Institution: University of Oxford

Unit of Assessment: UOA5

Title of case study:

Securing the future of the globally threatened Large Blue butterfly

1. Summary of the impact

The Large Blue butterfly, formerly extinct in the UK, was successfully reintroduced over two decades to sites in south-west England. New research at the University of Oxford has greatly improved its conservation status and identified key factors that determine the ability of this extreme specialist to survive, especially in the context of climate change. Since 2008 this has led directly to new, larger and more stable populations, to significant expansion of the butterfly's range into cooler regions, and to new 'races' with greater environmental tolerance. The research has thus contributed directly to the positive upgrading of this species' global conservation status.

2. Underpinning research

The Large Blue butterfly, *Maculinea arion*, is an extreme specialist: larvae feed briefly on thyme flowers before living for 10 months underground in *Myrmica* ant colonies, preying on ant grubs whilst being tended by the workers whose Queens and larvae they mimic[1-3]. In the 20th century the species declined across Europe, becoming extinct in the UK in 1979 despite huge efforts to protect its dwindling colonies. In the 1980s Professor Jeremy Thomas, then at the Centre for Ecology & Hydrology, led a major initiative to reintroduce *M. arion* to restored UK habitats. His research established that *M. arion* survival depended on sufficient densities of one ant, *Myrmica sabuleti*, a warmth-loving species that requires a very short sward (< 1.4 cm) to maintain optimum temperatures in its brood chambers. These findings informed conservation efforts, and led to intensive regimes of grazing to maintain critical grass lengths: by 2006 several sites held colonies of the butterfly although with one exception, all were small, isolated and unstable.

In 2007, Professor Thomas moved to the University of Oxford's Department of Zoology where his greatly increased scope for research has not only improved existing conservation practices for *M. arion* but also identified important factors that determine its survival (and that of other endangered species) both now and as future environments change.

At Oxford, Thomas' studies of the ecology, population dynamics, behaviour and physiology of *M. arion* (and other *Maculinea* species) confirmed, and for the first time quantified, the extreme host specificity of this butterfly and its close relatives[3]. The research revealed important new findings about habitat quality and the butterfly's ability to disperse and persist in meta-populations across landscapes[4]. New analyses of population dynamics[1,4] quantified the need for ≥ 68% of initial larval foodplants to grow within foraging range of *M. sabuleti* for a population of *M. arion* to persist. The analysis also showed, remarkably, that habitat with 100% coexistence supported *c.*100-fold higher densities of butterfly than other apparently suitable, but sub-optimal, habitats. Similar micro-habitat variation was shown to affect other butterfly species, providing the first explanation as to why many species whose potential UK ranges had increased by >100 km due to climate warming had failed to expand[4]. Thomas' group also investigated how *Maculinea* larvae engage in chemical[3] and acoustical[2] mimicry of their host ants, showing that their specialisms were more extreme and host-specific at local scales than was previously thought. Thomas' 2007-9 analyses also tested mathematical models describing *M. arion* population dynamics under different conditions, and showed that they closely predicted data recorded from reintroduction sites. These validated models are now used to adjust management on suites of sites across landscapes[1, 4-6].

Research at Oxford University also showed that optimum conditions for *M. arion* were changing. Weaker grazing, generating a taller 2.1 cm sward, is now optimal under the warmer climates of the past 20 years. Moreover, on UK sites with exceptionally warm microclimates (e.g. steep sheltered embankments), Thomas found that the niche of *M. sabuleti* shifts to turf that is too tall (10-15 cm)

for *Thymus* to flower. Instead the butterfly lays on *Origanum*, a related labiate that flowers 10-14 days later and on which larval survival is even higher. This has led to the evolution of a late-emerging race of Large Blue, coinciding with peak *Origanum* flower production. In contrast, on cooler sites Thomas found that races had adapted to match the brief window of thyme-flowering; 20 generations after establishment, some populations develop more quickly than the original stock used to re-establish UK colonies[6].

Thomas had long argued that the restoration of a declining type of habitat for one threatened species was likely to enhance the status of other rarities that had been declining for broadly similar reasons. However, this was disputed, and empirical confirmation was lacking. His group at Oxford University quantified the beneficial increases in other species that were evident anecdotally, and explained the reasons why this occurred. For example, they found that the rare Pale Heath Violet, which has increased 80-fold on sites managed for *M. arion*, has seeds adapted to dispersal by *Myrmica* ants, but not by ants of other genera. On these sites increases were also found in other rare butterflies, other insects, plants and birds[5,6], confirming Thomas' predictions.

3. References to the research

1. Thomas JA, Simcox DJ, Clarke RT. (2009) Successful conservation of a threatened *Maculinea* butterfly. Science 325: 80-83. doi: 10.1126/science.1175726 ***First rigorous analysis of 20-years'* M. arion *conservation data; first test of models of population; first analysis of* M. arion *metapopulations and niche shifts under warmer climates.***
2. Barbero F, Thomas JA, Bonelli S, Balletto E, Schönrogge K. (2009) Queen ants make distinctive sounds that are mimicked by a butterfly social parasite. Science 323: 782-785. doi: 10.1126/science.1163583 ***First demonstration in any ant that queens make distinctive sounds, and of acoustical mimicry by any social parasite.***
3. Thomas JA, Elmes GW, Sielezniew M, Stankiewicz-Fiedurek A, Simcox DJ, Settele J, Schönrogge K. (2013) Mimetic host shifts in an endangered cuckoo-species of butterfly social parasite. Proceedings of the Royal Society B 280: 711-719. doi: 10.1098/rspb.2012.2336 ***First demonstration of regional host switches and local chemical adaptation in Maculinea larvae.***
4. Thomas JA, Simcox DJ, Hovestadt T. (2011) Evidence-based conservation of butterflies. Journal of Insect Conservation 15: 241-258. doi: 10.1007/s10841-010-9341-z ***First study of relationship between metapopulation structure and habitat quality of the Large Blue and other butterflies, revealing key conditions for successful expansion of populations.***
5. Thomas JA, Simcox DJ, Bourn NAD. (2011) Large blue butterfly. In *Global Re-introduction Perspectives 2011*, ed PS Soorae, IUCN, Gland, pp 10-14. ***Review of the successful application of new science to Large Blue conservation in UK and across Europe.***
6. CLIMIT Report to the EU, held on file at Oxford University and UFZ (Helmholtz) Leipzig/Halle. ***Includes CLIMIT research results already communicated and applied to conservation policy and practice while under review or 'in prep' for publication in ISI journals.***

Funding for research: Grants of €1.4M have been received for this work since 2007, through the EU FP6 Biodiversa programme CLIMIT (*CLimate change impacts on Insects and their MITigation*).

4. Details of the impact

Since 2008, the new findings that emerged from Professor Thomas' research at the University of Oxford have had a major beneficial impact on the global conservation of *M. arion*. In the UK, where links were already established, the rapid communication of emerging results provided the essential foundation for new large-scale reintroduction programmes, which have made significant progress towards restoring the butterfly's former (19th century) range. Crucially, the strength of the scientific underpinning for the conservation programme has made funding more forthcoming for these efforts [7,8]. As a result of the new information on the precise criteria for optimum *M. arion* habitat, the management of all current and potential new UK Large Blue sites has been modified by the

interested conservation bodies (National Trust (NT), Natural England, Clarke Trust, Network Rail, Somerset Wildlife Trust (SWT), Gloucestershire Wildlife Trust (GWT), and Butterfly Conservation) to meet Thomas' specifications[7-9]. This resulted in the UK Large Blue population more than doubling from 128,000 eggs in 2007 to 272,000 in 2012, with huge increases on some key sites, e.g. the NT's Collard Hill, where a previously stabilised population of *c.*230 adults has grown ten-fold since 2009[9].

The research into *M. arion*'s adaptation to warmer microclimates has enabled the design and creation of new areas of high-quality habitat adjacent to established sites, providing optimum conditions for meta-population expansion and the evolution of more dispersive races. In major constructions by Network Rail[10], two new *Origanum*-using sites have been built from scratch – a level of habitat manipulation never previously attempted for an insect in any country. These and two other newly managed *Origanum* sites supported around 20% of the UK Large Blue numbers in 2012-13. In addition, management elsewhere (by Natural England, SWT, GWT and the NT) has been modified to extend the breeding area on eight *Thymus*-using sites to encompass *Origanum*. This has enlarged the available habitat for Large Blues (and hence increasing population size) and, equally importantly has dampened the fluctuations of populations in years of extreme weather[7,8]. Selection for a race of Large Blue adapted to use *Origanum* anticipates a time in coming decades when all sites supporting *Thymus* are predicted to become too hot to support the ant host, *M. sabuleti*, and hence *M. arion*.

The experimental selection[6,10] for early-emerging races adapted to thyme-flowering on cooler sites was crucial to the reintroduction of *M. arion* to the Cotswold hills, where all previous attempts at reintroduction in the 1980s and 1990s had failed. It also showed that the sites selected previously had microclimates too cool for the UK populations. As a result, Natural England, GWT and the NT switched management to sites with warmer terrains and used the early-emerging races for new introductions in 2010. These coincide precisely with the flowering of local thyme, and the butterfly already thrives on two sites[8]. This provided the rationale for an ambitious restoration programme (led by Butterfly Conservation and Natural England, funded by Biffa through landfill taxes) on a further nine Cotswold sites[7]. Two more introductions were made in 2013, and it is predicted that the butterfly will now spread across the landscape after an absence of 50 years.

Within landscapes, Thomas' research on adult Large Blue dispersal has guided conservation bodies' decisions about which new sites to develop. For example, it prompted the NT and Clarke Trust in 2009 to embark on creating a new visitor site within range of the existing one at Collard Hill[7]. By clearing secondary woodland from a potentially suitable hillside and imposing a targeted grazing regime the site was colonised by the butterfly within four years[7]. The research also provided the rationale for a consortium of conservation bodies, led by Butterfly Conservation, to bid successfully for a SITA (landfill) award in 2011-14. The award funded the restoration of former sites, and the creation of new ones in the West Polden Hills, adjacent to the East Poldens landscape where the butterfly already thrives[7].

Thomas' demonstration that targeted management of a single species leads to collateral gains in other declining wildlife enabled conservation bodies to argue that management for the Large Blue would benefit entire communities of threatened species, attracting funding that would not otherwise be forthcoming. Thus, the NT have imposed 'Large Blue management' on four Dartmoor sites, with the prime aim now being to promote habitat for four declining species of violet-feeding fritillary butterfly (capitalising on Thomas' discovery that the Pale Heath Violet thrives in *M. arion* habitat due to seed dispersal by *Myrmica* ants). This strategy has been highly successful[9], with some of the largest known UK populations of High Brown and Pearl-bordered Fritillary breeding in 2012-13 on all four sites. In comparison, both experienced *c.*80% extinctions elsewhere, making the High Brown the most endangered UK butterfly species. These sites have also been colonised by other UK Biodiversity Action Plan species, including other butterflies and rare insects[7, 9]. A new programme is currently underway on the Atlantic coast of Cornwall, with the same aim[9].

Since 2008, grant funding for the development of new Large Blue sites has totalled over £200,000, excluding local economic impacts (£13,000 to nurseries to propagate thyme plants; £50,000 to

contractors to undertake practical management and surveys). The new programmes have resulted in significant local engagement of the community (for example involving volunteers in programmes clearing scrub, planting thyme and monitoring butterflies). The support of major national charities such as the NT, Natural England, Wildlife Trusts and Butterfly Conservation underlines the breadth of impact of Thomas' research. There are today more than 100 sites across the UK being carefully prepared for *M. arion* – at least double the number in 2008 – of which 40 already support the butterfly, making the UK a European and global stronghold of this iconic species. Indeed, the Large Blue is one of just three UK butterflies to meet the Convention of Biological Diversity's target to reverse species' declines by 2010[11,12]. Notably, the successful conservation of the other two also derives directly from Thomas' research[4,12]. Natural England states that Oxford based research '*has provided essential knowledge that has enabled Natural England to fulfil its statutory duties in reversing the decline of the EU Habitats Directive Species* Maculinea arion'[8]. The impact has been felt across Europe too, with several *M. arion* (and other species') sites in other nations having implemented Thomas' findings and achieved significant growth in numbers[10]. As a consequence, *M. arion*'s global IUCN listing has changed from 'Vulnerable to 'Near-threatened'.

The NT's site at Collard Hill (with a busy web-site and blog) now attracts over 1000 visitors in June-July when Large Blues are on the wing, making it one of NT's prime public sites for wildlife watching[8,13]. Widespread media coverage of the reintroduction of the large blue butterfly has reached a very large audience within the UK via a range of media, including BBC's The One Show (4.48 million viewers) and Countryfile (over 6 million viewers) in 2012, documentaries on local and national TV and radio (e.g. Radio 4's *Nature* August 2009 and *Saving Species* 2010[14]), and many articles in the national broadsheets[11].

5. Sources to corroborate the impact

7. Letter from the Chief Executive of Butterfly Conservation UK and Vice Chair of Butterfly Conservation Europe (held on file), ***confirming changes in site management, management of sites to mitigate the effects of climate change, creation of sites to take advantage of more mobile races of Large Blue, and gains in other threatened species.***

8. Letter from the Land Management Senior Adviser for the Cotswolds at Natural England (held on file), ***confirming changes in site management, management of sites to mitigate the effects of climate change, establishment of new sites in the Cotswolds and ability to fulfil its statutory duties under the EU Habitats Directive.***

9. Letter from the Wildlife Countryside Adviser for the National Trust South West Region (held on file), ***confirming changes in site management, increases in butterfly numbers, creation of sites to take advantage of more mobile races of Large Blue, gains in other threatened species as a result of 'Large Blue management', and greatly increased visitor numbers and public interest.***

10. http://www.biodiversa.org/553 EU Biodiversa Policy Brief 'Conservation of Threatened Insects in Europe: Managing Habitats for land-use and Climate Change adaptation', compiled in 2013 by IUCN from CLIMIT (largely UK *M. arion*) research results and ***confirming increases in Large Blue numbers elsewhere in Europe as a result of Thomas' research.***

11. http://www.theguardian.com/environment/datablog/2011/dec/07/uk-butterfly-species-populations Double page article from the Guardian, ***confirming an increase in Large Blue numbers against a general backdrop of plummeting butterfly populations in the UK.***

12. http://www.cbd.int/doc/world/gb/gb-nr-04-en.pdf 2009 Fourth UK National Report to the United Nations Convention on Biological Diversity; confirms (p25) the increase in Large Blue numbers.

13. National Trust Collard Hill: http://ntlargeblue.wordpress.com ***Links to a popular blog about this visitor site.***

14. http://www.bbc.co.uk/programmes/b00m17qb, http://www.bbc.co.uk/programmes/b00tpq63 ***Links to two Radio 4 broadcasts on the Large Blue.***