

<b>Institution: Institute of Zoology</b>
<b>Unit of Assessment: B7</b>
<b>Title of case study: Amphibian chytridiomycosis</b>
<p><b>1. Summary of the impact</b> (indicative maximum 100 words)</p> <p>Amphibian population declines are recognised as one of the largest biodiversity crises in modern history. Professor Andrew Cunningham, Institute of Zoology (IOZ) headed the team that identified a novel chytrid fungus as the major cause of amphibian population declines and species extinctions. Our work is the basis for the scientific and conservation responses to this disease, and led to the fungus being listed by the OIE (World Organisation for Animal Health). We have established national surveillance programmes for the pathogen across the EU and elsewhere, identifying species at risk and developing mitigating measures to prevent pathogen introduction and species extinction.</p>
<p><b>2. Underpinning research</b> (indicative maximum 500 words)</p> <p>In the mid-1990s, Professor Andrew Cunningham at the Institute of Zoology (IOZ) initiated investigations into infectious causes of global amphibian mortality and declines. As leader of the Pathology and Diseases Working Group of the IUCN Declining Amphibian Populations Task Force, he co-discovered a novel chytrid fungus causing a disease of amphibians, and showed that a common infectious cause of amphibian mortality was associated with population declines on two continents. This work was described in <i>Nature</i> (394, 418-419) as “an exemplary example of international scientific collaboration”. Following on from this, IOZ researchers demonstrated that the infectious agent, <i>Batrachochytrium dendrobatidis</i> (<i>Bd</i>), a non-hyphal chytrid fungus that produces the disease amphibian chytridiomycosis, is a major cause of amphibian mortality, population declines and species extinctions globally [1].</p> <p>Since then, IOZ scientists have significantly advanced our understanding of amphibian chytridiomycosis through a wide range of projects. In 2003, Cunningham worked with post-doctoral researchers Trent Garner and Matthew Fisher on a NERC-funded project to investigate the ecological and genetic determinants of <i>Bd</i> emergence in European amphibian populations. This research demonstrated that chytridiomycosis is caused by a novel, emerging fungus that arose through substantial recombination and chromosomal copy number variation and that post-emergence disease dynamics are governed by an interaction between pathogen genotype, host species and community structure and a range of environmental factors, including altitude, water and air temperature, and salinity [2] [3]. Furthermore, IOZ scientists showed that not all cases of emergence result in amphibian declines or even mortality [2] and conversely that exposure, even in the absence of infection, can result in amphibian mortality.</p> <p>Since 2004, projects co-founded by IOZ with Fisher, now a Professor at Imperial College, have revealed the extent of the global distribution of <i>Bd</i> and have described infection in more than 500 amphibian species [4]. IOZ has been working in the Caribbean since 2003 and in Europe since 2007 to investigate the ecology and infection dynamics of <i>Bd</i> in multi-species host communities. This work has identified areas and amphibian taxonomic groups that are at greater risk of disease emergence and decline due to chytridiomycosis [5] and we have shown how the introduction of non-native species, translocations for conservation purposes and the amphibian trade are all key routes for the range expansion of <i>Bd</i> [6].</p> <p>Our disease mitigation research is on-going, but has included investigating safe treatments to cure the disease in captive animals; whether field treatments can be used to reduce the impact of the disease on wild populations of Critically Endangered amphibians; whether the impact of the pathogen can be reduced through pre-exposure of animals to a hypovirulent lineage of the fungus); and whether restocking is a useful conservation tool following declines due to chytridiomycosis [7].</p>
<p><b>3. References to the research</b> (indicative maximum of six references)</p> <p>[1] Berger L, Speare R, Daszak P, Green DE, Cunningham AA, Goggin CL, Slocombe R, Ragan</p>

**Impact case study (REF3b)**

MA, Hyatt AD, McDonald KR, Hines HB, Lips KR, Marantelli G, Parkes H. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. *Proc Natl Acad Sci U S A*. 1998 Jul 21;95(15):9031-6.

<http://www.pnas.org/content/95/15/9031.long> Cited >1100 times on Google Scholar

- [2] Walker SF, Bosch J, Gomez V, Garner TWJ, Cunningham AA, Schmeller DS, Ninyerola M, Henk D, Ginestet C, Christian-Philippe A, Fisher MC. Factors driving pathogenicity versus prevalence of the amphibian pathogen *Batrachochytrium dendrobatidis* and chytridiomycosis in Iberia. *Ecology Letters*. 2010;13:372-82. <http://dx.doi.org/10.1111/j.1461-0248.2009.01434.x>. Cited 55 times already on Google Scholar
- [3] Garner TWJ, Rowcliffe JM, Fisher MC. Climate change, chytridiomycosis or condition: an experimental test of amphibian survival. *Global Change Biology*. 2011 Feb;17(2):667-75. <http://dx.doi.org/10.1111/j.1365-2486.2010.02272.x>
- [4] Garner TW, Perkins MW, Govindarajulu P, Seglie D, Walker S, Cunningham AA, Fisher MC. The emerging amphibian pathogen *Batrachochytrium dendrobatidis* globally infects introduced populations of the North American bullfrog, *Rana catesbeiana*. *Biol Lett*. 2006 Sep 22;2(3):455-9. <http://dx.doi.org/10.1098/rsbl.2006.0494> Cited 182 times already on Google Scholar
- [5] Bielby, J et al. Predicting susceptibility to future declines in the world's frogs. *Conservation Letters* 1 (2008): 82-90. DOI: 10.1111/j.1755-263X.2008.00015.x Cited 82 times already on Google Scholar
- [6] Fisher, MC, Garner, TWJ. The relationship between the emergence of *Batrachochytrium dendrobatidis*, the international trade in amphibians and introduced amphibian species. *Fungal Biology Reviews* 21 (2007): 2-9. <http://www.sciencedirect.com/science/article/pii/S1749461307000085> Cited >100 times on Google Scholar
- [7] Walker SF, Bosch J, James TY, Litvintseva AP, Oliver Valls JA, Piña S, García G, Rosa GA, Cunningham AA, Hole S, Griffiths R, Fisher MC. Invasive pathogens threaten species recovery programs. *Curr Biol*. 2008 Sep 23;18(18):R853-4. <http://dx.doi.org/10.1016/j.cub.2008.07.033>

**Key Grants**

Fisher MC, Cunningham AA. Ecological and genetic determinants of *Batrachochytrium dendrobatidis* emergence in European amphibian populations. NERC. 2003-6. £193,193.

Cunningham AA. Addressing a threat to Caribbean amphibians: capacity building in Dominica; Darwin Initiative for the Survival of Species; 2005-8; £204,834.

Fisher MC, Garner TWJ, Cunningham AA. Relationship between environmental, ecological and genetic drivers of emergence in amphibian chytridiomycosis. NERC. 2007-10. £70,032.

Fisher MC, Garner TWJ, Donnelly C. Modelling the amphibian response to infection by the chytrid *Batrachochytrium dendrobatidis*. BBSRC. 2007-8. £128,195.

Cunningham AA. Investigation of amphibian chytridiomycosis: national surveillance and local monitoring. Natural England. 2007-8. £61,000.

Garner TWJ and six coapplicant European institutions. R.A.C.E. **Risk Assessment of Chytridiomycosis to Europe's Amphibians**. EU BiodivERsA Programme, UK funding through NERC and Defra. 2008-13. Total budget €1.5m, IOZ component £236,617.

Cunningham AA. Epidemiological aspects of amphibian chytridiomycosis caused by *Batrachochytrium dendrobatidis*. Defra. 2009-12. £264,000.

Bosch J, Garner TWJ, Fisher MC, Bielby J. Disease mitigation in declining amphibian populations. Fundación General CSIC Proyectos Cero. 2010-ongoing. €224,355.

**4. Details of the impact** (indicative maximum 750 words)

The underpinning research described above has prompted an international effort to understand the emergence, distribution, epidemiology, impact and control of *Bd*. This work has illustrated how *Bd* is unrivalled among pathogens in host range and its impact on biodiversity. Before *Bd*, wildlife

## Impact case study (REF3b)

disease was considered a specialist, peripheral subject of interest, but is now firmly on the ecology and conservation biology agendas.

### Bd surveillance

As a result of his research into *Bd*, Cunningham was invited in 2006 to become a founder member of the World Organisation for Animal Health (OIE) amphibian disease *ad hoc* group. This group reviewed available research (much from IOZ) and unanimously agreed to recommend that amphibian chytridiomycosis be listed by the OIE. This was agreed by the OIE General Session in May 2008, making amphibian chytridiomycosis (along with ranaviral disease) the first OIE-listed amphibian pathogen [a]. This listing made chytridiomycosis internationally notifiable and thus subject to OIE standards, which aim to assure the sanitary safety of international trade in live amphibians and their products. A total of 178 Member Countries are Signatories to the OIE – these countries are now obliged to instigate surveillance and control measures for chytridiomycosis. As a result, a network of government agencies, research institutions, NGOs and other parties have developed regional and national surveillance schemes. Our work has led to diagnostic labs for *Bd* detection being set up and staff trained by Cunningham, Garner and Becki Lawson (IOZ Research Fellow) in several countries [b].

Since 2009, the European surveillance effort has been coordinated through the IOZ via the RACE project, which involves NGOs, universities and government agencies in 15 EU Member and Associate States [c]. Data from this and other projects, including the UK national *Bd* surveillance project (commissioned by the UK conservation agencies and Defra and conducted by Cunningham in 2008 and 2011), are open access and used by disease researchers across the globe. The results of our 2008 UK *Bd* surveillance, which involved the training and engagement of hundreds of citizen science volunteers, led to Natural England requiring any protected amphibians being translocated to be tested for, and free of, *Bd* prior to issuing a translocation licence [d]. The surveillance results also led to Defra commissioning IOZ to conduct a three-year study to investigate the epidemiology of the pathogen in the UK, which will be used to inform UK government policy on the control of *Bd* in the UK.

### International policy

Although amphibians are not listed in the Appendices of the Convention on Migratory Species, chytridiomycosis was one of the diseases that alerted the Convention on Migratory Species (CMS) Scientific Council to the importance of disease as a conservation threat to wildlife, prompting the adoption of two CMS Resolutions: 9.8 Responding to the Challenge of Emerging and Re-Emerging Diseases in Migratory Species, Including Highly Pathogenic Avian Influenza H5N1 (2008), and 10.22 Wildlife Disease and Migratory Species (2011). Resolution 9.8 led to the creation of the UNEP-CMS and FAO Co-convened Scientific Task Force on Wildlife and Ecosystem Health. In 2012, Cunningham was technical editor for the disease factsheet on amphibian chytridiomycosis which formed part of the Ramsar Wetland Disease Manual (Ramsar Technical Report No. 7), produced by the Wildfowl & Wetlands Trust for the Ramsar Convention (an international treaty on the conservation of wetlands) [e].

### Mitigating the effects of *Bd*

Research by Cunningham, Garner and their students have developed chemical antifungal treatments for *Bd* (primarily using Itraconazole) for captive animals and these are now used by zoos (e.g. by the Team Leader in Herpetology, ZSL London Zoo) and others across the world. Working with Defra, we produced a national risk assessment for *Bd* in the UK – the first of its kind in the world [f].

In 2008, Cunningham convened an international workshop in Dominica, from which representatives of nine governments in the region attended. This workshop produced a Chytridiomycosis Management Plan for the Lesser Antilles Region [g]. This plan markedly raised awareness about amphibian conservation and wildlife disease amongst wildlife departments and others in the region, leading to conservation measures in the region [h].

Biosecurity measures used in amphibian conservation programs in the Caribbean, across Europe, and in China were first developed by Cunningham and are communicated to a wider audience as best practice guidelines for field researchers working in aquatic environments and are available on

## Impact case study (REF3b)

the websites of a variety of GOs and NGOs [i].

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

- [a] Final Report of the OIE 76th General Session • Paris, 25-30 May 2008.  
<http://www.oie.int/doc/ged/D11922.PDF> See p.66-7
- [b] Our work training for *Bd* diagnosis can be verified by a supporting statement from the Curator of Herpetology Collection at the Hungarian Natural History Museum. Copy available on request.
- [c] <http://www.bd-maps.eu/>
- [d] The impact of our work on Natural England policy and practice can be verified by a supporting statement from the Conservation Director, Amphibian & Reptile Conservation. Copy available on request.
- [e] The relevant resolutions are available at  
[http://www.cms.int/bodies/COP/cop10/resolutions\\_adopted/10\\_22\\_diseases\\_e.pdf](http://www.cms.int/bodies/COP/cop10/resolutions_adopted/10_22_diseases_e.pdf),  
<http://www.ramsar.org/pdf/lib/rtr7-disease.pdf> see p.176 and  
<http://www.ramsar.org/pdf/cop11/res/cop11-res12-e.pdf>, and Cunningham's contribution can be verified by a supporting statement from Head of Wildlife Health Wildfowl & Wetlands Trust, Slimbridge. Copy available on request.
- [f] Peel AJ, Hartley M, Cunningham AA. Qualitative risk analysis of introducing *Batrachochytrium dendrobatidis* to the UK through the importation of live amphibians. *Dis Aquat Organ*. 2012 Mar 20;98(2):95-112. <http://dx.doi.org/10.3354/dao02424>. Use by Defra can be verified by European Specialist in Wildlife Population Health at Zoo and Wildlife Solutions Ltd.
- [g] <http://www.mountainchicken.org/wp-content/uploads/2010/11/Chytridiomycosis-Management-Plan.pdf>
- [h] Conservation impacts resulting from the Chytridiomycosis Management Plan for the Lesser Antilles Region can be verified by a supporting statement from the Director of Forestry, Wildlife and Parks, Ministry of Agriculture and Forestry, Commonwealth of Dominica. Copy available on request.
- [i] [www.snh.gov.uk/docs/B349121.pdf](http://www.snh.gov.uk/docs/B349121.pdf)