

*Tasmanian*  
**Chytrid Management**  
*Plan*



Biodiversity Conservation Branch,  
DPIPWE, Tasmania, 2010





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photo: Josh Griffiths

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# INTRODUCTION


## 1.1 The need for a chytrid management plan

*Batrachochytrium dendrobatidis* (hereafter chytrid fungus) is a fungal pathogen that causes the emerging infectious amphibian disease, chytridiomycosis (Berger *et al.*, 1998; Daszak *et al.*, 2003). Chytrid fungus is thought to kill amphibians by invading their skin, which is of critical importance, affecting its structure and function, resulting in electrolyte imbalance and death (Voyles *et al.*, 2009). It has been implicated in significant declines and extinctions globally in all continents where amphibians occur (eg. Berger *et al.*, 1998; Garner *et al.*, 2005; Lips *et al.*, 2006; Skerratt *et al.*, 2007; Weldon *et al.*, 2004). Currently approximately one-third of all amphibian species are considered threatened worldwide (Stuart *et al.*, 2004). The threat that chytridiomycosis poses to global amphibian diversity is unprecedented (Skerratt *et al.*, 2007), and it is now formally recognised by the World Organisation for Animal Health (OIE) as an international notifiable disease. Addressing the global amphibian crises presents a huge challenge and has triggered the development of the Amphibian Conservation Action Plan (IUCN, 2005) which calls for an international response to confront this issue.

In Australia, 32 frog species have recently declined and are now listed as threatened. Eight species have not been seen in the wild since initial observed declines in the late 1980s (Hero & Morrison, 2004). There is substantial evidence that many of these declines are linked to chytridiomycosis (Skerratt *et al.*, 2007). Chytrid fungus is currently distributed along the east coast

from northern Queensland to Victoria and Tasmania, and west to South Australia and the south-west of Western Australia (Speare *et al.*, 2005). The Australian government has recognised chytridiomycosis as a key threatening process under the *Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act 1999)* and a Threat Abatement Plan (TAP) was produced to mitigate the impact of the disease (Department of the Environment and Heritage, 2006). While chytrid fungus eradication is not currently thought possible, the TAP aims to restrict the spread and impact of the pathogen. The five TAP objectives are:

1. to prevent the spread of chytrid fungus into areas where it may impact threatened amphibian species or may lead to amphibian species becoming threatened,
2. to promote the recovery of nationally listed threatened amphibian species that are known or perceived to be threatened by infection with chytrid fungus,
3. to improve the effectiveness and efficiency of the management of infection with the amphibian chytrid through appropriate research and monitoring programs,
4. to share information with Australian state and territory management agencies, researchers and other academics, landholders, relevant industries and the public about the Threat Abatement Plan's actions and their outcomes, and
5. to coordinate management activities effectively.



These national objectives form the basis for the development of a Tasmanian chytrid management plan.

## 1.2 Goals

The overarching goal of this plan is to conserve ecologically resilient Tasmanian amphibian populations by:

- minimising the spread of chytrid fungus into populations of Tasmanian amphibians that are currently free of the disease, and
- decreasing the impact of chytridiomycosis on currently infected amphibian populations.

## 1.3 Scope

The scope of this plan relates to managing the spread of chytrid fungus and minimising its impact on amphibians in Tasmania. Threatened and endemic amphibians are the focus within the plan due to concerns for their conservation status and uniqueness respectively. This plan also broadly considers a number of additional key threatening processes that may affect the host-pathogen dynamic, with potential to result in expression of chytridiomycosis. This plan considers the impact and management of chytridiomycosis over a five year period. The dynamic relationship between host, pathogen and the environment, and ongoing research highlights the need for this plan to be reviewed and adapted as information and priorities change.

The Strategy for Managing Wildlife Disease in the Tasmanian Wilderness World Heritage Area (Philips & Driessen, 2008) identified chytridiomycosis as the highest priority for research and management. This plan is the outcome of a two-year study funded by the Australian and Tasmanian Governments (through NRM North and the Tasmanian Wilderness World Heritage Area fauna program) that investigated:

- distribution and prevalence of chytrid fungus in Tasmania,
- susceptibility of key amphibian species to chytridiomycosis,
- impacts of chytridiomycosis on key amphibian species, and
- methods for surveying amphibian populations.

## 1.4 Target audience

This management plan is primarily intended for land and water managers within government and non-government agencies, but will also be useful to researchers, students and the general public. Its style is intended to make it accessible to any informed individual.

photo: Drew Lee

This section describes a qualitative method to broadly assess the risk that chytridiomycosis poses to each of Tasmania's amphibians. While it is difficult to attribute or quantify relative causality to species' declines or even extinctions, it is clear that non-disease threatening processes such as climate change, habitat degradation, interactions with introduced species, and chemical pollution can alter host-pathogen relationships, resulting in disease expression (Alford & Richards, 1999; Pounds *et al.*, 2006; Vredenburg & Wake, 2007). The complexities of host-pathogen-environmental interactions combined with our limited knowledge of these complexities within the Tasmanian context, makes it difficult to incorporate them into a risk assessment process without an excessive degree of uncertainty. However, non-disease threatening processes should be considered as potential contributors to the expression of chytridiomycosis. An overview of threatening processes affecting Tasmanian amphibians is given in Appendix I.

### 2.1 Information used in the risk assessment

Background information used in the risk assessment includes historic and current knowledge relating to the distribution and ecological traits of amphibians, as well as the current and predicted distribution of chytrid fungus in Tasmania.

#### Tasmania's amphibians

Eleven species of amphibians occur in Tasmania (Littlejohn, 2003) including three endemic and two threatened species. Tasmania's endemic species are distributed largely or entirely within the Tasmanian Wilderness World Heritage Area (TWWHA, Driessen & Mallick, 2003). The Tasmanian tree frog (*Litoria burrowsae*) occurs primarily in buttongrass moorlands in the south and west of the state, primarily within the TWWHA (Littlejohn, 2003). The Tasmanian froglet (*Crinia tasmaniensis*) occurred historically in a variety of habitats across much of Tasmania though its range appears to have contracted significantly; currently it appears to be mostly distributed in the south and west primarily within the TWWHA (Wilson, 2010a, Figure 2). The moss froglet (*Bryobatrachus nimbus*) is a cryptic, terrestrial species. Its distribution is limited to the south-eastern regions of the TWWHA where it occurs in rain forest at sea level to alpine heath at 1,100 m (Ziegeler, 1994).

Two threatened species occur in Tasmania; the green and gold frog (*Litoria raniformis*), and the striped marsh frog (*Limnodynastes peronii*). *Litoria raniformis* is listed as vulnerable under state and national legislation (Tasmanian *Threatened Species Protection Act 1995* and the *EPBC Act 1999* respectively) because of declines probably associated with habitat loss and alteration (Threatened Species Unit, Department of Primary Industries, Parks, Water and Environment, 2001). *Limnodynastes peronii* is listed as endangered under state legislation because it has a restricted Tasmanian



distribution that may be related to habitat loss and alteration (Threatened Species Listing Information Sheet, DPIPW). *Litoria raniformis* occurred historically across a variety of habitats in northern Tasmania including King and Flinders Islands, the east coast and the Hobart region (Tasmanian Natural Values Atlas, NVA, a computerised database maintained by DPIPW). Although *L. raniformis* is persisting across the north coast of the state particularly in the central north, targeted surveys indicate with a high degree of confidence that its range has contracted, particularly in the south around Hobart (Wilson, 2010b, Appendix 2). *Limnodynastes peronii* has a restricted distribution in coastal habitat in the north-east, the central-north and the north-west including King Island (Littlejohn, 2003, Appendix 2).

Historic and current distribution maps for each of the five key species are included in Appendix 2. Relevant life history, behavioural traits and results of laboratory susceptibility trials are summarised in Table 2 below.

### **Chytrid fungus**

#### **distribution and predicted distribution**

Chytrid fungus was first diagnosed in Tasmania in a captive bred frog at the Animal Health Laboratories (AHL), Launceston in 1993 (AHL records) and in wild amphibian populations in 2004 (Obendorf & Dalton, 2006). Though chytrid fungus was not identified in retrospective analyses of museum amphibian specimens (Stewart, 2010) it is likely that wild populations have been infected for some time pre-2004. Since then four studies have investigated chytrid fungus distribution; in urban and rural areas in the south east and central north of the state (Obendorf & Dalton, 2006), within and around the TWWHA (Pauza *et al.*, in press; Ricardo, 2006), and in areas where threatened and endemic species occur (Philips *et al.*, 2010).

Chytrid fungus has now spread across much of Tasmania, particularly to areas associated with human activities and habitation (Obendorf & Dalton, 2006; Pauza *et al.*, in press; Philips *et al.*, 2010). The pathogen occurs at King and Flinders Islands, across the north coast including north-east and north-western areas, and in the Hobart region (Figure 1). Chytrid fungus is largely absent from the TWWHA and the two sites surveyed in the Freycinet Peninsula area appear to be uninfected. The current distribution pattern suggests that anthropogenic involvement in pathogen spread is

likely to be significant (Pauza *et al.*, in press; Phillott *et al.*, 2010). Within infected regions, chytrid fungus is patchily distributed where positive and negative sites often occur adjacent to each other. This heterogeneity in occurrence emphasises the need to mitigate pathogen spread, even within areas where it is widely distributed (Adams *et al.*, 2010).

Both threatened species are distributed entirely within infected areas (Wilson, 2010a, Appendix 2, Figure 1). This highlights the importance of monitoring for long-term effects of chytrid fungus, and implementing effective management actions to minimise the impact of disease.

Whilst chytrid fungus has been found in most areas in Australia where it is predicted to occur (Retallick, 2003), Tasmania still supports naïve endemic amphibian populations in the TWWHA in areas predicted to be highly suitable for pathogen occurrence (Philips *et al.*, 2010, Figure 2). Whilst chytrid fungus has made incursions into the TWWHA associated with roads and the township of Strathgordon, the majority of this area remains uninfected (Pauza *et al.*, in press). This highlights the importance of implementing effective mitigation measures to minimise pathogen spread to at risk naïve endemic amphibian populations within the TWWHA as soon as possible.

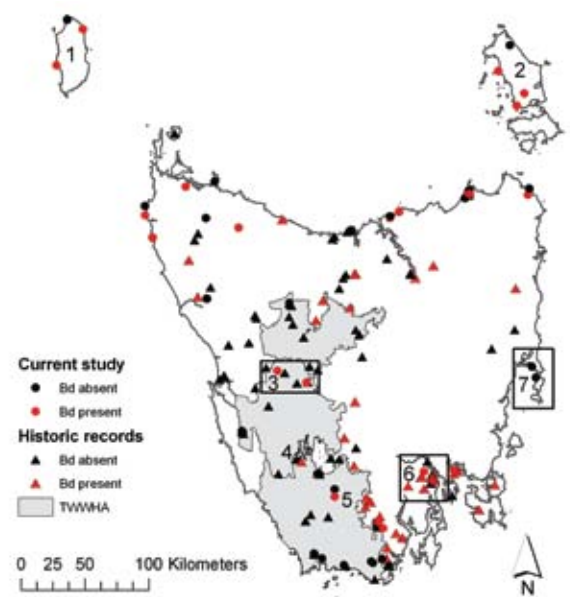


Figure 1. Current distribution of chytrid fungus in Tasmania. Sources: current study from Philips *et al.* (2010), historic records from Obendorf and Dalton (2006), Ricardo (2006) and Pauza *et al.* (in press). 1 = King Island, 2 = Flinders Island, 3 = Lyell Highway, 4 = Strathgordon, 5 = Scotts Peak Dam Road, 6 = Hobart region, 7 = Freycinet Peninsula.

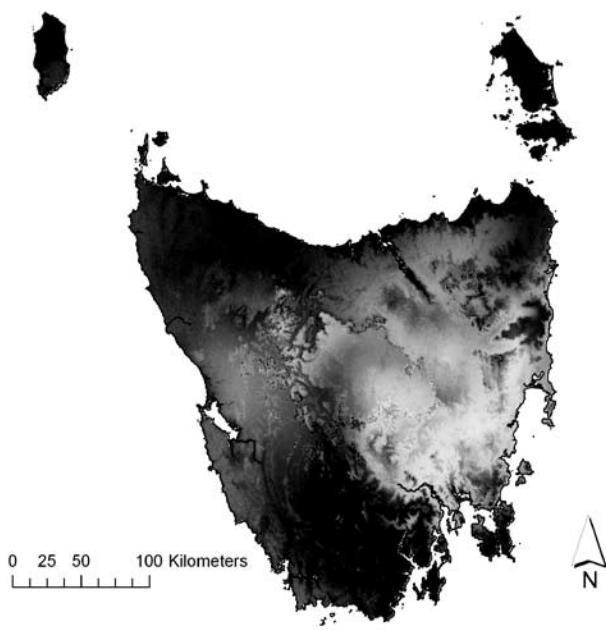


Figure 2. Predicted distribution of chytrid fungus in Tasmania. Probability of chytrid fungus occurrence increases with grey shading. Source: Philips et al. (2010). Note that much of the area with low probability of pathogen occurrence was not sampled.

## 2.2 Risk assessment process

The risk assessment process allows us to broadly rank species in order to direct future research and management. We assess the risk of chytridiomycosis to Tasmanian amphibian species by taking into account the following risk factors:

1. Likelihood of exposure of each species to chytrid fungus by comparing the distribution of each species (Littlejohn, 2003, Appendix 2) and chytrid fungus (Figures 1 & 2),
2. The susceptibility of amphibian species based on laboratory trials,
3. Whether or not the species is known as a host for chytrid fungus, and
4. Other ecological traits of each species which may alter the host-pathogen-environmental relationship.

Each species is given a risk rating (explained in Table 1) based on the current or potential impact of chytridiomycosis on the conservation status of that species (Table 2). The levels of confidence associated with risk ratings will vary as some species have been studied in more detail than others.

Table 1. Explanation of risk rating scores

Risk Rating	Impact on the status of Tasmanian amphibians
Very high	<p>The impact of chytridiomycosis is likely to be <b>extreme</b>, including:</p> <ul style="list-style-type: none"> <li>• A significant broad scale impact on a non-threatened species such that the species is likely to become threatened,</li> </ul> <p>AND/OR</p> <ul style="list-style-type: none"> <li>• A significant broad scale impact on a threatened species such that its conservation status would be <b>worsened</b>, including the potential for extinction.</li> </ul>
High	<p>The impact of chytridiomycosis is likely to be <b>highly significant</b>, including:</p> <ul style="list-style-type: none"> <li>• Local population impacts (the species may become locally extinct or suffer significant declines) on a non-threatened species, with <b>more than one population</b> per species effected,</li> </ul> <p>AND/OR</p> <ul style="list-style-type: none"> <li>• Local population impacts on a <b>threatened species</b>, with a <b>single population</b> per species effected (the species may become locally extinct or suffer significant declines).</li> </ul>
Medium	<p>The impact of chytridiomycosis is likely to be <b>significant</b>, including:</p> <ul style="list-style-type: none"> <li>• Local population impact on <b>one</b> non-threatened species, with a <b>single population</b> per species effected (the species is presumed absent or may suffer significant declines).</li> </ul>
Low	<p>The impact of chytridiomycosis is <b>unlikely to be significant for populations or individuals</b>.</p>

Table 2. Chytridiomycosis risk assessment

Criteria	Conservation status	Species Distribution	Host-pathogen overlap	Susceptibility to disease	Known host in Tasmania	Ecological group	Overall risk rating	Priority for further research / monitoring
<b>Definitions</b>	Threatened species listing under state and/or national legislation.	Geographic range size of target species based on historic and current records of species occurrences.	Overlap in distribution between amphibian species and chytrid fungus incorporating predicted distribution of pathogen.	From laboratory testing.	Positive chytrid fungus infections in the species.	Association with water bodies, life history behavioral traits.	Combines all risk factors to give qualitative assessment.	High or unknown risk species.
<i>Litoria burrowsae</i> Tasmanian tree frog	Not listed.	Endemic to Tasmania. Distribution restricted to the south and west, mainly within the TWWHA.	Most populations naive within the TWWHA which has high probability of pathogen occurrence. May now be absent from chytrid fungus positive sites at Lune River where they were recorded previously.	High mortality in infection experiments.	Positive infections in wild tadpoles.	Permanent and ephemeral ponds.	Very high.	Monitor impact at infected and adjacent uninfected sites.
<i>Litoria raniformis</i> Green and gold frog	Vulnerable state and national legislation.	Once common including King and Flinders Islands, declining since 1970s. Further range contraction particularly in the south around Hobart.	Persisting in infected areas across the north coast, particularly in the central north.	Low mortality in infection experiments.	Positive infections in wild tadpoles and adults.	Permanent ponds, Basks in sun.	Medium.	Assess long term impacts at infected sites.
<i>Limnodynastes peronii</i> Striped marsh frog	Endangered state legislation.	Restricted distribution in the north-east, the central-north and the north-west including King Island.	Total overlap between distribution and infected areas.	Some mortality observed in infected individuals.	Positive infections in wild tadpoles and adults.	Permanent ponds.	Medium.	Low intensity monitoring needed at infected sites.
<i>Litoria ewingi</i> Brown tree frog	Not listed	Widespread including King and Flinders Islands.	Widely distributed and abundant in infected areas. May be a reservoir species.	Unknown.	Positive infections in wild tadpoles and adults.	Permanent and ephemeral ponds.	Low.	
<i>Crinia signifera</i> Common froglet	Not listed.	Widespread including King and Flinders Islands.	Widely distributed and abundant in infected areas. May be a reservoir species.	Unknown.	Positive infections in wild tadpoles and adults.	Permanent and ephemeral ponds.	Low.	
<i>Limnodynastes dumerilii</i> Banjo frog	Not listed.	Widely distributed in east and north including King and Flinders Islands.	Widely distributed and abundant in infected areas. May be a reservoir species.	Unknown.	Positive infections in wild tadpoles and adults.	Permanent ponds.	Low.	

<b><i>Limnodynastes tasmaniensis</i></b> Spotted marsh frog	Not listed.	Widely distributed in east and Flinders Island.	Occurs in infected areas.	Low mortality in infection experiments.	Unknown.	Permanent and ephemeral ponds.	Low.	Susceptibility trials. Monitor wild populations particularly where disease is thought to be emerging.
<b><i>Crinia tasmaniensis</i></b> Tasmanian froglet	Not listed.	Endemic to Tasmania with historic wide spread distribution. Range has contracted - currently persisting in south and west largely within the TWWHA.	Recent declines from chytrid infected areas. Currently persists in uninfected areas largely within the TWWHA which has high probability of pathogen occurrence.	Unknown.	Unknown.	Ephemeral ponds.	Unknown.	Targeted monitoring Hartz Mtn population.
<b><i>Bryobatrachus nimbus</i></b> Moss froglet	Not listed	Endemic to Tasmania with restricted distribution in south-eastern regions of the TWWHA.	Distribution is limited to uninfected areas with high probability of pathogen occurrence. A chytrid infected site is only 2kms away from the Hartz Mtn population.	Unknown.	Unknown.	Terrestrial.	Unknown.	
<b><i>Geocrinia laevis</i></b> Smooth froglet	Not listed	Historically distributed in north (including King Island) and centrally.	Historic range overlaps with chytrid infected areas. No known change in range.	Unknown.	Unknown.	Eggs develop to tadpole stage on land. After flooding tadpoles become aquatic.	Unknown.	
<b><i>Pseudophryne semimarmorata</i></b> Southern toadlet	Not listed.	East including Flinders Island.	Historic range overlaps with chytrid infected areas. No known change in range.	Unknown.	Unknown.	Eggs develop to tadpole stage on land. After flooding tadpoles become aquatic.	Unknown.	
<b>References</b>	Tasmanian Threatened Species Protection Act 1995, EPBC Act 1999.	(Littlejohn 2003; Wilson 2010; NVA).	(Littlejohn 2003; Phillips et al. 2010; Pauza et al. in press; NVA). Note - Murray et al. (in prep) predicts the whole of Tasmania to have high average environmental suitability for chytrid fungus.	(Voyles et al., 2010; Woodhams et al., 2007).	(Obendorf & Dalton, 2006; Pauza et al., in press; Phillips et al., 2010).	(Littlejohn, 2003).		



# 3

## MONITORING TO INFORM TRIGGERS FOR MANAGEMENT INTERVENTION AND EMERGENCY RESPONSE

photo: Annie Philips

Once species have been prioritised through the risk assessment process, targeted monitoring of both high risk amphibian populations and chytrid fungus are necessary to identify triggers for an appropriate management response.

### 3.1 Monitoring high risk amphibian populations and chytrid fungus

#### Monitoring key amphibian species presence and abundance

Repeated call surveys can provide presence and absence status at specific sites, and site occupancy data over larger scales for species identified as requiring ongoing monitoring (Table 2). This method can also provide an index of abundance (by recording the number of calling males) although mark recapture methods should be used when a more accurate abundance estimate is required. Call survey detection probabilities have been established for nine of the 11 Tasmanian amphibian species (Wilson *et al.*, 2010). Detection probabilities for each species can be used to determine the number of times a site needs to be surveyed during the most detectable period (usually spring / summer) to be 90% confident of species absence. For most species, 20 minute nocturnal surveys are optimal over 2-9 nights (Wilson *et al.*, 2010). Detection probabilities can be improved by incorporating visual surveys for frogs and tadpoles, and in some cases by using call playback techniques (Wilson *et al.*, 2010).

#### Monitoring chytrid fungus presence and prevalence

Presence and prevalence of chytrid fungus is determined by swabbing tadpole mouthparts and/or adult frogs, which are then analysed using Taqman real-time PCR assay (Hyatt *et al.*, 2007). Individuals should be selected randomly for sampling within a site. The sample size depends on an estimation of the prevalence of chytrid within the population (see Philips *et al.* (2010) for prevalence in Tasmania), the sensitivity and specificity of the PCR test, and the confidence limits (set at 95% by convention), (Skerratt *et al.*, 2008).

### 3.2 Possible population responses to disease emergence

By considering the possible responses that high risk naïve and infected populations may have to chytrid fungus, we can pre-determine what level of response is appropriate and feasible. This process needs to be adaptable as information and priorities change. Possible responses to disease emergence include:

1. No detectable decline - Under this scenario chytrid fungus introduction does not result in the manifestation of chytridiomycosis and therefore, has no obvious impact on amphibian populations. Example: *Rana catesbiana* (Daszak *et al.*, 2003).
2. Rapid decline with population recovery - An outbreak of chytridiomycosis causes a mass-mortality event reducing species abundance but the host species makes a recovery to previous population numbers. Example: *Litoria genimaculata* (McDonald *et al.*, 2005).



3. Rapid decline with slow ongoing decline where population remains depressed - An initial outbreak of chytridiomycosis causes a rapid decline followed by sporadic mortality events. Amphibian populations are unable to recover to previous population numbers and are possibly at risk of extinction due to other threatening processes and/or stochastic events. Example: *Litoria pearsoniana* (Murray *et al.*, 2009).
4. Rapid decline to extinction - The introduction of chytrid fungus causes high levels of mortality in a species/population that has a restricted distribution

and possibly behavioural characteristics (i.e. aggregating for breeding) that favour transmission - recovery from the initial chytridiomycosis outbreak is unlikely. Example: *Taudactylus acutirostris* (Schloegel *et al.*, 2006).

As scenarios 2-5 all begin with rapid species declines after disease emergence, high intensity monitoring is required until the ongoing population response and effectiveness of management regimes have been determined. The management options outlined in Table 3 below are described in more detail in the next section.

Table 3. Triggers for management intervention in different scenarios on a scale of increased intervention and cost. Note any scenario at a high risk site (eg. entry point to TWWHA) or a remote site with high risk species or high amphibian diversity (e.g. Melaleuca, Birches Inlet) may increase level of intervention. See next section for descriptions of management options.

Possible responses of amphibian populations to chytrid fungus	Least intervention →				Emergency intervention	
	Ongoing low intensity monitoring	Ongoing high intensity monitoring	Targeted biosecurity	Quarantine	Treatment <i>in situ</i>	Establish insurance populations
1. No detectable decline after chytrid fungus emerges	×					
2. Naïve, high risk population adjacent to an infected population		×	×			
3. Rapid decline with population recovery		×				
4. Rapid decline with slow ongoing decline where population remains depressed		×			×	
5. Rapid decline towards extinction		×	×	×	×	×

# 4 ACTION PLAN



photo: Jamie Voyles

The sections below describe options currently available to manage the spread of chytrid fungus and the impact of chytridiomycosis. Chytrid management strategies are currently a focus for worldwide research so actions presented in this plan will need to be adapted and modified as new information becomes available and priorities change.

Amphibian species considered to be at very high, high or medium risk from the impact of chytridiomycosis (Table 2) are prioritised within the Action Plan. Priority is also given to under-researched species whose risk level is currently unknown but available data to date suggests they may be impacted by chytridiomycosis. Populations of these key species will be managed according to their infection status. Within areas that are not infected with chytrid, such as the TWWHA, actions aim to mitigate pathogen spread by establishing biosecurity and hygiene measures, and possibly quarantine (Sections 4.2 and 4.3 respectively). Within infected areas, actions aim to minimise the impact of disease in at-risk populations. These actions may involve *in situ* treatment, establishment of insurance populations, reintroductions and other disease mitigation measures (Sections 4.4-4.7).

A number of guiding principles have been considered in the formulation of management actions. These include rigorous scientific principles, consideration to the scale of the response, the time required, resources available or sought and associated costs, and the optimum way to assess the success of the response.

Each action has been allocated a category to reflect its

priority based on risk assessment and contribution to the goals of the plan:

Priority 1a: Very high risk, urgent action required

Priority 1b: Actions that can be easily implemented without significant additional funding

Priority 2: High risk, action required

Priority 3: Moderate to low risk, watching brief required

## 4.1 Monitoring actions

Ongoing targeted monitoring of key amphibian species and chytrid fungus underpin many of the actions described in the sections below. Monitoring provides information on the status of amphibian populations (see Section 3 above for details), host-pathogen dynamics to understand the impact of disease (Actions 4.1.5-4.1.7 below), and the spread of chytrid fungus (See Section 4.2 below). Monitoring is required to determine the success or otherwise of management actions.



## Monitoring key amphibian population status to inform triggers for management

**Action 4.1.1:** Monitor the status of *L. burrowsae* and *C. tasmaniensis* populations by call surveys in infected and adjacent uninfected areas. This involves visiting 10-20 sites 3-4 times to determine the proportion of sites occupied (MacKenzie & Royle, 2005). A greater than 50% decline in sites occupied during five years of annual monitoring would trigger investigation and management intervention (Table 3). All sites where declines are detected should be screened for chytrid fungus (Priority 1a).

**Action 4.1.2:** Monitor the status of *L. raniformis* populations by call surveys at sites within infected areas. This involves visiting 10-20 sites 3-4 times to determine proportion of area occupied (MacKenzie & Royle, 2005). A greater than 50% decline in area of occupancy during five years of annual monitoring would trigger investigation and management intervention (Table 3). All sites where declines are detected should be surveyed / resurveyed for chytrid fungus (Priority 2).

**Action 4.1.3:** Monitor the status of Hartz Mountain *B. nimbus* population by monthly call surveys through the spring and summer as this population is at high risk of chytrid fungus emergence due to a nearby infected site. Declines would trigger broad scale monitoring and management intervention (Table 3) (Priority 1b).

**Action 4.1.4:** Facilitate monitoring of *L. peronii* by repeated call surveys targeting infected sites during the spring and summer, particularly on King Island. This may involve engaging community members or rangers. A greater than 50% decline in area of occupancy during five years of annual monitoring would trigger investigation and management intervention (Table 3) (Priority 2).

**Action 4.1.5:** Prepare establishment reports for all amphibian and chytrid monitoring programs in accordance with DPIPWE's Wildlife Monitoring Strategy (Priority 1b).



### Monitoring to investigate the impact of chytrid fungus

High intensity monitoring to determine the initial and ongoing impact of chytrid fungus is needed for very high, high or medium risk species (Table 2). To improve our understanding of how chytrid fungus impacts at risk populations, temporal changes in abundance, recruitment and survivability can be assessed by mark-recapture studies. To obtain information on pathogen transmission and for defining the scale of management responses, appropriate method includes radio-tracking.


**Action 4.1.5:** Monitor infected and adjacent naïve *L. burrowsae* populations to improve our understanding of how chytrid fungus impacts this species (Priority 1a).

**Action 4.1.6:** Monitor infected and adjacent naïve *L. raniformis* populations to improve our understanding of how chytrid fungus impacts this species (Priority 2).

### 4.2 Biosecurity and hygiene measures

Effective biosecurity and hygiene protocols are critically important to minimise chytrid fungus spread to naïve wild populations because once chytridiomycosis emerges in an area, eradication of the pathogen is very difficult or impossible (Department of the Environment and Heritage, 2006). Although chytrid fungus is already present in Tasmania, it is still important to identify potential transmission routes into the state, as imported frogs have the potential to transmit new potentially virulent strains or other exotic pathogens to susceptible local amphibians (Berger *et al.*, 2005). In a recent survey, 71% of Tasmanian retailers reported finding live frogs in the last 10 years in fresh imported produce, though few have been found in the past five years (Blackhall *et al.*, 2010). This highlights the need to investigate the processes that result in the accidental introduction of frogs and associated pathogens so that preventative measures can be instigated and incorporated into the plan.

Although chytrid fungus is now widely distributed in Tasmania it appears to be largely absent from areas such as the TWWHA and Freycinet Peninsula (Figure 1, Pauza *et al.*, in press; Philips *et al.*, 2010). The pathogen predominantly occurs in areas associated with human activities and habitation (Obendorf & Dalton, 2006; Pauza *et al.*, in press; Philips *et al.*, 2010) and the current distribution pattern suggests that anthropogenic involvement in pathogen spread is likely to be significant (Pauza *et al.*, in press; Phillott *et al.*, 2010). This highlights the importance of effective biosecurity targeting areas



with potential for human mediated pathogen spread into uninfected areas. Within infected regions, chytrid fungus is patchily distributed where positive and negative sites often occur adjacent to each other. This heterogeneity in occurrence emphasises the need to mitigate pathogen spread between sites, even within areas where it is widely distributed (Adams *et al.*, 2010).

The rate of 'natural' transmission of chytrid fungus between sites and areas in Tasmania remains unknown. Transmission of chytrid fungus between tadpoles and frogs is known to occur (Berger *et al.*, 1998; Rachowicz & Vredenburg, 2004), and movement by infected frogs to uninfected sites may be an important factor in the local spread of the pathogen. Tasmanian frogs are either pond or terrestrial breeders and little is known about home ranges or movements (Littlejohn, 2003) and how these factors affect transmission rates. Further studies on high risk species are required to investigate transmission further.

**Action 4.2.1:** Review current permit system for control of frog (and possibly new chytrid fungus strain) movement into Tasmania and ensure that biosecurity and quarantine adequately addresses the threat. Develop and regularly update chytrid fungus risk assessments (in conjunction with the Wildlife Management animal import assessment group) for frogs with unknown disease status requested for import into Tasmania (Priority 1b).

**Action 4.2.2:** Develop measures to prevent the introduction of frogs via import of fresh produce (Priority 1b).

**Action 4.2.3:** Undertake a statewide education program to implement freshwater hygiene protocols outlined in 'Keeping it Clean - A Tasmanian field hygiene manual to prevent the spread of freshwater pests and pathogens (Allan & Gartenstein, 2010) (Priority 1a).

**Action 4.2.4:** Monitor potential pathogen entry points into currently uninfected areas (primarily the TWWHA and Freycinet Peninsula) annually for chytrid fungus and frogs to assess pathogen spread and the effectiveness of hygiene actions. Sites include: Birches Inlet, Cradle Mountain, Lake Ct Clair, Lyell Hwy (sites adjacent to two infected sites), Strathgordon (adjacent to infected site), Scotts Peak Dam Rd (adjacent to infected site), Lune River (adjacent to infected site), Cockle Creek, Hartz Mountain (adjacent to infected site), Melaleuca and Freycinet Peninsula (Priority 1a).

**Action 4.2.5:** Develop island biosecurity protocols in collaboration with the Parks and Wildlife Service to reduce the risk of the introduction of chytrid fungus to off-shore islands and chytrid free reserves within mainland Tasmania (Priority 1b).

**Action 4.2.6:** Facilitate targeted biosecurity including boot washdown and educational signs at the start of Hartz Mountain walking track (Priority 1a).

### 4.3 Quarantine

Quarantine restrictions are likely to be most useful as an emergency response if anthropogenic movement transfers chytrid fungus into a single remote location of high frog conservation significance. Authorisation for initiation and cessation of restrictions comes from the Chief Veterinary Officer under the Tasmanian *Animal Health Act 1995*. The Wildlife Health Officer (DPIPWE) would be responsible for many of the on-ground actions. Once a site is quarantined, treatment of amphibians *in situ* is likely to be the best coordinated response. Examples of Tasmanian sites where quarantine may be applicable include Melaleuca and Birches Inlet. Both these areas support endemic species at high risk from the impact of chytridiomycosis. In addition both sites are remotely situated within the TWWHA and are primary entry points for people and equipment via plane or boat. Introduction of chytrid fungus to either site would allow the pathogen to spread directly into pristine locations of high conservation significance.

Quarantining an infected site or frog population would involve setting up a Restricted Area and a Control Area in accordance with AUSVETPLAN (Animal Health Australia, 2002) recommendations. A Restricted Area is a relatively small declared area around an infected premises that is subject to intense monitoring and movement controls. Movement out of the area will in general be prohibited (suitable fencing would be necessary to prevent frog movement), while movement into the Restricted Area would only be by permit. Multiple restricted areas may exist within one Control

Area (Animal Health Australia, 2002). A Control Area is larger than a Restricted Area where restrictions will reduce the chance of the disease spreading further afield. In principle, animals and specified product will only be able to be moved out of the control area into the free area by permit (Animal Health Australia, 2002). Treatment *in situ* (see Section 4.4 below for details) would involve an ongoing appropriate testing regime to indicate whether chytrid fungus persists post-treatment and if so the associated pathogen densities, or whether eradication occurs.

Actions that relate to quarantine within the Tasmanian context are in the preliminary stage:

**Action 4.3.1:** Assess the viability, resources and general logistical support needed to establish field quarantine restrictions (Priority 1b).

**Action 4.3.2:** Assess viability of combining quarantine with treatment *in situ* program (Section 4.4) for chytrid fungus eradication (Priority 1b).



#### 4.4 Treatment *in situ*

Regimes for *in situ* treatments have been trialed with some success (Parker *et al.*, 2002) and may prove to be very useful as an early intervention within the Tasmanian context, although clinical laboratory trials need to be performed first to optimise and validate methodologies. Treatments would involve setting up a small in-field clinic to treat amphibians during a disease outbreak using methods such as anti-fungal baths. Treated amphibians can then be released directly back to the collection site. The aim is to increase amphibian survivability while pathogen densities are high, resulting in population persistence through a disease outbreak. With time pathogen densities should reduce so that new generation amphibians will be less likely to succumb to disease.


Treatment *in situ* is likely to be most useful when combined with quarantine restrictions (Section 4.3) as an emergency response if anthropogenic movement transfers chytrid fungus into a single remote location of high frog conservation significance. If successful, *in situ* treatment presents a potential alternative to the establishment of captive insurance populations.

**Action 4.4.1:** Collaborate in treatment trials for high risk frog populations in the laboratory initially, then in the field if laboratory trials have proven successful. Mark-recapture techniques should be used to validate these methods in free-living amphibians (Priority 1a).

#### 4.5 Captive insurance programs

The establishment of captive insurance programs from captured naïve high risk frog species involves considerable short and long-term investment. This emergency response should be informed by monitoring high risk species and triggered when species are considered to be at risk of extinction (see Table 3). Captive insurance programs are not a final solution to the conservation of high risk species but in some scenarios may be the only chance to preserve species for eventual re-introduction to secured habitat (Mendelson III *et al.*, 2005). Captive breeding should be considered as early as possible in a management response to allow time to liaise with potential collaborative institutions and to organise resources and logistics for the collection of frogs and other related actions. Multiple institutions should be considered to spread any risks associated with captive breeding. In addition frogs should be collected from different areas to increase the likelihood of capturing genetic heterozygosity. Captive insurance plans should integrate other components to improve long term species' survival rates in the wild including research on: amphibian biology, demographics, genetics, disease including the possibility of selection for resistance, optimal husbandry, and mitigation of threats in the wild (Mendelson III *et al.*, 2005).

Potential institutions for captive programs include: Tasmanian and mainland zoos and wildlife parks (particularly those with established captive frog breeding programs eg. Taronga Zoo, DPI/PWE captive breeding facilities at Tarooma, Tasmanian amateur



frog breeders, and Amphibian Ark captive programs. Amphibian Ark represents an important potential source of knowledge and resources. Tasmania's high risk amphibians may present varied challenges to captive husbandry to sustain high survivability. Notably, wild populations of *B. nimbus* occupy habitats with very specific requirements that may be difficult to replicate in a captive scenario.

**Action 4.5.1:** Investigate funding opportunities to support potential long-term programs (Priority 1b).

**Action 4.5.2:** Develop collaborations with appropriate captive breeding institutions (Priority 1b).

**Action 4.5.3:** Ensure high standards of husbandry and biosecurity within any potential breeding facility (Priority 1b).

**Action 4.5.4:** Prepare resources and logistics for the collection of frogs. Consider animal ethics requirements, permits, personnel, methods for frog collection and transport, stringent biosecurity and hygiene protocols (Priority 2).

**Action 4.5.5:** Prepare a report on what knowledge is available on captive breeding of Tasmanian frogs (Priority 2).

**Action 4.5.6:** Trial small breeding programs for key species to learn about species husbandry and breeding requirements (Priority 1a).

**Action 4.5.7:** Develop full captive insurance program when / if required (Priority 2).



## 4.6 Reintroduction

Reintroduction of frogs to the wild does not solely relate to the primary purpose of captive breeding programs. In many instances, reintroduction of amphibians may be achieved more efficiently, more safely and for significantly less cost if there is no captive breeding component (Griffiths *et al.*, 2005). Examples include: the direct translocation of spawn or tadpoles from a high risk site to a site likely to improve amphibian survivability, or collecting and raising in captivity tadpoles which are vulnerable to chytridiomycosis, then reintroducing them at a less vulnerable life stage, for example post-metamorphosis (Griffiths *et al.*, 2005).

Within the Tasmanian context, reintroduction post captive breeding should be given due consideration at the appropriate time. However non captive breeding reintroduction options should be considered for high risk species as a potential management response in the short to medium term. Any reintroduction or translocation will be undertaken in accordance with relevant government policy. Reintroduction is more likely to be successful if the following criteria are met: all known threatening processes are reversed or mitigated, natural recolonisation is occurring, sites have previously supported species of interest, and the number of individuals and appropriate life stage of a species are released (Griffiths *et al.*, 2005). Post-release monitoring is vital to evaluate the success of any reintroduction activity.


**Action 4.6.1:** Assess the viability of reintroduction of captive-bred species when appropriate (Priority 1b).

**Action 4.6.2:** Assess viability of reintroduction of wild amphibians or those that have been captive for part of their life stage (Priority 1b).

## 4.7 Other disease mitigation measures

A variety of disease mitigation measures have been suggested for future amphibian conservation strategies but are not currently available for management due to a need for further research. These strategies include promoting natural disease resistance, immunisation and the use of anti-fungal agents in the field.

Promoting natural disease resistance will require captive breeding programs that have selectively bred individuals for disease immunity over multiple generations whilst protecting the genetic diversity of amphibians. These strategies are sometimes called 'ex situ programs' because they involve disease treatment for amphibians in captivity, rather than in the wild. This strategy is being initiated and investigated for four amphibian species (<http://portal.isis.org/partners/AARK/ExSituPrograms/default.aspx>).



Amphibian immunisation to chytrid fungus has been attempted but to date has been unsuccessful (Stice & Briggs, 2010). Although amphibians have highly complex immune systems, physiological studies have been unable to explain the lack of robust innate or acquired immune responses to infection (Berger *et al.*, 2005; Rollins-Smith *et al.*, 2005) and a preliminary study of genetic expression patterns suggested that chytrid fungus may contain genes for immune evasion (Rosenblum *et al.*, 2008). Thus, stimulation of adaptive immune responses is unlikely to be an effective conservation strategy, however further research in amphibian immunity (e.g. studies of the MHC complex) is important (Barribeau *et al.*, 2008).

Lastly, it has been suggested that augmenting natural populations of bacteria on amphibian skin could confer a defence against chytrid fungus infection (Harris *et al.*, 2006). The suggestion of biological application of anti-chytrid fungus bacteria or bacterial compounds to the field is somewhat controversial because at present we do not fully understand ecological consequences or the efficacy of such treatments for disease control (Marm Kilpatrick *et al.*, 2010). Although further research is critical, the possibility of using anti-fungal agents over large geographical areas in the field is an option that many researchers hope will become viable in the future.

**Action 4.7.1:** Maintain current awareness of chytridiomycosis treatment research developments particularly in relation to: promoting natural disease resistance, immunisation and the use of anti-fungal agents in the field (Priority 1b).

**Action 4.7.2:** Assess the viability of potential treatment regimes within the Tasmanian context (Priority 1b).



photo: Jamie Voyles

## 4.8 Future research

Most priority research projects have been included in sections above. Other research actions to underpin adaptive management are included below.

**Action 4.8.1:** Facilitate laboratory susceptibility trials for *C. tasmaniensis* (Priority 1a).

**Action 4.8.2:** Promote research of priority projects to relevant universities, organisations and government. Priority projects, in addition to those listed above include: (1) examining comparative virulence and pathogenicity of chytrid fungus, (2) examining whether the low pH of Tasmania's buttongrass moorlands is likely to offer some natural protection to the frog inhabitants, (3) collaborating with researchers aiming to examine MHC heterogeneity and determine if this relates to susceptibility to disease, (4) researching the ecology of Tasmanian frog species, especially in relation to their requirements for captive breeding (Priority 2).

## 4.9 Education and training

**Action 4.9.1:** Continue to provide education and resources to all Tasmanian Quarantine and DPIPWE staff in relation to the need to report frog importations. This advice will need to be periodically reinforced (Priority 1b).

**Action 4.9.2:** Ensure all fresh produce importers targeted in the 'Survey for disease introductions via frog imports in fresh produce' (Blackhall *et al.* 2010) are collecting and reporting stowaway frogs as requested. Issue periodic reminders of the importance of notification and vigilance (Priority 1b).

**Action 4.9.3:** Educate field workers, scientists, rangers, and the general public on how to recognise clinical signs of chytridiomycosis, and record and report any findings and mortality events. This may include requests for observations in permits issued to researchers, shooters, recreational fishers, wildlife tourism operators etc (Priority 1b).

**Action 4.9.4:** Collaborate with researchers to encourage them to collect dead frogs opportunistically for assessment (Priority 1b).



## 4.10 Communication and evaluation

Relevant information from research to date and actions within the management plan will be shared with community members, Tasmanian land managers, relevant land users, industry groups, and researchers. The aim is to disseminate information to increase the effectiveness of management actions and to contribute to researching chytridiomycosis within the Tasmanian context.

**Action 4.10.1:** Distribute the Tasmanian Chytrid Management Plan to land managers including appropriate government and non-government bodies to assist with relevant actions (Priority 1b).

**Action 4.10.2:** Provide annual updates relating to chytrid fungus and frog status, and the success of management actions, to relevant national and international bodies including the Department of the Environment, Water, Heritage and the Arts, the Australian Amphibian Diseases Threat Abatement Committee, the Australian Wildlife Health Network, and the OIE (Priority 1b).

**Action 4.10.4:** Review the Tasmanian Chytrid Management Plan in two years or when necessary. Evaluate the success of actions annually (Priority 1b).



photo: Jamie Voyles

# ABBREVIATIONS AND GLOSSARY

## Abbreviations

- AHL** Animal Health Laboratory
- CVO** Chief Veterinary Officer
- DEH** Department of the Environment and Heritage (now Department of the Environment, Water, Heritage and the Arts)
- DPIPWE** Department of Primary Industries, Parks, Water and Environment
- MHC** Major Histocompatibility Complex
- NRM** Natural Resource Management
- NVA** Natural Values Atlas
- OIE** World Organisation for Animal Health
- PCR** Polymerase Chain Reaction
- TAP** Threat Abatement Plan
- TWWHA** Tasmanian Wilderness World Heritage Area

## Glossary

- AUSVETPLAN** Australian Veterinary Emergency Plan. A series of technical response plans that describe the proposed Australian approach to an emergency animal disease incident
- Biosecurity** The protection of people, animals and ecological systems against disease and other biological threats
- Disinfectant** A chemical used to destroy disease agents outside a living animal

**Emerging disease** A disease which is either newly recognised or was previously recognised by science and has increased in prevalence or geographic range

**Endemic** Species that occur only in Tasmania

**Introduced animal** Non-native species which can establish self-sustaining populations in the wild

**Monitoring** Routine collection of data for assessing the population and/or health status of species

**Morbidity** Sickness or diseased state

**Mortality** Death

**Movement control** Restrictions placed on movement of animals, people and objects to prevent spread of disease.

**Polymerase chain reaction** A method of amplifying and analysing DNA sequences that can be used to detect the presence of virus DNA or mRNA.

**Prevalence** The proportion (or percentage) of animals in a particular population affected by a particular disease (or infection or positive antibody titre) at a given point in time

**Vaccination** Inoculation of healthy individuals with weakened or attenuated strains of disease-causing agents to provide protection from disease

# APPENDIX I KEY THREATENING PROCESSES AFFECTING TASMANIA'S AMPHIBIANS

photo: Jamie Voyles

Threat	Mechanisms	
<b>Disease</b>	<p>Chytridiomycosis</p> <p>Iridoviruses</p> <p>Other pathogens and parasites.</p>	
<p><b>Climate change</b></p> <p>Bureau of Meteorology Tasmania model predictions (mid-point of spread of models, medium emissions) by 2030: Warming up to 1.5°C particularly in east and north. Up to 5% less rain in east and north, up to 2% more rain in south-west.</p>	<p>Increased drought frequency</p> <p>Reduction in aquatic habitats</p> <p>Increased flood severity</p> <p>Increased fire frequency / severity</p> <p>Increased human demand for water – may change human population distribution and land management practices</p>	
<b>Introduced predators / competitors</b>	<p>Fish – particularly trout and <i>Gambusia</i></p> <p>Pet cats and dogs</p> <p>Feral cats and dogs</p> <p>Foxes (<i>Vulpes vulpes</i>)</p>	
<b>Habitat loss and degradation</b>	<p>Urbanisation</p> <p>Forestry</p> <p>Mining</p> <p>Agriculture</p>	
<p><b>Chemical pollution</b></p> <p><b>Other pollution</b></p>	<p>Pesticides</p> <p>Herbicides</p> <p>Organic pollution including human and livestock waste / sewerage</p>	
<b>Synergistic Interactions of above processes</b>		

Table 4: Key threatening processes with potential to impact Tasmanian amphibians over the next five years (note that climate change impacts are considered over a 20 year period).

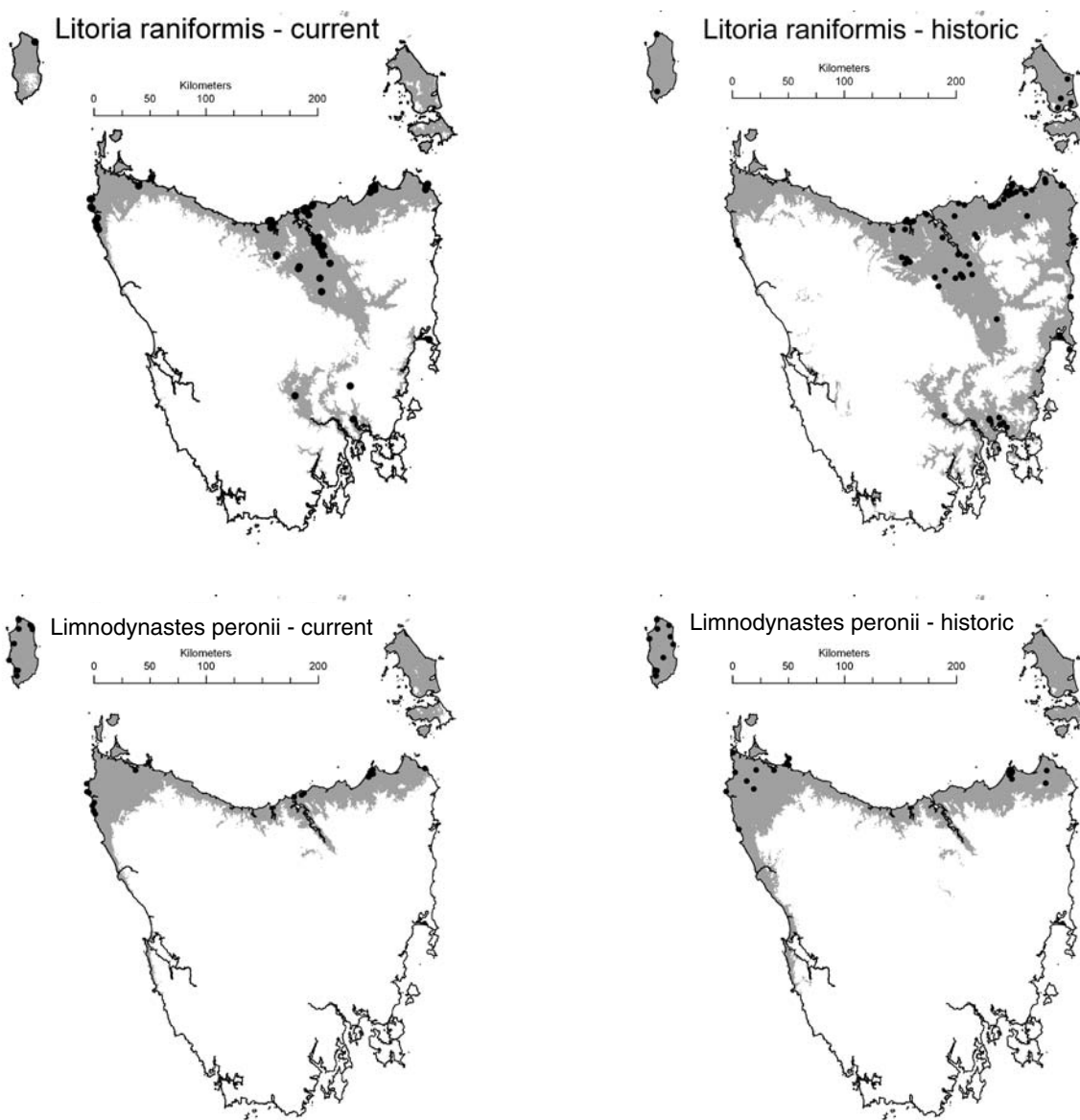
Potential Impacts
<p>Chytridiomycosis –Mass mortality in susceptible species / populations. Declines / worsening of conservation status of species. Potential to cause species' extinction/s.</p> <p>Iridoviruses – Ranavirus of particular concern. Current distribution NSW,ACT, and Vic, while Tasmania is currently free of disease. Amphibian morbidity and mortality expressed as ulcerative / haemorrhagic syndromes. Pathogenic experimentally in mainland Australia to some <i>Limnodynastes</i> species (Whittington <i>et al.</i>, 2010).</p>
<p>Warming with loss or contraction of aquatic habitats in north and east. Reduced connectivity between water bodies with possible fragmentation of populations. Reduction in water availability will magnify impacts of habitat loss and degradation section (see below).</p> <p>Fires alter habitat and can cause amphibian mortality (Pilliod <i>et al.</i>, 2003).</p> <p>Potential to promote emerging infectious diseases including chytridiomycosis (Pounds <i>et al.</i>, 2006). May shift host-pathogen relationships.</p> <p>Shift in altitudinal and longitudinal distribution of amphibians, their prey and their predators.</p>
<p>Trout compete by reducing availability of aquatic prey to amphibians - frogs are 10 times more abundant in the absence of trout (Vredenburg &amp; Wake, 2007). Trout predate on tadpoles (Vredenburg, 2004). Brown trout are widespread in Tasmania (Jackson, 2005) overlapping the range of most species (Philips <i>et al.</i>, 2010).</p> <p>Cats, dogs and foxes can predate on amphibians.</p> <p>Introduced animals can act as vectors for parasites and diseases.</p>
<p>Loss of aquatic and/or terrestrial habitats.</p> <p>Habitat degradation includes erosion, sedimentation, loss of riparian vegetation, habitat fragmentation, nutrient run-off, introduced weeds, toxin pollution, and agricultural chemical pollution.</p> <p>Other potential impacts include loss or changes in abundance / diversity of tadpole food items including algae, plants or microbes, loss or changes in abundance / diversity of frog prey including invertebrates and vertebrates, loss or changes in abundance / diversity of amphibian predators including snakes and birds.</p>
<p>Heavy metals and chemicals used in pesticides and herbicides can be toxic to tadpoles (Alford &amp; Richards, 1999). For instance atrazine, a commonly used herbicide in Tasmania, can lead to frog sterility (Hayes <i>et al.</i>, 2010).</p> <p>Toxins can cause direct mortality or indirect mortality by impairing reproduction, reducing growth rates, endocrine disruption, or increase susceptibility to disease by immunosuppression or inhibiting immune development (Alford &amp; Richards, 1999).</p>
<p>Climate change in many areas is predicted to shift environmental conditions towards the growth optimum of pathogens such as chytrid fungus, which may trigger disease outbreaks (Pounds <i>et al.</i>, 2006).</p> <p>The combined effects of climate change, habitat degradation, intensive animal production, increasing human populations and urbanisation can influence wildlife health (Black <i>et al.</i>, 2008).</p> <p>Environmental toxicants can increase susceptibility to disease by immunosuppression or inhibiting immune development (Alford &amp; Richards, 1999).</p> <p>Environmental stressors such as extreme weather events may reduce immune function and precipitate disease outbreaks (Alford &amp; Richards, 1999).</p> <p>In California pesticide drift has been linked to frog disappearance, possibly by enhancing impact of chytrid fungus infection on a population already weakened by interactions with introduced trout (Vredenburg &amp; Wake, 2007).</p>

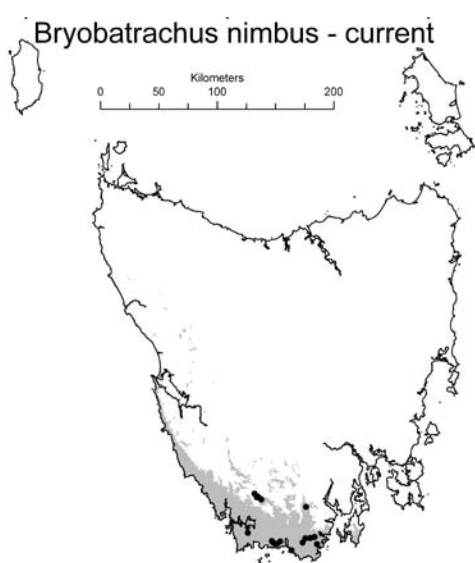
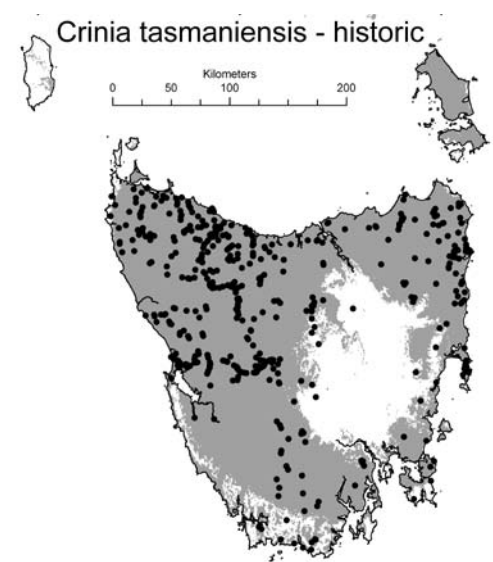
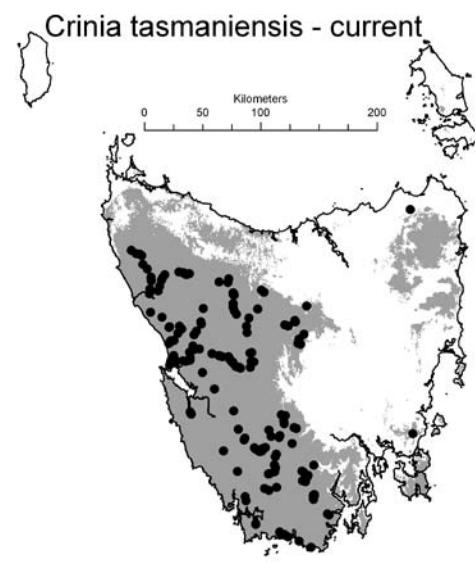
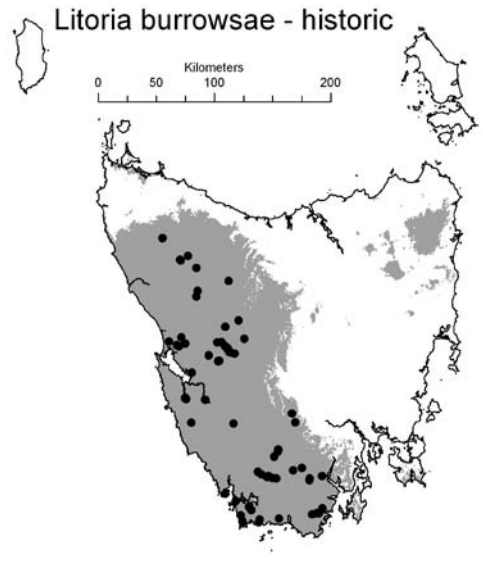
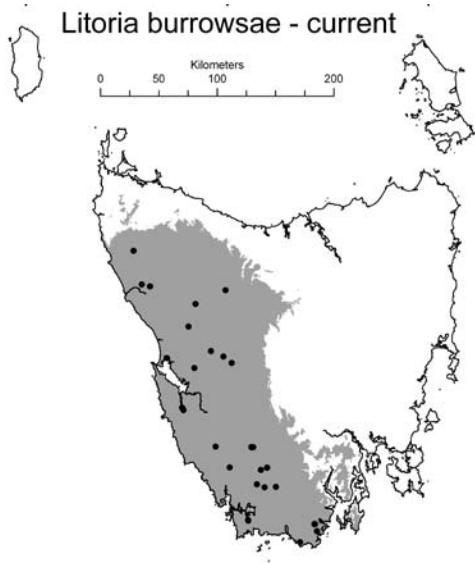
# APPENDIX 2

## DISTRIBUTIONS AND PREDICTED DISTRIBUTIONS OF TASMANIA'S TWO THREATENED AND THREE ENDEMIC FROG SPECIES

photo: Iain Sych

Figure 3. Current (1995-2010) and historic (pre 1995) distributions and predicted distributions of Tasmania's two threatened (*L. raniformis* and *L. peronii*) and three endemic (*L. burrowsae*, *C. tasmaniensis*, *B. nimbus*) frog species. Points indicted species presence (either by visual identification or call surveys). Grey shading indicates predicted distribution. Note we assume chytrid fungus was introduced to wild Tasmanian amphibians in mid 1990's. Note also historic records are not available for *B. nimbus*. Source: Wilson, (2010a)







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photo: Annie Philips

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photo: Iain Stych

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# NOTES





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