Institution: Cardiff University		
Unit of Assessment: Biological Sciences (5)		
Title of case study: Embedding genetic biodiversity in global conservation policies to protect endangered species		
Period when the underpinning research was undertaken: 2006 - 2018		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Bruford, Michael Orozco-terWengel, Pablo Russo, Isa-Rita	**Role(s) (e.g. job title):** Professor Senior Lecturer Lecturer	**Period(s) employed by submitting HEI:** 01/04/1999 - present 01/08/2011 - present 01/02/2012 - present
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact (indicative maximum 100 words)

While conservation genetics grew rapidly as a discipline from the 1990s onwards, it had little impact on real-world conservation activity. Conservation policies and activities at best ignored genetic biodiversity, and at worst, eroded it. A Cardiff research programme to assess genetic diversity of species, monitor genetics in conservation and highlight the dangers of intentional genetic manipulation changed: 1) the Namibian government's national policy on selective breeding; 2) species-specific conservation practice for the African rhinoceros, Bojer's Skink and Monserrat Mountain Chicken Frog; and 3) global standards for monitoring biodiversity for worldwide conservation efforts, including EU commitment to inclusion of genetic monitoring in their Biodiversity Strategy for 2030.

2. Underpinning research (indicative maximum 500 words)

Genetic variation is an essential component of biodiversity and an important factor in building the resilience of populations, species and ecosystems against environmental changes. Until recently, consideration of genetic variation in biodiversity planning and conservation policy was minimal. For example, the UN's Convention on Biological Diversity (CBD) *Strategic Plan 2011-2020* only focussed on genetics in one out of its twenty strategic aims.

A series of Cardiff ecological research studies, led by Bruford, helped address this gap. Focused on genetic analysis and biodiversity in both wild and domesticated animal species, they highlighted a complex interplay of genetics, behaviour, social structures, physical environment and human activity required for biodiversity conservation **[3.1]**.

Key research expertise, and studies, that underpinned Cardiff's impact are outlined below:

2.1 Understanding genetic risks to endangered species: key methodologies

The Cardiff team's relevant biodiversity expertise included:

a. Assessing genetic diversity to understand the extent of species loss in a range of endangered populations by analysing mitochondrial and nuclear genomes of various species and quantifying the full extent of genetic loss in wild populations. This type of analysis enables conservation actions, such as translocation of individuals to improve localised breeding which protects or improves genetic diversity at the same time as improving population numbers **[3.2, 3.3, 3.4]**.

b. Compiling **genetic data to monitor populations** of conservation concern, thereby ensuring that captive populations are representative of the genetic diversity of the full wild population. This is particularly important in species at known risk from fast-acting threats, such as the threat of chytridiomycosis to amphibians, which can decimate a population in less than a generation **[3.1, 3.4]**.

c. Highlighting the damaging effects of **intentional genetic manipulation** on wildlife**,** including approaches such as unregulated breeding, inbreeding, hybridisation and translocation of animals. Such practices are motivated by organisations who prioritise the desires of tourists and game hunters, rather than the best interests of species conservation **[3.5]**.

Application of Cardiff's research methods consolidated an approach to conservation which prioritised the assessment of genetic data to inform conservation practice on the ground.

2.2 Genetic analyses of endangered species

Through a systematic series of collaborative research projects, Cardiff researchers brought their broader expertise in genetic analysis (Section 2.1) to inform understanding of the following endangered species:

a. Bojer's skink

The Bojer's skink is the only species in its genus, having diverged from its nearest living relative over 30 million years ago. It is both genetically unique and critically endangered. The Cardiff Team, led by Bruford, undertook an analysis of genetic diversity in these reptiles in their native habitat of the offshore islands of mainland Mauritius. The research discovered demographic population history and a likely origin and recommended using additional translocation from other south-eastern islands to further genetically support the diminishing populations **[3.3]**.

b. Montserrat Mountain Chicken Frog

In a collaborative research project initiated by the Durrell Wildlife Conservation Trust, the Cardiff group, led by Orozco ter-Wengel, carried out genetic analysis of a critically endangered species of frog, the Montserrat Mountain Chicken Frog, following the effects of a devastating chytridiomycosis epidemic. They characterised the range of genetic diversity within the species and discovered that populations on two separate islands share the same mitochondrial haplotype, strongly indicating that Dominican and Montserrat mountain chickens represent the same species and the same evolutionary significant unit **[3.4]**.

c. Black rhinoceros

The Cardiff team, led by Russo, worked with the International Union for Conservation of Nature (IUCN) Species Survival Commission African Rhino Specialist Group to analyse the genetic structure of historic and modern rhinoceros populations using the largest sample of black rhinoceroses ever studied. Using mitochondrial and nuclear datasets, the team discovered a 69% loss of the species' mitochondrial genetic variation, highlighting the critical need for new conservation management approaches for this species **[3.2]**.

2.3 Establishing pathways to influence conservation policy

To facilitate inclusion of conservation genetics in international policymaking, Bruford led the European ConGRESS project (€1.14M FP7 funding, 12 European partners) **[G3.1]** to develop an integrated genetics policy-making portal. The team used Cardiff's research findings to advocate for a closer partnership between academic conservation geneticists and conservation practitioners, thereby maximising the potential of genetic analysis to support conservation efforts **[3.6]**.

Following the success of ConGRESS **[G3.1]**, in 2014 the IUCN established the Conservation Genetics Specialist Group (CGSG) as an evidence provider for conservation policymakers in its 208 member states. IUCN appointed Bruford as co-chair, with Segelbacher (University of Freiburg). Additionally, Cardiff's Russo was appointed to co-lead the African chapter of the CGSG, while Orozco-terWengel was appointed to co-lead the South American CGSG. Under the Cardiff team's leadership, CGSG worked on reports and evidence guidelines, which included Cardiff research.

2.4 Describing deficiencies in the Post 2020 Global Biodiversity Framework

Upon release of the draft Post-2020 Global Biodiversity Framework by the Convention on Biological Diversity (of which the EU are key contributing members), Bruford collaborated with geneticists and environmental conservation organisations to assess the efficacy of the

Framework as a policy mechanism to maintain biodiversity, highlighting deficiencies with species scope. Cardiff's research recommended that all species should be conserved rather than limiting the Framework's remit to species of agricultural value. The research also proposed new indicators to support improved monitoring of genetic diversity of species **[3.7]**.

3. References to the research (indicative maximum of six references)

[3.1] Hoban S, Arntzen JA, **Bruford MW**, Godoy JA, Rus Hoelzel A, Segelbacher G, et al. (2014). Comparative evaluation of potential indicators and temporal sampling protocols for monitoring genetic erosion. *Evolutionary Applications*, 7, 984–998. DOI: 10.1111/eva.12197

[3.2] Moodley Y, **Russo IM**, Dalton DL, Kotze A, Muya S, Haubensak P, Balint B, Munimanda GK, Diemel C, Setzer A, Dicks K, Herzig-Straschil B, Kalthoff DC, Siegismund HR, Robovsky J, O'Donoghue P, **Bruford MW** (2017). Extinctions, genetic erosion and conservation options for the black rhinoceros (Diceros bicornis). *Sci Rep,* 7: 41417. DOI: 10.1038/srep41417

[3.3] Du Plessis SJ, Howard-McCombe J, Melvin ZE, Sheppard EC, **Russo IM**, Mootoocurpen R, Goetz M, Young RP, Cole NC, **Bruford MW** (2018). Genetic diversity and cryptic population re-establishment: management implications for the Bojer's skink (Gongylomorphus bojerii). *Conserv Genet*., 20 (2), 137-152. DOI: 1007/s10592-018-1119-y

[3.4] Hudson MA, Young RP, D'Urban-Jackson J, **Orozco-ter Wengel P**, Martin L, James A, Sulton M, Garcia G, Griffiths RA, Thomas R, Magin C, **Bruford MW**, Cunningham AA (2016). Dynamics and genetics of a disease-driven species decline to near extinction: lessons for conservation. *Sci Rep,* 6: 30772. DOI: 10.1038/srep30772

[3.5] Russo IM, Hoban S, Bloomer P, Kotze A, Segelbacher G, Rushworth I, Birss C, **Bruford MW** (2018). 'Intentional genetic manipulation' as a conservation threat. *Cons Genet Res*, 11 (2), 237-247. DOI: 10.1007/s12686-018-0983-6

[3.6] Hoban SM, Hauffe HC, Pérez-Espona S, Arntzen JW, Bertorelle G, Bryja J, Frith K, Gaggiotti OE, Galbusera P, Godoy JA, Hoelzel AR, Nicholas RA, Primmer CR, **Russo IM**, Segelbacher G, Siegismund HR, Sihvonen M, Vernesi C, Vila C, **Bruford MW** (2013). Bringing genetic diversity to the forefront of conservation policy and management. *Conservation Genet Resour,* 5, 593–598. DOI: 10.1007/s12686-013-9859-y

[3.7] Hoban SM, **Bruford MW**, et al. (2020). Genetic diversity targets and indicators in the CBD post-2020 Global Biodiversity Framework must be improved. *Biological Conservation*, 248. DOI: 10.1016/j.biocon.2020.108654

Selected grant:

[G3.1] FP-7 ENVIRONMENT "Conservation Genetic Resources for Effective Species Survival" (ConGRESS). Overall budget €1,140,421; 1/5/2010 – 30/4/2013; Grant ID 244250.

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

Since 2014, Cardiff research: 1) led to policy change in Namibia to counter the detrimental impacts of intentional genetic manipulation on ecosystems; 2) changed species-specific conservation practice for the African rhinoceros, Bojer's Skink and Monserrat Mountain Chicken Frog; and 3) generated global standards for monitoring biodiversity, used worldwide in conservation, and influencing the proposed EU Biodiversity Strategy 2030.

4.1 Combatting genetic manipulation in Namibia

Trophy hunting is a multi-million dollar industry in some Africa nations (article in *The Conversation,* 'Counting the contribution of hunting to South Africa's economy', 15 November 2018), and creation of game animals with unnatural genetic traits, such as specific novel coat colours, has become a threat to natural biodiversity. The Namibian Government engaged with the International Union for Conservation of Nature (IUCN) Conservation Genetics Specialist Group (CGSG) to facilitate development of a robust policy designed to stop these genetic manipulations. Based on Cardiff research **[3.5]**, the Namibian Government launched a National Policy on Selective and Intensive Breeding of Wildlife for Commercial Purposes **[5.1]** to "*protect the long-term viability of…wildlife populations*" **[5.2]**. The policy committed to **[5.1]**:

i. regulate the practice of selective and intensive breeding "through development of regulations…including the registration of selectively and intensively bred animals";

ii. manage and mitigate "environmental aspects associated with intensive and selective breeding of wildlife";
iii. monitor "genetic integrity of the selectively and intensively bred wild animals…and to protect free roaming wildlife from potential impacts of genetic manipulation".

Deputy Director of Wildlife Monitoring and Research in the Ministry of Environment and Tourism, Namibia confirmed: *"The involvement of the IUCN Conservation Genetics Specialist Group via Professor Mike Bruford…and the recent publication of the article 'Intentional Genetic Manipulation' as a conservation threat'* **[3.5]***…has played a central role in the development of our policy thinking in this arena"* **[5.2]**.

4.2 Species-specific genetic conservation

Through leadership of the IUCN CGSGs, and a long-term collaboration between the Cardiff team and the Durrell Wildlife Trust, Cardiff research changed conservation management plans for the following endangered species:

a. Bojer's skink

Found only in Mauritius, conservation of the Bojer's skink was a critical priority for the Mauritian Wildlife Foundation (MWF). Working in conjunction with the National Parks Service of Mauritius, the MWF's Conservation Director confirmed that Cardiff research **[3.3]** analysing the genetic diversity of the local population "*supplied the evidence required to assist our conservation efforts"* **[5.3]**. The Foundation used the 2018 analysis **[3.3]** to support translocation of populations between Mauritius' islands. This evidence helped "*in managing the re-establishment of the skink populations on Il de la Passe and Ile aux Fouquets"*, two islands where the native populations had significantly diminished **[5.3]**. "*A further two skink translocations from the other islands"* were since undertaken **[5.3]**.

b. Montserrat Mountain Chicken Frog

The Durrell Wildlife Trust used Cardiff research on the genetic diversity of the Montserrat Mountain Chicken Frog **[3.4]** to improve their captive breeding programme. The Trust's Head of Herpetology, notes that Cardiff's study was the "*first to describe the impact of the* [chytridiomycosis] *disease on the genetic diversity of an affected species*" **[5.4]**. Cardiff's confirmation that the Trust currently held "*a representative sample of genetic diversity from the species*" **[5.4]** allowed the organisation to design a new captive breeding programme which avoided the need for additional animals. The research "*was essential in developing our captive breeding strategy for the species, excluding the need for further collections of individuals, with the focus now on maintaining the diversity already present*" **[5.4]**.

Further, having discovered that the two remaining populations of frog on Dominica and Montserrat had the same mitochondrial haplotype, the Trust consolidated their species management across the two islands: "*Using this finding as evidence… we moved from managing the populations independently, to managing them as a single unit. This has freed up resources*" **[5.4]**. The Trust committed to use the insights beyond the frog population: "*In Durrell's wider work, this has made us more cognisant of the need for pre-emptive action in securing genetic diversity in populations facing similar disease threats*" **[5.4]**.

c. African rhinoceros

Cardiff research on the African rhinoceros **[3.2]** was also highly prized by the IUCN African Rhino Specialist Group. A joint statement from the Chair and Scientific Officer of the group confirmed: "*Our genetics education has been advanced thanks to the understandable and clear way…[Bruford] presented and explained the latest genetic issues and concepts (especially to those of us rhino conservationists who are not geneticists)*" **[5.5]**. Previously absent, genetic data is now used in conservation strategies for these critically endangered animals. For example, it was used to inform a decision "*to move away from the static idea of a subspecies to the dynamic idea of populations"* **[5.5]**. The Africa Rhino Specialist Group committed to use the insights to "*inform future translocation planning*", in particular information about when genetic exchange in specific situations is and is not an optimal conservation option **[5.5]**.

4.3 Global impact on biodiversity policy and standards

a. Global standards for monitoring genetic biodiversity

Cardiff researchers partnered with the Group on Earth Observations (GEO), a global collaboration of 111 world governments and a further 129 'participating organisations', including UNEP (United Nations Environment Programme). GEO uses big data to tackle some of the world's most complex challenges in sustainable development and environmental management. Working directly with the GEO Biodiversity Observation Network initiative, the Cardiff team played a key role in the production of *The GEO Handbook on Biodiversity Observation Networks,* a manual setting out global standards for genetic monitoring of biodiversity **[3.1, 3.2, 5.6]**.

The *Handbook* has been downloaded 251K times since its 2017 publication **[5.7]**. 'Chapter 5: Monitoring Changes in Genetic Diversity' (co-authored by Bruford and informed by Cardiff's genetic conservation research **[3.1]**) was cited in a UN Environment Program policy document highlighting the importance of genetic diversity "in maintaining and enhancing the diversity of cultivated plants and breeds of livestock underpinning the resilience of agricultural systems and food security" **[5.8**, p153**]**.

b. *EU Biodiversity Strategy 2030*

In January 2020, the UN Convention on Biological Diversity (CBD) started consultation on a draft *Post 2020 Global Framework on Biodiversity*. Bruford's research highlighting the deficiencies of the draft Framework **[3.7]** also influenced the *EU Biodiversity Strategy 2030*. While finalisation of the *Global Framework* was impeded by Covid-19, the *EU Biodiversity Strategy 2030* launched in May 2020 **[5.9]**.

The *EU Biodiversity Strategy* implements Bruford's recommendations **[3.7]** to ensure a broader focus on species outside of agriculture. Moving beyond agricultural species protection, the EU Strategy further commits to "no human-induced extinction of species" and establishes a target that "[t]here is a 50% reduction in the number of Red List species [the IUCN's species at risk of extinction] threatened by invasive alien species" **[5.9]**. To achieve this, the Strategy commits that (a) the EU should "set up ecological corridors to prevent genetic isolation" and (b) each member state should "ensure no deterioration in conservation trends and status of all protected habitats and species by 2030" **[5.9]**.

In summary, Cardiff research on genetic diversity and conservation shaped policy, recommendations and engagement work of the IUCN CGSGs, a critical platform which transformed conservation policy, and practice in endangered species management, around the world.

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

[5.1] Namibian National Policy on Selective and Intensive Breeding of Wildlife for Commercial Purposes (2018)
[5.2] Testimonial: Deputy Director, Wildlife Monitoring and Research, Namibian Government
[5.3] Testimonial: Conservation Director, Mauritian Wildlife Foundation
[5.4] Testimonial: Head of Herpetology, Durrell Wildlife Conservation Trust
[5.5] Testimonial: IUCN SSC African Rhino Specialist Group
[5.6] Walters M, Scholes RJ (eds), 2017. *The GEO Handbook on Biodiversity Observation Networks* Chapter 5 "Monitoring Changes in Genetic Diversity"
[5.7] Springerlink webpage for GEO Handbook on Biodiversity Observation Networks, showing number of downloads
[5.8] *Global Environment Outlook – GEO-6: healthy planet, healthy people* (2019)
[5.9] *EU Biodiversity Strategy 2030* (2020)