valuable advice on the design of field work and together with Hayley Ricardo and 15 volunteers (listed by name in the acknowledgements) provided logistical and field assistance throughout this project.

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ABSTRACT

Amphibians are declining at an alarming rate and approximately one third of species are currently threatened with extinction. A primary cause of this decline has been the emergence of the disease chytridiomycosis caused by the pathogen, *Batrachochytrium dendrobatidis* (*Bd*). Historically, the extinction of free-living species due to disease is exceedingly rare; however, dozens of amphibians in recent years are feared gone due to *Bd*. For disease to drive extinction, theory indicates a reservoir host is needed to maintain a positive force of infection on susceptible individuals to prevent pathogen "fade out" as the doomed species decline. Accordingly, understanding pathogen dynamics (e.g. prevalence, intensity, transmission, seasonality) within reservoir hosts is critical to properly understand and mitigate species declines and prevent extinction. In the case of chytridiomycosis, no non-amphibian hosts have been found, however, less susceptible adults and amphibian larvae can serve as reservoirs.

While most research has focused on infection in adults, tadpoles probably are important reservoirs; they carry the pathogen and are thought to suffer few negative effects, and most species that have declined are associated with aquatic habitats. To better understand the role tadpoles play in pathogen dynamics I investigated the epidemiology of *Bd* in a tadpole assemblage (consisting of five species) within two rainforest streams over two years. I studied changes in prevalence and intensity of infection over time and how their values were affected by abiotic factors such as temperature and water flow rate, as well as by biotic factors such as the ecology, behaviour and developmental rate of each species. In species with a high prevalence of infection, I studied the response of tadpoles to infection and the effects these responses had on the infection and on their physical condition. A saprobic or long-lived life stage of *Bd* could significantly alter pathogen dynamics among hosts. To investigate this possibility, I developed a method to detect *Bd* in the environment and I used this to sample the stream over the course of one year.

I found significant species-specific variation in space and resource use within the tadpole assemblage; these differences appear to affect susceptibility to infection. Torrent-adapted tadpoles were significantly more likely to be infected than pool-adapted tadpoles. This is likely due to differences in rates of development that affect duration of exposure to *Bd* and differences in behaviour that affect pathogen transmission. Prevalence of infection in torrent tadpoles increased with body size (proxy for duration of exposure) indicating that transmission occurred throughout the year. Prevalence varied seasonally between ~ 25-100% and was driven by a combination of duration of exposure, recruitment of small tadpoles and metamorphosis of large tadpoles. Drivers of infection intensity are less clear, however, body size and water flow are important and in fast-flowing habitats repeat transmission from the external environment appears to be more important than self-reinfection in determining individual infection intensities.

After infection most torrent tadpoles suffered significant tooth loss. This loss severely decreased their ability to feed (in some cases causing apparent starvation), which led to significant decreases in body condition for many individuals. Most tadpoles, however, regrew mouthparts despite continued infection, resumed feeding, and metamorphosed. The relationships between infection intensity, prevalence, tooth loss and body condition indicate that these tadpoles have a measure of tolerance or increased resistance, which may be a result of strong selection pressure exerted by chytridiomycosis.

Environmental sampling for *Bd* revealed that environmental levels are low throughout the year, but may increase when prevalence in tadpoles is highest, suggesting that tadpoles are the major source of *Bd* zoospores in the environment.

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