Institution:	University of York
Unit of Assessment:	5, Biological Sciences
Title of case study:	Developing the rationale for landscape-scale conservation policies

1. Summary of the impact

York research on the responses of species to habitat fragmentation has led to a paradigm shift in the approach to conservation that has permeated non-governmental organisations (NGOs), governmental agencies and intergovernmental bodies; the traditional concept of protecting and managing populations of species in isolated reserves has largely been replaced by landscape-scale conservation strategies, which increase the long-term survival of species. This new approach is now accepted government policy and has altered practical land designation and management for conservation over millions of hectares in the UK, as well as affecting the strategies adopted by most global conservation organisations and countries in the world.

2. Underpinning research

A high fraction of the world's land surface has been converted to agriculture and other intensive land uses, leaving only small fragments of (semi-) natural habitats available for wild species to exploit. Professors Chris Thomas and Jane Hill played a pivotal role, collaborating with Ilkka Hanski and his research group in Helsinki, in developing the science of metapopulation ecology. They established that remaining habitat fragments are often too small for species to be able to survive indefinitely (there are high rates of local extinction in small and low-quality habitat patches), and hence long-term survival depends on the capacity of species to establish new populations in empty habitat patches (re-colonisation rates are higher for habitat patches that are close enough to be reached by dispersing individuals). Recognition of the significance of this work and its implications for policy are documented in Thomas' 2012 FRS citation (http://royalsociety.org/people/chris-thomas/). Thomas ranks 2nd after Hanski for numbers of 'metapopulation' citations, out of >8,000 authors listed by Web of Science (March 2013), and Hill features in the top 50. Hill has been based in York from 2001, and Thomas from 2004, since when they have published over 50 papers on habitat fragmentation and heterogeneity, including their work on the applications of metapopulation ecology. Their research at York has shown that:

- **Failed colonisation in fragmented landscapes results in habitat specialists declining** (Warren, Hill, *et al*. 2001). Hill carried out the key analyses for this paper in York.
- **Many suitable habitats are too isolated to be colonised naturally.** Hill, Thomas and three PDRAs at York showed that released butterflies were able to establish populations in empty habitat beyond their natural dispersal range (Menéndez *et al.* 2006).
- **Species spread rapidly across landscapes with high habitat availability.** Thomas' 30-year field survey and modelling project (the last ten years at York) shows that silver-spotted skipper butterflies spread faster in landscapes containing more, larger, more suitable and less isolated patches of habitat (e.g. Wilson *et al*. 2009).
- **Species disproportionately colonise nature reserves when they spread across fragmented landscapes** (Thomas *et al*. 2012). Thomas and Hill co-ordinated this NERC project, which involved collaboration with multiple NGOs and government agencies.
- **Habitat quantity, quality, and spatial arrangement are key predictors of population persistence, and hence conservation success** (e.g. Hodgson *et al*. 2009).
- **Habitat aggregation, which favours metapopulation survival, can be integrated into highly efficient conservation strategies.** Thomas and York PDRAs contributed to the development and implementation of a novel approach to spatial conservation planning; the Zonation software (Moilanen *et al*. 2005 *et seq*).

Our conclusion is that both the survival and range expansion of species are enhanced if habitats are large in area, of high quality, and sufficiently close together to enable the (re)colonisation of empty habitats. This requires conservation of entire networks of habitat patches over regions of 100 km^2 to >10,000 km^2. The traditional emphasis on protecting single populations in individual habitats or nature reserves thus needed to be transformed into a landscape-scale approach to ensure that populations and species will survive over periods of a century or more.

3. References to the research. This work has been funded by peer-reviewed NERC and European grants/fellowships, and published in high-ranking journals, including *Nature* and *PNAS*. York PIs are shown in **bold**, York-associated PDRAs & students underlined, NGO/Charity co-

authors *italicised*. Governmental co-authors in CAPS. Citation data from Google Scholar, Sept 2013.

Hodgson J.A., **Thomas C.D.**, Wintle B. & Moilanen A. (2009) Climate change, connectivity and conservation decision making: back to basics. *J. Appl. Ecol.* **46**, 964-969. DOI: 10.1111/j.1365-2664.2009.01695.x. >130 citations

Menéndez R., González-Megías A., **Hill J.K.**, Braschler B., Willis S.G., Collingham Y., *Fox R.*, Roy D.B. & **Thomas C.D.** (2006) Species richness changes lag behind climate change. *Proceedings of the Royal Society, B*. **273**, 1465-1470. DOI: 10.1098/rspb.2006.3484. >155 citations

Moilanen A., Franco A.M.A., Early R.I., *Fox R.*, Wintle B. & **Thomas C.D.** (2005) Prioritising multiple-use landscapes for conservation: methods for large multi-species planning problems. *Proc Roy Soc, B.* **272**, 1885-1891. DOI: 10.1098/rspb.2005.3164. >165 citations

Thomas C.D., Gillingham P.K., *Bradbury R.B.*, Roy D.B., Anderson B.J., BAXTER J.M., *Bourn N.A.D.*, CRICK H.Q.P., FINDON R.A., *Fox R.*, Hodgson J.A., Holt A.R., MORECROFT M.D., O'Hanlon N.J., Oliver T.H., Pearce-Higgins J.W., PROCTER D.A., Thomas J.A., *Walker K.J.*, WALMSLEY C.A., Wilson R.J. & **Hill J.K.** (2012) Protected areas facilitate species' range expansions. *Proceeding of the National Academy of Sciences, USA.* **109**, 14063–14068. DOI: 10.1073/pnas.1210251109. 18 citations

Wilson R.J., Davies Z.G. & **Thomas C.D.** (2009) Modelling the effect of habitat fragmentation on range expansion in a butterfly. *Proc Roy Soc, B.* **276**, 1421-1427. DOI: 10.1098/rspb.2008.0724 >35 citations

Warren M.S., **Hill J.K.** *et al.* (2001) Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature* **414**, 65-69. DOI: 10.1038/35102054. >630 citations

4. Details of the impact

The work by York researchers **changed conservation mind-sets, strategies and practice**. Traditional conservation concentrated on the protection and management of individual sites, despite continued degradation taking place elsewhere. York metapopulation research showed that populations generally require networks of habitat patches to persist and spread, and hence stimulated a paradigm shift permeating NGOs, governmental agencies and intergovernmental bodies, whereby the 20th century 'isolated population' conceptual framework for conservation has largely been replaced by landscape-scale thinking and policies. These aim to maintain and restore habitat networks and connections to ensure the long-term survival of species in landscapes where habitats are fragmented.

Reaching and collaborating with stakeholders. York researchers reached a broad audience by extensive dissemination through the media, individual discussions, correspondence and workshops. Thomas and Hill gave >200 oral presentations and contributed to >25 meetings with NGOs, agencies and governmental bodies since 2008. They pioneered co-working with stakeholders, for example developing the UKPopNet programme (2004-2010) that was co-funded by English Nature and NERC (Fitter was Director). Thomas and Hill co-ordinated a NERC-funded Knowledge Exchange grant (2010-11) involving Defra, Natural England, Scottish Natural Heritage, Countryside Council for Wales (CCW, now Natural Resources Wales, NRW), Joint Nature Conservation Committee, Royal Society for the Protection of Birds (RSPB), Butterfly Conservation (BC), Botanical Society for the British Isles, British Trust for Ornithology, Centre for Ecology & Hydrology, and Forest Research. This and other projects resulted in multiple York-Government-NGO co-authored articles (e.g. Thomas *et al*. 2012) and lectures, influencing participant organisations and their membership.

Impacts on NGO policy and practice in the UK. UK conservation NGOs have developed landscape-scale programmes to meet the challenges that the York research identified, e.g.:

- **Butterfly Conservation's Landscape Target Areas** (BC 2012) were directly inspired by Thomas and Hill's underpinning research: "*Prof Thomas' research on the impact of habitat fragmentation and the functioning of metapopulations has been a strong driving force in the development of Butterfly Conservation's landscape scale approach to the conservation of threatened species*", according to BC's Chief Executive, Martin Warren. BC Target Areas cover >5 million ha (>20% UK land), including locations identified by York Zonation analyses. BC helps manage ~300,000 ha, where BC staff and "*13,000 active volunteers contributing over £9.5 million worth of labour during the financial year 2010/11*" work with local communities, NGOs and government bodies to deliver landscape-scale conservation. BC's (2012) report on

the scheme's outstanding success was launched by Biodiversity Minister Richard Benyon (House of Commons, 04/12/12; Thomas an invitee). Metapopulation principles developed by York researchers were used to establish new habitats within species' colonisation distances, leading to the following increases by threatened species: 55% increase in area occupied by the Heath Fritillary in Kent (2008-11), 395% increase in Duke of Burgundy abundance in a Yorkshire metapopulation (1999-2011), up to 167% more colonies of four Lepidoptera in Warwickshire (2008-11), 1000% increase in Marsh Fritillary in a managed metapopulation on Dartmoor (2005-10), and 200% increase in Pearl-bordered Fritillary population size in the Wyre Forest (2008-11; BC 2012). "*The success we have recorded with this approach is undoubtedly because it is rooted in the sound science produced by Prof Thomas and his team*" according to Warren, and "*Prof Hill's research … has been equally influential, helping us understand … why some species have been constrained by lack of connected habitats … justifying our efforts to link up habitats in the landscape...*"

- **Invertebrate conservation NGO Buglife developed 'B-lines'** to connect landscapes; to create and restore 150,000 ha of flower-rich habitat across Britain through community and NGO activities, with implementation started in Yorkshire and Humber. The "*main principles and guidelines of the B-lines approach developed in consultation with Jenny Hodgson* [York PDRA] *and Chris Thomas* [of the] *University of York*" (Evans 2012).
- **The Royal Society for the Protection of Birds** invited Thomas to provide the scientific basis underpinning its **Futurescapes** programme at its Westminster launch (Keynote, 07/06/10). Futurescapes aims to connect fragmented landscapes and is funded by the EU-Life Nature programme to "*encourage the development and implementation of landscape-scale conservation... in 34 priority areas across the UK* [which] *cover... 2.18 million ha*". The scientific rationale influenced a change in NGO practice, whereby ~1,300 RSPB staff and ~18,000 volunteers work with landowners and other stakeholders to improve wildlife and societal appreciation of the countryside in Futurescape projects across 9% of the UK.
- **The Wildlife Trusts** (47 UK County Wildlife Trusts) **have developed over 100 Living Landscapes**, covering 1.5 million hectares (6% of UK land surface), explicitly in response to the problem of habitat isolation in fragmented UK landscapes – identified most clearly for UK landscapes by the York authors; the Scottish Wildlife Trust, for example, citing Moilanen *et al.* (2005) as evidence that "*a patchwork of habitats* [will] *increase functionality through… enhancing metapopulations*" (Hughes & Brooks 2009).

Policy reviews, government policies and land designation in the UK. Our underpinning science has been central to national policy developments:

- York research featured prominently in the two major reviews of conservation and environmental management in Britain. Fitter was a co-author and Thomas provided evidence to **Defra's Lawton Review** (Lawton *et al.* 2010) on the future of conservation. According to Sir John Lawton, the "*York research was critical to* [my] *2010 government-commissioned review for Defra… which has more citations to Thomas and Hill than to any other ecologists upon whose work we draw*". York work is also quoted extensively in the **National Ecosystem Assessment** (NEA), where Thomas, Hill and Fitter-authored work is cited in 16 separate NEA chapters.
- The Lawton and NEA Reviews, and hence York research, provided the evidence base for the **Natural Environment White Paper** (Defra 2011), establishing the government conservation strategy. The Secretary of State's speech to launch the White Paper repeated the Lawton conclusion that "*we need more, bigger, better, joined up*" conservation; itself a conclusion that directly stems from our work.
- The White Paper initiated **Nature Improvement Areas** (NIAs) to deliver landscape-scale conservation, as suggested by Lawton *et al.* (2010), drawing on York work. A national NIA competition took place, involving 76 bidding landscapes. Thomas has provided advice to representatives of four (South Downs, Purbeck, North Devon, Morecambe Bay) of the 12 successful bids. According to Lawton, by "*a chain of events (original research with seminal contributions from York, establishment of scientific consensus, my government-commissioned review, government policy development, co-ordination of the Nature Improvement Area competition by the government agency Natural England, and awards of NIA status to a dozen landscapes), new management strategies for biodiversity have been achieved over large areas of some of the most important parts of the English landscape for biodiversity, and created some*

remarkable consortia of people from all walks of life to make it happen." The consortium members include farmers, other land-owners, councils, businesses, utility companies, Environment Agency, conservation NGOs, and other citizens.

- NIAs generated **new conservation strategies for hundreds of thousands of hectares** (Natural England 2012), leveraged over £40m of additional funds, and generated over 3000 *additional* volunteer days in the first 9 months alone, according to Chris De Grouchy of Defra (27/3/13). Conservation management changes are achieved in priority landscapes by Defra-funded Higher Level Stewardship (200,000 ha in 2012/13, 400,000 ha in 2013/14), Landfill Tax and EU (Life); over £1 billion *pa* is spent to maintain and improve rural environments at farm and landscape scales (Nat Eng ~£650m; Scot Govt ~£500m; Welsh Govt ~£240m).
- Comparable projects are taking place in Wales and Scotland (e.g. CCW/NRW established the first designated metapopulation-scale Site of Special Scientific Interest, in response to our work on the Marsh Fritillary butterfly in Wales). **Landscape-scale conservation now covers around 25% of land in Britain**, with at least 800 active projects of 10 km^2 or larger (Dr N Macgregor, Nat Eng, 27/03/13).

Impacts on international policies and conservation actions. International impact has been achieved by the published scientific literature reaching an international audience (>5000 citations), helping to develop a globally-distributed pool of experts who have influenced NGOs and governments participating in the development of global biodiversity strategies and treaties. The Pan-European Ecological Network, International Union for the Conservation of Nature red-listing criteria, World Wildlife Fund landscape-scale projects in >50 countries, Conservation International of 'biodiversity hotspots', and US-based Nature Conservancy 'threatened areas' all address habitat fragmentation issues; drawing on York-influenced metapopulation and spatial ecology as a component of the scientific justification. For example:

The Zonation approach, co-developed by Moilanen in Helsinki and York, **has been used to develop practical conservation applications in at least six countries**, using metapopulation principles. Tom Lovejoy, formerly Chief Biodiversity Adviser to the President of the World Bank and Senior Adviser to the President of the United Nations Foundation, notes that the software has been applied directly to practical conservation: "*in Finland (forest conservation*) *… for northern spotted owls in the USA, in Australia (Victoria State* [and] *around Melbourne),* [and] *in New Zealand (river conservation priorities … marine priority areas …). Professor Thomas and colleagues have produced the most detailed conservation prioritisation analysis for any tropical biodiversity hotspot ever–for Madagascar. Not a textbook example, this has actually been implemented by extending the protected area system by over 4 million hectares*" (in conjunction with additional information; Atlas Team 2009). These locations will safeguard animal and plant species in one of most evolutionarily distinct (~80% endemic) and threatened biodiversity hotspots on Earth.

5. Sources to corroborate the impact

Atlas Team (2009) *Madagascar Digital Conservation Atlas Report*. Final Version 2009.

BC (2012*) Landscape Scale Conservation.* http://tinyurl.com/BC-Landscape-Scale

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Evans, P. (2012) Making B-Lines. Buglife, UK. http://www.buglife.org.uk/campaigns-and-our-work/habitat-projects/b-lines

Hughes, J & Brooks, S (2009) Living landscapes. Scottish Wildlife Trust, Edinburgh

Lawton, J.H. … Fitter, A. *et al.* (2010) *Making Space for Nature: a review of England's wildlife sites and ecological network.* DEFRA. http://tinyurl.com/spacefornature

Lawton, Sir John (2013) Letter dated 7th March 2013.

Lovejoy, T. (2013) Letter dated 5th March 2013.

Natural England (2012) *The 12 Nature Improvement Areas* http://tinyurl.com/The12NIAs

RSPB Futurescapes Programme (2010) http://www.rspb.org.uk/futurescapes/ & http://www.rspb.org.uk/community/ourwork/b/markavery/archive/2010/06/08/futurescapes-launch.aspx

UK NEA (2011) The UK National Ecosystem Assessment. http://uknea.unep-wcmc.org/

Warren, M. S. (2013) Letter dated March 2013