Institution:
University of Leeds

Unit of Assessment:
UoA5 Biological Sciences

Title of case study:
CS6 Biosecurity and sustainable tourism in the Galapagos Islands

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

The impacts in this case study arise from research into the pathways, and processes by which novel vectors and vector borne diseases may be introduced into the Galapagos islands. On the basis of the research, the Ecuadorian government changed national legislation on biosecurity, and implemented a suite of new mitigation measures including requiring all aircraft flying to Galapagos to have disinsection treatments, and banned direct international flights to the archipelago. The work increased general awareness of potential impacts from introduced diseases on Galapagos biodiversity, and the need to improve the biosecurity of the islands, influencing policy decisions in a range of other international organisations including UNESCO. The globally important biodiversity of Galapagos is the basis of a significant fraction of the tourist and national economy of Ecuador.

2. Underpinning research (indicative maximum 500 words)

The impacts derive from research started in 2003 to identify potential disease risks to native Galapagos species, and to understand the biological, ecological and socioeconomic factors driving impacts from introduced pathogens. The programme also aimed to build physical and human capacity for the Ecuadorian authorities to identify and manage disease risks to Galapagos. The lessons learnt in this system are generaliseable to introduced disease impacts on other vulnerable ecosystems globally. Several of the papers arising from this research e.g. references **1** and **2**, are now highly cited in relation to other studies and reviews of disease invasions.

Goodman was the PI for the overall programme and supporting grants. **Goodman**, together with Cunningham and Cedeño conceived the programme and managed the staff implementing the work. The work was started in 2003 while **Goodman** was a research fellow at the Institute of Zoology (IoZ), Zoological Society of London, before his move to Leeds in November 2004. The programme continued for 11 years, led by **Goodman** (at Leeds 2004-2013) and was performed in collaboration with IoZ, together with the University of Guayaquil (UoG), Ecuador, the Galapagos National Park Service (GNP), Concepto Azul (an Ecuadorian biotechnology/social enterprise organisation), New York State Department of Health (NYS DoH) and the US (New York) NGO Ecohealth Alliance.

The specific impacts presented here arose from the development of a risk analysis framework to assess pathways for the potential introduction of West Nile Virus **(1)**, and studies of the population genetics and disease ecology of mosquito species in Galapagos, conducted to refine models of the potential epidemiology of West Nile Virus should it be introduced **(2-6)**. The Kilpatrick *et al.* (2006) risk analysis **(1)** was developed at an expert workshop in 2004 (Galapagos West Nile Virus Workshop, Galapagos National Park Headquarters, Puerto Ayora, 29th April 2004), co-organised by **Goodman** as part of Darwin Initiative grant 162-12-17. Kilpatrick was engaged by **Goodman** and Cunningham to provide modelling expertise, while **Goodman** and other participants of the workshop defined and parameterised the system to be modelled.

Transport of infectious mosquitoes on aircraft **(1)** posed the most significant risk for the introduction of West Nile Virus and other vector borne diseases to the Galapagos. This prediction was confirmed **(2)** using genetic approaches, showing that there had been regular ongoing introductions of the mosquito *Culex quinquefasciatus* from the continent via aircraft, and that human activities were transporting mosquitoes around the islands. Only native species of mosquito (*Aedes taeniorhynchus*) had the potential to be a bridge vector for disease transmission among multiple species, and that the population structure, and human transport would likely allow rapid dissemination of any invading vector borne disease **(3,4)**. *Culex quinquefasciatus* and *Aedes taeniorhynchus* in Galapagos were shown to be competent vectors for West Nile Virus **(5,6)**, and therefore that a significant risk existed that a West Nile Virus disease cycle could be initiated were the pathogen to reach the archipelago.

Lead investigator: Dr Simon **Goodman** (University of Leeds 2004-Present)
Co-Investigators: Prof Andrew Cunningham (IoZ 2003-present); Dr Virna Cedeño (UoG/Concepto Azul, Ecuador 2003-present)

Collaborators: Dr Marm Kilpatrick & Dr Peter Daszak (EcoHealth Alliance, New York, USA, 2004-2006); Dr Laura Kramer (NYS DoH, USA, 2004-present)
Researchers at Leeds (on grants in the programme): Mr Leandro Patiño (Research assistant, 2004-2007); Dr Marilyn Cruz (Research assistant, 2004-2009); Dr Arnaud Bataille (PhD student, 2005-2009); Dr Gillian Eastwood (PhD student, 2007-2012); Mr A. Constaninou (Leeds Masters Student, 2007).

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

1. Kilpatrick AM, Daszak P, **Goodman** SJ, Rogg H, Kramer LD, Cedeño V, and Cunningham AA (2006) Predicting Pathogen Introduction: West Nile Virus Spread to Galápagos. *Conservation Biology* **20:**1224-1231. DOI: 10.1111/j.1523-1739.2006.00423.x [Scopus citations 30/08/2013: 37]
2. Bataille A, Cunningham AA, Cedeño V, Cruz M, Eastwood G, Fonseca D, Causton CE, Azuero R, Loayza J, Cruz Martinez JD, and **Goodman** SJ. (2009) Evidence for regular ongoing introductions of mosquito disease vectors into the Galápagos Islands. *Proceedings of the Royal Society of London B.* **276**:3769-3775. DOI: 10.1098/rspb.2009.0998 [Scopus citations 30/08/2013: 11]
3. Bataille A, Cunningham AA, Cedeño V, Patiño L, Constaninou A, Kramer LD, and **Goodman** SJ (2009) Natural colonization and adaptation of a mosquito species in Galápagos and its implications for disease threats to endemic wildlife. *Proceedings of the National Academy of Sciences of the United States of America* **106**:10230-10235. DOI: 10.1073/pnas.0901308106 [Scopus citations 30/08/2013: 16]
4. Bataille A, Cunningham AA, Cruz M, Cedeno V, and **Goodman** SJ. (2011). Adaptation, isolation by distance and human-mediated transport determine patterns of gene flow among populations of the disease vector *Aedes taeniorhynchus* in the Galapagos Islands. *Infection, Genetics and Evolution* **11:** 1996-2003. DOI: 10.1016/j.meegid.2011.09.009 [Scopus citations 30/08/2013: 2]
5. Eastwood G, Kramer LD, **Goodman** SJ, and Cunningham AA (2011) West Nile Virus vector competency of *Culex quinquefasciatus* mosquitoes in the Galápagos Islands. *American Journal of Tropical Medicine & Hygiene* **85:**426–433. DOI: 10.4269/ajtmh.2011.10-0739 [Scopus citations 30/08/2013: 2]
6. Eastwood G, **Goodman** SJ, Cunningham AA, and Kramer LD. (2013) *Aedes taeniorhynchus* vectorial capacity informs a pre-emptive assessment of West Nile virus establishment in Galápagos. *Scientific Reports*, **3**, Article Number: 1519. DOI: 10.1038/srep01519 [Scopus citations 30/08/2013: 0]

Grants: The work was funded by 2 Darwin Initiative grants to **Goodman** as PI (refs: 162-12-17, £260,713, 2003-2006; EIDPO15, £119,696, 2006-2009) and colleagues; a Marie Curie doctoral training grant which supported Bataille (PhD registered in Leeds, supervised by **Goodman** and Cunningham, 2005-2009); a NERC molecular genetics facility grant (to **Goodman** and Cunningham, ~£15,000, 2007) and a NERC PhD studentship which supported Eastwood (PhD registered in Leeds, supervised by **Goodman**, Cunningham and Kramer, 2007-2011).

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

Our research led to new national legislation and a major shift in national biosecurity policy in Ecuador, together with the implementation of new biosecurity measures for the Galapagos islands.

Context: Galapagos biodiversity is unique and has an immense economic value to Ecuador as it drives a large part of the Ecuadorian tourist industry, which is the 3rd largest contributor to Ecuadorian GDP (contribution estimated at US$1.24 billion for 2011: World Travel & Tourism Council – Travel and Tourism Economic Impact 2012: Ecuador). Moreover Galapagos biodiversity has a priceless global scientific and cultural value for the role it played in the formulation of Darwin's theories, and as a natural laboratory for modern evolutionary and conservation science. Biosecurity issues are the primary threat to the sustainability of Galapagos biodiversity, therefore it is critical to have appropriate science based biosecurity protection measures in place for the archipelago.

Overview of how the research led to impact: The underpinning research identified critical pathways for West Nile Virus introduction, and other ecological risk factors, and recommended specific biosecurity mitigation measures to reduce the risks of infectious West Nile Virus vectors and hosts being transported to the islands. The initial stimulus was the 2004 West Nile Virus

workshop. After the workshop, the local stakeholder participants considered the potential threat to Galapagos of such concern that they initiated lobbying of the Ecuadorian government and airlines to develop the necessary changes in government policy and legislation. The workshop also identified research priorities which **Goodman** led from Leeds. The subsequent research provided the empirical evidence to substantiate the risk factors first identified during the workshop. Together, the workshop report (Proceedings of the Galapagos West Nile Virus workshop, Galapagos National Park Headquarters, Puerto Ayora, 29th April 2004), and papers arising from the later research (**1-6**, above), were used to inform legislative and policy changes, which have been in force (see below) throughout the REF period. Once these legislation and policy changes were in place, the institutions went on to implement the recommended mitigation measures to enhance biosecurity for Galapagos. Our team (**Goodman**, Cunningham and Cedeño) supported the relevant institutions with technical advice and provided the supporting scientific evidence throughout the lobbying process, and the implementation of the new mitigation measures.

Specific impacts: A summary of the impact is given below. Some activities took place 2004-2007, these are not claimed below as REF impact, but they are presented as part of a continuum which led to the key impacts in the REF period of the implementation of the biosecurity measures recommended by the original research.

i) **Changes in Ecuadorian national legislation:** Following the April 2004 workshop, Galapagos stakeholders immediately began lobbying the Ecuadorian government's Ministry of Environment, requesting that the policy changes recommended by the West Nile Virus workshop be reflected in national legislation. The lobbying was primarily driven by UN Global Environment Facility project staff based in Galapagos, and a local independent conservation consultant to the Galapagos National Park Service. This continued to 2006 when the change in legislation was enacted **[A-E]**. As recommended by the 2004 workshop, the new national legislation on aircraft biosecurity (which has been in full force throughout the REF impact period) required disinsection treatments on all aircraft flying to Galapagos **[E]**, banning of direct international flights to Galapagos **[E]**, and restriction to Quito and Guayaquil as the point of origin for all Galapagos flights **[E]**. The Ecuadorian Civil Aviation Authority was responsible for enforcing the legislation, requiring compliance from Ecuador's 3 major airlines serving the islands.

ii) **Lobbying, technical consultation, and implementation of mitigation measures on aircraft**: Prior to the REF period (between May 2004-Dec 2007), we supported a lobbying and technical consultation for the uptake of mitigation measures by Ecuadorian airlines (TAME, AeroGal, LAN). The lobbyist helped the airlines source the materials and procedures necessary for the disinsection treatment of their aircraft. From September 2008 (ongoing to present), this resulted in the adoption of a World Health Organisation approved disinsection treatment on all aircraft flying to Galapagos **[F]**; the banning of direct international flights to Galapagos; and restriction to Quito and Guayaquil as the point of origin for all Galapagos flights **[A-C]**. In addition to the changes to practice by the 3 airlines (which together fly more than 150,000 passengers per year to Galapagos), compliance and monitoring procedures were established by the relevant government agencies (Civil Aviation Authority, Ministry of Environment; **[A-C, F]**.

iii) **Development and implementation of West Nile Virus emergency response plan:** During 2006 **Goodman** & Cunningham were commissioned to produce an emergency response plan for West Nile Virus (by UN GEF project). Testing and implementation of the plan took place in 2007. The plan was adopted by all Galapagos management agencies from 2008 onwards, and remains to present as the official response procedures should West Nile Virus be detected in Galapagos **[A-C, G]**. The response plan influences practice by all the Galapagos management institutions, and potentially the whole population (>30,000 people) in the event of an introduction.

iv) **Lobbying, technical consultation, and implementation of mitigation measures on boats:** Beginning in 2007 the lobbyist used our research to drive the uptake of 'insect zappers' on tourist boats travelling around the archipelago to reduce accidental transport of insects between islands. This practice was adopted from 2008 onwards, and now continues to be used by all tourist operators to present **[A-C]**. At the time of writing lobbying by

stakeholders is ongoing for the introduction of disinsection procedure for cargo ships travelling to Galapagos. Together the practice changes relating to aviation and boat travel influence a tourist industry worth 100s of millions of dollars per year **[A-C]**.

v) **Wider recognition of disease threats and increased investment in biosecurity control capacity:** Our research contributed to the recognition of introduced diseases as a major threat to the Galapagos by the Ecuadorian authorities and wider international community including UNESCO. Between 2007-2010, UNESCO placed the Galapagos on the 'List of World Heritage Sites in Danger'. The risk of West Nile Virus and inadequate quarantine procedures were cited as part of the justification for this **[H]**. During the REF period, there has been increased investment in biosecurity infrastructure and personnel by the Ecuadorian government leading to restructuring of the Ecuadorian agricultural health and quarantine agency and establishment of the Agencia de Regulacion y Control del la Bioseguridad y Cuarentena para Galapagos, which now has responsibility for Galapagos biosecurity. The increased investment is ongoing, but is estimated to exceed US$10 million during the REF period **[A-C]**. Improvements in biosecurity measures contributed to the removal of Galapagos from the UNESCO at risk register in 2011.

Although not listed as a formal impact, there has been intense media interest arising from the underpinning research and the issues it raises relating to Galapagos biosecurity. There have been 100s of newspaper and internet articles (including features in major national newspapers in several countries) about our mosquito research, plus TV and radio interviews globally (e.g. **Goodman** and Cunningham were interviewed for Sky TV News, and the story was broadcast globally) and in Ecuador **[I]**. The coverage would suggest an increased public awareness of Galapagos biosecurity issues.

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

[A] Letter of confirmation – Executive Director Agencia de Regulacion y Control del la Bioseguridad y Cuarentena para Galapagos. Confirms that the research outputs from the University of Leeds made significant contributions to improving biosecurity of the Galapagos, guiding development and implementation of new biosecurity measures.

[B] Letter of confirmation – Director Galapagos National Park Service (05/03/2013). Confirms that policies which have a fundamental impact on improvement of biosecurity of the Galapagos Islands were directly derived from the research program of **Goodman** *et al.*

[C] Letter of confirmation – Independent conservation and technical consultant to Galapagos National Park Service (27/02/2013). Confirms that the research outputs of **Goodman** *et al*. were key to developing and implementing new biosecurity policies; confirms the support provided by **Goodman** *et al*. during the process of developing and implementing new legislation.

[D] Global Environment Facility (GEF) Project "Control of Invasive Species in the Galapagos archipelago" report. Hosted at http://www.thegef.org/gef/project_detail?projID=763
Defines the biosecurity strategy and actions for implementation consistent with Ecuadorian legislation (source E) informed by the **Goodman** research. Refers to risk assessments and contingency plans developed from the research.

[E] Ecuadorian statutes (2010) relating to aircraft biosecurity. Defines the new biosecurity legislation implemented as a result of the research. *Copy of original Spanish document and English translation available on request.*

[F] SESA SICGAL Aircraft disinsection procedure manuals. Defines procedures for aircraft disinsection based on recommendations originating from **Goodman**'s research. *Copy of original Spanish manual and English translation available on request.*

[G] West Nile Virus emergency response plan, prepared by **Goodman** and Cunningham, 2007: Emergency procedures to be implemented if West Nile Virus introduction occurs (in force to present day). *pdf of original Spanish document, and English translation available on request.*

[H] UNESCO State of Conservation Report http://whc.unesco.org/en/soc/1154/ section (a) accelerated loss of ecological isolation, citing West Nile Virus and inadequate quarantine as a threat to Galapagos. Refers to 2004 workshop.

[I] Selected list of media coverage, with links to ~100 high profile newspaper articles and other media covering the research.