The Badger Project

(Downloaded on 15May2016 from https://www.wildcru.org/research/the-badger-project)

WildCRU's badger project began in 1987, building on earlier observational data stretching back to the early 1970s. Focused on badgers living at Wytham Woods, Oxfordshire (an Estate owned and managed by Oxford University), this population is amongst the densest in the world, with around 200-250 adult badgers, producing 20-80 cubs per year, spread between 23 social groups, with setts (group dens) distributed over 4km2 of woodland, but foraging also over surrounding farmland, giving a population range of around 6km squared.

Using a systematic trap / release programme, we have followed the births deaths and marriages of over 1600 badgers, charting their life-histories against outbreaks of disease, changing habitat and weather, and effects of their food supply. This has produced one of the most detailed and enduring databases for any carnivore species in the world.

Of particular interest to us is the social structure of badger society, for while they live in groups, new genetic research has shown that half of the cubs born are fathered by a male from outside of the mothers group. Furthermore, unlike many group-living carnivores, all adult badgers mate – and they do so rather freely and promiscuously, without evident mating competition. Consequently, several females in each group produce cubs each year (litter size 1-4, averaging 1.5), especially in years with good conditions. New tracking technology – moving beyond conventional VHF and GPS systems, to use RFID location tags, magneto-inductive underground tracking and accelerometry (see below) – has revealed that a substantial proportion of badgers make excursions outside of their own group affiliation, visiting neighbours and sometimes staying over in neighbouring setts for several days. This behaviour obviates the need for permanent dispersal, which is rare, and we are currently investigating the genetic basis to which these movements link to the extra-group paternity of cubs and visits to 'extended family' members. These insights into the complexities of badger society expose that badger groups are neither exclusive nor breeding cliques. Coupled with extensive video surveillance evidence that badgers engage in only the most superficial co-operative behaviours, on a tit-for-tat basis, we see that these badger groups are little more than assemblages of individuals co-sharing a subterranean den.

As to why badgers form groups, therefore, we have researched very extensively an 'ecological', rather than 'sociological' basis for gregariousness. The diversity of foods badgers eat (insects, fruits, cereals, nut crops), with a principal reliance on earthworms, means that it would be totally inefficient for an individual to try to defend an exclusive territory. Any territory producing enough food availability throughout the year to support one badgers will also yield enough food to support several others most of the time. So, provided these resources can be shared out satisfactorily between resident badgers (with no feeding hierarchy being implicit) individuals can co-habit a range and benefit from sharing a sett/den through the architectural complexity that multiple tunnel diggers can achieve.

In studying these badgers we are also dedicated to good welfare practice and responsible research ethics. We do not intervene in the natural dynamics of badger society because our objective is to understand the processes that go on in the wild. Nevertheless, while we strive to interfere with the population as little as possible, it is necessary for our studies to trap and sedate these badgers, which we do seasonally, catching about 50% of the population each session, giving us around an 83% total population trapping efficiency through the year. Trapping is also our opportunity to fit badgers with tracking collars. All our students and staff are trained thoroughly and licensed to undertake badger handling. This expertise allows us to cause the badgers minimal inconvenience, and all are released at the site at which they were captured later in the same day. Indeed, we are just publishing some work in the journal 'Animal Welfare' describing how we minimise any handling distress and we have

formerly pioneered blood tests measuring physiological stress, which proved useful not only for badgers, but also for other wildlife, and even to monitor the stress levels of athletes and executives.

This thumbnail sketch of the badger society we have uncovered also reveals our combined interests in both the ecological aspects of badger society and the behavioural ones, where below you will find a detailed list of some of our current projects.

Synopsis of some current research projects:

For a comprehensive summary of the work undertaken by the Badger Project see the badger chapter in WildCRU's new 2 volume book set:
Macdonald, D.W., Newman, C. & Buesching, C.D. (2015) Badgers in the rural landscape – Conservation paragon or farming pariah: Lessons from the he Wytham Badger Project. . In: Wildlife Conservation on Farmland. Volume 2: Conflict in the Countryside (Eds DW Macdonald & RE Feber).

Badgers and Climate Change: Badgers turn out to be an extremely sensitive model for looking at how the long-term survival dynamics of the population, as well as short-term behavioural adaptations, respond to weather patterns. We have seen that badgers actually benefit from mild winters (heavier, better survival, more cubs the next spring), although warm conditions make for less winter torpor, and we have seen that more badgers suffer collisions with cars in milder January mating seasons. Summer droughts prove bad, however, especially for developing cubs that simultaneously suffer from endemic gut parasites, to which they have not yet acquired immunity.

Weather variability also has a negative effect. Badgers like conditions through the year to conform to those they evolved to accommodate, and so the fine-tuning of their adaptive behaviours is thrown off course by aberrant weather patterns.

Our latest research has also shown that prevailing weather interacts with how fat, and thus not desperate for food, a badger is to affect their emergence patterns, and consequently their trappability. This unique work highlights the importance of being able to distinguish true changes in population demographics over time in response to climate change, rather than just changes in the behaviour of the species, altering the rate at which it can be observed or caught.

For more details, see recent publications listed by project leader Dr. Chris Newman and DPhil student Mike Noonan.

Communication: Living at high-density and in groups requires that badgers are able to communicate with one another effectively. Living underground and being active at night limits the use of vision. Badgers are also surprisingly quiet animals, although we have identified a repertoire of vocalisations they make, where playful cubs are especially chirpy.

WildCRU has previously worked on Badger vocal communication but this research is no longer current.

Principally though, badgers communicate using scent, or 'olfactory' signals. These smells are produced by two glandular secretions, the subcaudal glands and the anal glands.

Subcuadal gland (literally a pair of glands under the tail) secretion is under voluntary control; and using gas mass-spectrometry (GMS) our work has shown this fatty secretion encodes individual-specific information, such as age, sex, reproductive status and group membership. Behaviourally, infra-red video surveillance has shown us that badgers use this secretion to anoint themselves, and each other, as well as objects in their environment. Cubs do not produce subcaudal gland secretion

until they mature and thus crawl under the bellies of their mothers and other adults, to 'steal' secretion that makes them smell like one of their group.

Anal gland secretion is deposited on faeces, which badgers deposit in shared latrines. Neighbouring groups share latrines lying between their main setts, and if one draws a line linking these setts it is possible to conceptualise this delineation as a border, defining each groups territory. The problem with this interpretation is that our research is exposing that foraging badgers have no respect for these alleged borders, trespassing freely into shared feeding areas, visiting each others setts and even breeding with neighbouring group members. Increasingly, therefore, we are re-assessing the function of latrines, where the anal gland coating faeces deposited therein encodes information about the identity and status of the depositor. Latrines may thus act as a 'social media' site, where information is exchanged, or to define passive range limits – that is, beyond this point the other guys, coming the other way, have already eaten the available worms, so here-after you'll find less (which is different to 'you are not allowed to go there'). Our latest studies have also just shown that badgers can recognise the anal gland smell of familiar group members, versus neighbours, versus total strangers, and react differently to each. This has important implications for how badgers re-organise their society after management interventions, such a TB culling or sett closures for development.

For more information see recent publications listed by project leader Dr. Christina Buesching and external PhD Student Veronica Tinnesand.

Movement patterns: With on average 10 adult badgers per social group, making much more extensive movements than was thought formerly, tracking badgers with high-resolution is as difficult as it is important. –Old-fashioned' VHF tracking, with a hand-held aerial has its applications, but it becomes tricky to track several badgers at once, necessitating multiple trackers, which is labour-expensive and can compromise the behaviour of the badgers being tracked. GPS tracking, via satellites, is great for many animals, but for woodland badgers, they spend a lot of time underground, maintaining contact with those satellites is sporadic. Not least, each time a badger re-emerges from its sett, like a hand-held GPS unit used by hikers, the collar-based unit must refind satellites, which uses a lot of battery power.

Our solution has been to pioneer RFID tracking, which are essentially similar units to the tags shops attach to goods that sound an alarm if they are taken beyond the doorway detectors. Our system utilises a series of 'detectors' at key points around the badger group's range (setts, latrines, feeding sites) which log the presence of all the badgers in proximity, which they then report wirelessly back to us over the mobile phone network.

Tracking badger activity underground has, until our very recent innovation, been practically impossible – so much so that the easy assumption was that badgers did little underground aside from sleep. Attaching tiny magnets to the badger's collars allows us to measuring disruptions within a very weak electromagnetic field we create at the soil surface, using an array of buried wires. This allows us to track subterranean badger movements in real time, up to 4m deep. Rather than just sleep, badgers move between chambers a great deal through the day, possible to adjust temperature, avoid parasites, or to follow 'friends' around below ground. They also 'pop back' to their setts for a rest much more often during nocturnal foraging sessions than we had appreciated formerly.

The final component of our tracking collars is a 'tri-axial accelerometer'; similar to devices that measure acceleration and cornering G-forces in sportscars, these devices record the pitch, yaw and roll of badgers as they move around. This produces an activity trace that we can interpret in terms of overall dynamic body movement, in turn allowing us to estimate the badgers energy expenditure. And again, these data are relayed to us wirelessly. For more information see recent publications

listed for DPhil student Mike Noonan.

Bovine Tuberculosis Research: Central to concerns and interests about badgers is the role they play as a wildlife host linked to the epidemiology of TB in cattle. The WildCRU has been a major player in this field for decades, undertaking scientific research across the UK linked to the Krebs trial and subsequent badger removal operation strategies enacted by the government. Principle amongst our findings was the 'Perturbation Effect', that is, the tendency for culling programmes to cause so much stress and disturbance amongst surviving badgers that the fabric of their carefully organised society was wrenched apart – worsening, rather than improving, the spread of disease.

Until very recently, there had been no TB in the vicinity of our Wytham Woods research site. Sadly, however, the advancing front of TB sweeping across southern England from the Southwest has reached us and an adjacent farm contracted TB in 2014, although has since tested TB free. Testing our Wytham badgers revealed that only a very few badgers in 2 social groups bordering this farm contracted TB. This has remained the case into 2015, and indeed even the tests used to diagnose TB are proving equivocal, suggesting that TB infection in some formerly infected individuals has resolved itself. Nevertheless, this outbreak and the looming spectre of TB generally, has prompted us to undertake research into how the badgers' immune system operates, and what makes badgers such a susceptible wildlife host. We are thus commencing participation in Defra's 'Badger Edge Vaccination Scheme' (BEVs).

Immunology: While a lot of work has been done on managing TB outbreaks and trying to better understand how cows and badgers interact, the actual immunology of badger susceptibility to TB had received little until. We are thus currently looking at badger immunity by challenging blood samples, in vitro in the lab and looking at innate/cellular and acquired/antibody responses. In particular, we have noted that badgers make a poor cellular response to TB challenge and their cytokine responses are different to those more typical amongst mammals exposed to TB. We hope to publish some breakthrough discoveries very soon. For more details watch out for emerging papers by DPhil student Kirstin Bilham.

Genetics: For the majority of our investigative work, assigning parentage to badgers and thus establishing a population pedigree, or genealogy, eluded us due to a lack of genetic variation between badgers amenable to typical genetic fingerprinting techniques. This was until breakthroughs using 'microsatellites' in the late 2000s, which finally allowed us to piece together the population family tree, which revealed the unexpectedly high levels of extra-group paternity in this population – something also now apparent in other high-density badger populations.

On the back of this breakthrough, we have been able to examine mate selection amongst badgers much more thoroughly, observing that while they avoid inbreeding, they are otherwise not obviously picky about mate choice. Our initial hypothesis had been that perhaps extra-group breeding was a strategy to find better or different genes, and enhance the vigour and fitness of offspring. Evidence to this effect is equivocal, however, with extra-group offspring appearing to do less-well than within-group offspring by several criteria, other than that for males philandering does seem to lead to more grandchildren. For more information, see those recent papers listed led by former doctoral student Geetha Annavi – now lecturing at Kuala Lumpur University.

Combining genetics with immunology, we've also explored the 'Major Histocompatibility Complex' (MHC) – cell surface molecules involved in the primary recognition of pathogens, triggering an immune (T-cell) response. Again the genetic diversity attainable through out-breeding was expected to be beneficial to the ability of individuals to resist internal parasites and infections, yet this too proved to be far from clear-cut, with certain MHC genes conferring an advantage against certain pathogens. For more information, see those recent papers listed led by former doctoral student Yung

Wa ‘Simon’ Sin – now a researcher at Harvard.

Collaborations

A lot of what we do involves collaboration with colleagues and labs not only in the UK, but also around the world. Too numerous to list in their entirety, we highlight current collaborations with:

Prof. Youbing Zhou, at the Chinese Academy of Sciences, Beijing University, China. In addition to our European badgers, there are several other species of badger, especially in Asia. Our work with Youbing looks at Hog badgers, Chinese Ferret badgers and a host of other small carnivores, such as yellow-throated martens and masked palm civets.

Through Youbing, we also have a collaboration with Zhaomin Zhou, with the Chinese Wildlife Enforcement agency, policing illegal wildlife trade. This too has led to several high-impact publications recently.

Prof. Yayoi Kaneko, at Tokyo University of Agriculture and Technology. We have worked with Yayoi for many years, where again she specialises in another badger species, the Japanese badger or ‘Anakuma’. Less is known about the Japanese than the European badger and so we are working with Yayoi to better understand the society of these similar badgers.

Prof. Frank Rosell, at Telemark University, Norway. Initially working with Frank to explore similar climatic responses in his beaver data set to those we have observed with our badgers (via then student Dr. Roo Campbell, now with SNH), we now have a joint PhD student, Veronica Tinnesand, working with us on badger scent communication.

Dr. Andrew Markham, Oxford University Computing lab. Andrew’s expertise has led to the development and manufacture of all the latest tracking collar technology that we use.

Dr. Hannah Dugdale, Sheffield University. An alumni of the badger project, Hannah now runs her own research group, but continues to collaborate in badger research and to co-supervise students involved in genetics.

Our Current Team:

For full details see Members Page.

Dr. Chris Newman and **Dr. Christina Buesching** run the Badger Project on behalf of Prof. David Macdonald, having joined the project as grad students themselves back in 1991 and 1996, respectively. Chris specialises in population ecology and climate change, Christina in animal behaviour and olfactory communication.

Michael Noonan (Canadian) is now heading into his final year of DPhil research, looking at badger movement patterns.

Kirstin Bilham (Swiss) is advancing with her DPhil, looking at badger immunology and oxidative stress.

Veronica Tinnesand (Norwegian) is a co-supervised student shared between WildCRU and Telemark University, looking at badger olfactory communication.

Nadine Sugianto (Indonesian) has joined us recently to undertake a Masters looking at badger

endocrinology.

Alice Kent (UK) is just about to join us on a Peoples Trust funded internship, looking at sexually transmitted diseases.

Recent Publications:

To find any of these publications check out titles at 'Google Scholar'.

For a comprehensive Badger Project summary see WildCRU's new book: Macdonald, D.W., Newman, C. & Buesching, C.D. (2015) Badgers in the rural landscape – Conservation paragon or farming pariah: Lessons from the he Wytham Badger Project. . In: Wildlife Conservation on Farmland. Volume 2: Conflict in the Countryside (Eds DW Macdonald & RE Feber).

Sin, W.A., Dugdale, H.L., Newman, C., Burke, T. & Macdonald, D.W. (2014) Pathogen burden, co-infection and major histocompatibility complex variability in the European badger (*Meles meles*). *Molecular ecology*, 23(20), 5072-5088.

Annavi, G., Newman, C., Buesching, C.D., Burke, T Macdonald, & Dugdale, H.L. D.W (2014) Heterozygosity–fitness correlations in a wild mammal population: single locus, paternal and environmental effects. *Ecology and Evolution*, 4: 2594–2609.

Noonan M.J., Markham, A., Newman, C. Buesching, C.D., Ellwood, S.A. & Macdonald, D.W. (2014) Climate and the Individual: Inter-Annual Variation in the Autumnal Activity of the European Badger (*Meles meles*). *PloS one*, 9(1), e83156.

Annavi, G., Newman, C., Dugdale, H.L. Buesching, C.D., Sin, Y.W. Burke, T & Macdonald, D.W (2014) Neighbouring-group composition and relatedness drive extra-group paternity rate in the European badger (*Meles meles*). *J. Evol. Biol.* 27: 2191–2203.

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Byrne, A., Fogarty, U., O'Keefe, J. & Newman, C. (2015) Spatial and temporal variation in body-weight: in-situ adaptive response to national climate and habitat quality variation in the European badger (*Meles meles*) throughout the Republic of Ireland. *Global Change Biology*.

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What we need:

Despite being a particularly productive project, in terms of scientific discovery, international collaboration and high-impact scientific journal publications, across wide-reaching paradigms, we still struggle for funding.
Badgers, though popular, do not have the charisma of large, tropical carnivores – indeed badgers suffer from being 'too familiar'. It is this broad adaptability and easy with which they can be studied that makes them such useful study animals for examining such a diversity of ecological questions.
We are always looking to finance more project offshoots, enabling us to take on more students and buy and replace equipment, from hard-worn vehicles to state of the art tracking collars.
If you are interested in badgers, and our far reaching conservation ecology work, please consider making a donation to the Badger Project through this link.