Institution: Canterbury Christ Church University		
Unit of Assessment: 5 - Biological Sciences		
Title of case study: ICS5.01 Pheromones as tools for insect conservation		
Period when the underpinning research was undertaken: 2014-20		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Dr Joe Burman	**Role(s) (e.g. job title):** Senior Lecturer	**Period(s) employed by submitting HEI:** 01/11/2009 – date
Period when the claimed impact occurred: 2015-20		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Declining insect numbers represent a global environmental and ecological challenge. For rare species, conservation is particularly challenging as these insects are difficult to find and hence monitoring them is financially and/or physically impractical. Canterbury Christ Church University (CCCU) research has i) developed and validated pheromone 'toolkits' that can be used to monitor some of Europe's rarest insects, which allowed ii) the implementation of these toolkits in more, and larger, monitoring programmes, which resulted in iii) the identification, rediscovery and characterisation of habitats for multiple rare species, and that iv) underpinned a fundamental change in the monitoring strategies of key national conservation organisations. CCCU research has therefore changed practice and policy in relation to the management and conservation of threatened species.

2. Underpinning research

We urgently need to conserve biodiversity and slow, or ideally stop, the increasing loss of species seen globally. Issues with achieving this include firstly, that the majority of species are undescribed and secondly, that we do not know the distributions of the species that are described. The first of these issues, the Linnean shortfall, refers to the discrepancy between the number of species that exist, and the number that are described. The second issue is the Wallacean shortfall that refers to a lack of knowledge about the geographical distribution of described species. Taken together, these issues mean that finding and monitoring some species is extremely challenging. One approach to addressing this is to use the chemicals associated with communication in the species of interest to make them come to you. For insects, the chemicals that allow this are the sex pheromones associated with mate finding. These pheromones are highly species-specific and hence will only attract individuals, often the males, of just the species being monitored. This approach is therefore a particularly valuable one as it avoids issues with cryptic species, addressing aspects of the Linnean shortfall, and allows rare animals to be found, addressing aspects of the Wallacean shortfall.

Work led by Dr Joe Burman has a) identified the specific synthetic pheromones needed for monitoring nine insect species and demonstrated the species-specificity and high detection ability of these pheromones **[R1]**, b) shown that use of these specific pheromones allow data collection at a previously impractical scale **[R2-3, R6]**, and c) demonstrated that the use of these synthetic insect pheromones does not harm the species monitored **[R4-5]**.

This research, which has been undertaken at multiple sites across Europe, shows that insect pheromones can be used as sampling tools to determine insect distribution at much larger scales **[R2]** than previous methods, and with significantly reduced sampling effort. For example, one comparison of pheromone sampling with transect walks undertaken at 48 sites in southern Sweden showed that pheromone sampling identified 100 times as many of the species of interest for approximately half the work-effort **[R6]**. This demonstrates their suitability for monitoring rare species, for understanding the reasons for their decline, and allows the use of

these species as indicators of habitat quality (*e.g.,* Burnett moths are considered to be good indicators of species-rich semi-natural grasslands and longhorn beetles are indicator species in forestry and forest biodiversity conservation).

The key research findings can be summarised as follows, with CCCU research:

a) Identifying specific synthetic pheromones and demonstrating species specificity and high detection ability

Synthetic pheromone tools have been developed for the Yellow-legged Clearwing (*Synanthedon vespiformis*), three longhorn beetles (*Phymatodes spp.*), the barred tooth-striped (*Trichopteryx polycommata*), three Burnet moths (*Zygaena spp.*), and the Kentish Glory (*Endromis versicolora*) **[R1-3, R5]**. These are the first pheromone attractants to be identified and produced for these species, some of which are Europe's most endangered **[R1, R3]**, with validation work showing that the pheromones are species-specific and can be used at very low concentrations. This research therefore demonstrates that they are suitable for field use in monitoring.

b) Validating data collection at landscape scale

Testing of these synthetic pheromones shows that entire national surveys can be carried out by a small number of people in a single field season. For example, use of these pheromones allowed 3 people to survey 251 locations in part of one season, identifying 77 site localities where the rare Yellow-legged Clearwing was present **[R1]**. By determining that spatial distribution data can be collected at such an unprecedented scale, this approach allows much more accurate assessments of species' habitat requirements. For example, in one field experiment, pheromone traps recorded 100 times more Burnet moths than transect walks with about half the work-effort **[R6]**. This allows determination of the landscape level factors driving change in the distribution of insect populations. In doing so, this research has uncovered novel information about insect ecology. This includes the use of clearcuts and forest edges for Burnet moth species that were previously assumed to be solely reliant on chalk grassland **[R6]** and the use of host plants not previously associated with Yellow-legged Clearwing's ecology **[R1]**.

c) Demonstrating that synthetic insect pheromones do not harm the species monitored

A potential risk in the use of synthetic pheromones for insect monitoring and conservation is that their use might harm the animals. This concern does not exist in cases where such lures are used for the management of insect pests and the aim is to suppress and kill the pest, but rightly matters if pheromones are to be used to monitor species for conservation purposes. This has served as a barrier to the uptake of pheromones in conservation. As most pheromones attract males, the key concern has been that males attracted to a synthetic pheromone lure would subsequently be unable to find females. Burman's direct testing of this demonstrates that mating disruption does not happen **[R4-5]**, providing a pivotal validation for the general use of synthetic pheromones for the monitoring of species of conservation concern.

In combination, this body of research has identified and validated specific synthetic pheromone blends for both rare and indicator species that could not previously be monitored in this way. This allows safe monitoring of these species in a novel way and at previously impossible scales.

3. References to the research

[R1] Burman, J., Westerberg, L., Ostrow, S., Ryrholm, N., Bergman, K.O., Winde, I., Nyabuga, F.N., Larsson, M.C. and Milberg, P., 2016. Revealing hidden species distribution with pheromones: The case of *Synanthedon vespiformis* (Lepidoptera: Sesiidae) in Sweden. *Journal of insect conservation*, *20*(1), pp.11-21.

[R2] Molander, M.A., Winde, I.B., Burman, J., Nyabuga, F.N., Lindblom, T.U., Hanks, L.M., Millar, J.G. and Larsson, M.C., 2019. Common cerambycid pheromone components as attractants for longhorn beetles (Cerambycidae) breeding in ephemeral oak substrates in Northern Europe. *Journal of chemical ecology*, 45(7), pp.537-548.

[R3] Oleander, A., Hall, D.R., Bray, D.P. and Burman, J.P., 2019. Identification of female sex pheromone for monitoring the Barred Tooth Striped Moth, *Trichopteryx polycommata*, a priority conservation species. *Journal of chemical ecology*, 45(8), pp.649-656.

[R4] Thackery, D. and Burman, J., 2016. The effects of synthetic pheromone exposure on female oviposition and male longevity in *Zygaena filipendulae* (Linnaeus, 1758) (Lepidoptera: Zygaenidae, Zygaeninae). *Entomologists Gazette*, 67.
[R5] Oleander, A., Thackery, D. and Burman, J., 2015. The effect of exposure to synthetic pheromone lures on male *Zygaena filipendulae* mating behaviour: implications for monitoring species of conservation interest. *Journal of insect conservation*, *19*(3), pp.539-546.
[R6] Bergman, K.O., Burman, J., Jonason, D., Larsson, M.C., Ryrholm, N., Westerberg, L. and Milberg, P., 2019. Clear-cuts are temporary habitats, not matrix, for endangered grassland burnet moths (*Zygaena* spp.). *Journal of Insect Conservation*, pp.1-9.

The quality of the underpinning research is demonstrated by a) the publication of all work cited above in peer-reviewed journals, b) the consistent citing of the work in the literature, and by c) the range of national (University of Greenwich) and international (*e.g.*, Linköping University, University of Gävle, and Lund University in Sweden, the University of Embu in Kenya, and the University of California and the University of Illinois in the USA) co-authors on the work.

4. Details of the impact

Impact is derived from the development, validation and implementation of pheromone 'toolkits', and is focussed on the identification, rediscovery and characterisation of habitats for rare species, and subsequent changes in policy and practice of key conservation organisations. Critically, all of this impact is underpinned by CCCU work that demonstrates that pheromones can be effectively and safely used on species of conservation importance

i) Development of pheromone 'toolkits'

The identification of novel attractant pheromones in the lab has allowed production and validation of synthetic pheromone blends for nine species. In combination with the protocols for their use, these synthetic pheromone blends form a pheromone 'toolkit' for each of the species, making them broadly available, easily usable and therefore allowing their widespread use. That is, toolkit development is critical in converting the research into something that can be used by non-specialists, a critical consideration as most sampling for the species considered here is performed by volunteers. These toolkits have now been used by conservation organisations in monitoring and public engagement events since 2014. These organisations include Scottish Natural Heritage, Natural England, Butterfly Conservation, and the Cairngorms National Park/Back from the Brink project **[S1-10]**.

ii) Monitoring and public engagement

Volunteers from the public are critical to the work of many insect monitoring programmes. The deployment of the pheromone toolkits allowed pheromone toolkit use by such groups, allowing more and larger monitoring programmes. This delivered impact by increasing monitoring activity and efficiency, and by increasing engagement of the public with specific conservation initiatives and with insect biodiversity and conservation more generally. For example, the Cairngorms National Park, the Back from the Brink project, and Butterfly Conservation Scotland have been using pheromone lures developed by CCCU for the Kentish Glory (*Endromis versicolora*) in their training/public engagement sessions and their monitoring programmes since 2016 **[S1-2]**. Other such monitoring projects directly benefitting from CCCU work include large-scale implementations such as the monitoring of the Barred Tooth Striped (*Trichopteryx polycommata*). Although only identified in 2017 (with results published in 2019 **[R3]**), the Barred Tooth Striped pheromone lure has already led to significant impact through an increase in volunteer engagement in the monitoring community, with Butterfly Conservation stating in their 2019 report that the "*Barred Tooth Striped pheromone lure is now an invaluable tool for surveying and monitoring populations of this rare and threatened moth*" **[S3].**

iii) Habitat identification, rediscovery and characterisation

The increased, and more effective, monitoring enabled by the pheromone toolkits has identified new sites where rare species are found, and rediscovered others in sites from which they had apparently been lost. This knowledge is critical for species conservation efforts. Specific examples include the identification of the Kentish Glory (*Endromis versicolora*) in new sites

across Scotland and its rediscovery in other sites from which it had not been reported for decades **[S2]**. For this species, the use of pheromones in monitoring has, since 2016, resulted in 312 positive records for the Kentish Glory compared to 191 records between 2000 and 2015 **[S4]**. This knowledge is now specifically informing discussions with Scottish Forestry around the selection of areas for the planting of new trees **[S4]**. Similarly, use of the Barred Tooth Striped pheromone toolkit by volunteers working for Butterfly Conservation has, since 2017, more than doubled the number of sites at which this species of principal importance is found, and produced a 449% increase in monitoring **[S3].** For the Barred Tooth Striped this has allowed Butterfly Conservation to directly assess population size and viability – via previously impossible mark-release recapture methods – as well as determining flight period, habitat preference and movement across and between habitats **[S3]**. Results are now being used to help manage the Barred Tooth Striped and other threatened species in Cumbria **[S4]**. Pheromone toolkits have also aided more site-specific conservation efforts such as work by Scottish Natural Heritage in conserving: *Zygaena viciae*, the New Forest Burnet, which is found in only one location in Western Scotland **[S5]**; and *Adscita statices*, the green forester, where use of the pheromone toolkit has identified four new sites where these normally hard to spot moths are found **[S6].**

iv) Shaping policy and future strategy

As a result of the success of the various pheromone toolkits developed from CCCU research (above), pheromone monitoring is now a key strategic goal for a number of organisations. For example, Scottish Natural Heritage, Butterfly Conservation Scotland, Butterfly Conservation UK and the Burnet Study Group now routinely include use of pheromones in their annual conservation action points, with reports provided by Burman providing key evidence used to inform priorities and actions **[S4, S7-9]**. Policy has also changed in that pheromone development and implementation are now key elements of the action plans developed for many species. For example, pheromone use is identified as a key priority for the Slender Scotch Burnet (*Zygaena loti)* and the New Forest Burnet (*Zygaena viciae)* **[S4]**, the Small Dark Yellow Underwing (*Coranarta cordigera*) and the Dark Bordered Beauty (*Epione vespertaria*) **[S10]**. The Kentish Glory pheromone is now also included in the action plan for the Cairngorms National Park/Back from the Brink project after initial success in its implementation **[S4, S11].** Beyond the UK, the pheromones, monitoring approaches and policy guidelines derived from this research are also being used and implemented internationally **[S12]**. These changes are highly significant as they represent a fundamental change in monitoring strategy that directly stems from CCCU research. Information from pheromone surveys is also now provided by conservation bodies to developers, land managers and landowners and this has directly led to positive changes in practice. For example, Butterfly Conservation Scotland is now directly working with the owner of one of the best sites for the Kentish Glory in Scotland to enhance the habitat and working more generally with Scottish Forestry in forest management planning **[S4]**.

Overall, CCCU research has therefore had broad impact by developing and validating the tools used to identify and monitor the habitats for rare species. It has provided the key evidence to allow changes in policy and practice to be made by key organisations involved in conservation. In line with the Unit of Assessment's policy for developing impact by building strong relationships with key stakeholders and working to address their priorities, CCCU research is therefore having a critical impact on conservation and management of threatened species both within the UK and internationally.

5. Sources to corroborate the impact

[S1] https://butterfly-conservation.org/events/kentish-glory-pheromone-luring-workshop
[S2] http://www.highland-butterflies.org.uk/pdf/Kentish%20Glory%20Pheromone%20Survey%202017%20Results.pdf
[S3] http://www.northwestinvertebrates.org.uk/wp-content/uploads/2020/01/BTS-Survey-Report-2019.pdf
[S4] Senior Conservation Officer, Butterfly Conservation Scotland.
[S5] https://scotlandsnature.blog/2020/01/23/16308/
[S6] https://southwestscotlandbutterflies.files.wordpress.com/2017/04/otsspring2017.pdf
[S7] Head of Moth Conservation, Butterfly Conservation UK.

[S8] Chair of the Burnet Study Group, Burnet Study Group.
[S9] Policy & Advice Officer, Biodiversity Strategy, Scottish Natural Heritage.
[S10] https://butterfly-conservation.org/in-your-area/scottish-office/priority-species-updates/small-dark-yellow-underwing-and-dark-bordered
[S11] https://butterfly-conservation.org/in-your-area/scottish-office/priority-species-updates/kentish-glory-and-forester
[S12] https://www.researchgate.net/project/Insect-pheromones-for-European-insect-monitoring