Badgers, badgers everywhere…

Foxes may not be a significant predator of hedgehogs, but what of Britain's largest native terrestrial carnivore; the Eurasian badger? Well, looking purely at the dietary studies you could be forgiven for thinking that they had only slightly greater impact than foxes. Scat analysis tends to yield few hedgehog remains; many studies make no mention of hedgehogs and those that do usually report hedgehog remains in fewer than 10% of faeces. Similarly, in his contribution to Badgers of Yorkshire and Humberside, Keith Bradbury notes that he found hedgehog remains in only three of the nearly 800 (about 0.4%) faecal samples that he analysed. Mr Bradbury writes:

"*This paucity of records for hedgehog remains in the dung, seems to imply that badgers eat them reluctantly, or that only certain individuals* [all remains were from the area, and two samples from the same sett] *develop the necessary skill for dealing with them…*"

As with foxes, however, remember that scat is the end-product of digestion and only contains the bits that are pretty resistant to digestion (fur, teeth, bones, etc.); we must consider which parts of the hedgehog are a badger will eat.

In a short note to the *Journal of Animal Ecology*, A. D. Middleton described the stomach contents of an adult (29 lb. / 13 kg) male badger hit by a car in Oxford during July 1935. From remains of feet, fur and spines the author and his colleague concluded that at least four different hedgehogs had been eaten and wrote that:

"*The badger seemed to have exercised considerable skill in taking only the inside edible portions of the hedgehogs, as only three or four spines were found in the stomach*."

The remains that Middleton described, bar the couple of spines, would almost certainly have made identification of hedgehog prey from the badger's scats difficult, if not impossible. Similar observations from the field suggest that badgers almost never eat the skin and spines. Indeed, in their book *Badgers*, Ernest Neal and Chris Cheeseman quote a rather gruesome extract from naturalist Christine Ferris' diary, in which she described how a badger family (a boar, sow and three cubs) stumbled across a female hedgehog with four hoglets. The sow and cubs ate the hoglets, while the boar concentrated on the adult hedgehog. According to Ms. Ferris, the badger rolled the hedgehog on its back and pushed its claws into the join (where the head curls into the body) at which point it pulled the hedgehog open, belly-up and pinned it at either end. When Ferris returned to the scene the following morning, she found the skin picked clean, except for a small part of the head. The authors go on to quote another similar example, where only the skin remained after the attack; no trace of viscera or blood were to be found.

The observations presented by Neal and Cheeseman are supported by various hedgehog tracking data. Studies following the fortunes of rehabilitated and translocated hedgehogs frequently report losses to badgers; typically identified by the presence of badger hair on the carcasses and/or the finding of a skin picked clean.

Pat Morris seems in little doubt that badgers represent a significant threat to hedgehogs and, in his *New Hedgehog Book*, he writes of how not only do they have the long claws and powerful musculature needed to 'break into' a hedgehog, the two also compete for earthworms; he notes that one badger can eat the same number of worms as seven hedgehogs. The predation and competition combined must spell bad news for hedgehogs and Morris says that, quite simply, more badgers must equal fewer hedgehogs; he estimates that the roughly 10% increase in the badger population between 1990 and 2004 probably resulted in some 100,000 fewer hedgehogs. Morris is careful to point out that he doesn't blame the badgers: "*it's just what they do*", he writes.

The suspicion that badgers can have a serious impact on hedgehog numbers invariably needs to be backed up with empirical data. With the exception of the occasional finding of several hedgehogs in a

single stomach, dietary studies typically fail to suggest significant predation of hedgehogs by badgers, while field observations have led some authors to the theory that hedgehog predation may be something that certain badgers learn to engage in.

Although not 100% indicative, fragments of hedgehog skin (left) tend to be the remains of fox predation, while a 'cleaned out' hedgehog skin leaving a jacket of spines (right) is characteristic of a badger attack.

Having looked at badger diet and behaviour, scientists decided to take a different perspective: the hedgehog's perspective. Rather than looking for hedgehog remains in badger latrines, they decided to look at how hedgehogs react to badgers.

It has long been known that the risk of being on someone else's menu is a key factor governing an animal's activity patterns. For some 20 years now, we have known that predation risk influences how long Grey squirrels (*Sciurus carolinensis*) stay at a feeding site and how they handle the food they eat. Squirrels were found to eat their food more quickly the further they are from cover (and thus the more vulnerable they are to attack) as well as choosing less nutritious (i.e. energetically less profitable) foods over more nutritious ones, because these could be carried away to be eaten in a safer spot. Similarly, we know that prey species are pretty quick to respond to the odour of potential predators. Studies on captive rabbits (*Oryctolagus cuniculus*) have shown that they become much more vigilant when exposed to Red fox odour, while rainforest rodents in Australia were shown to avoid feeding stations tainted with predator faeces, but weren't phased by the stations contaminated with herbivore odour.

In 1991, Patrick Doncaster -- at the time with Oxford University's Department of Zoology, now at the University of Southampton -- set about testing whether the presence of badgers affected the behaviour or distribution of hedgehogs. In May of that year, Doncaster released 50 adult hedgehogs equipped with radiotransmitters into Oxford's Wytham Woods (20 badgers per sq-km) and Eynsham Park (2 badgers per sq-km) and monitored their movements and fate. Twelve of the hedgehogs released into Wytham died, seven killed by badgers, compared with two from Eynsham (one killed by a fall, the other run over). By the end of the study, only three of the 30 hedgehogs released into Wytham remained in the wooded area around the release site, compared with 13 of the 20 released at Eynsham. Moreover, during the study, the Wytham hedgehogs were observed to disperse twice as far from the release point as those released into Eynsham. In effect, Dr Doncaster watched the hedgehogs move out of the woods and into nearby urban gardens; given that the habitat is very similar at both release sites, the conclusion was that the hedgehogs were moving away from the badgers. In his 1992 paper to the *Proceedings of the Royal Society of London*, Doncaster wrote:

"*… the higher density of badgers at Wytham appeared to be the crucial difference giving rise to the observed increases of mortality and dispersal … Badgers may be able to exclude hedgehogs from Wytham because they are sustained at high densities by alternative invertebrate prey…*"

In other words, there are lots of badgers in Wytham because there are plenty of worms and insects for them to feed on; hedgehogs don't seem to be a crucial food source for them.

A subsequent study by the same author during which hedgehog populations at three sites in Oxford were altered (increased or decreased by translocation) and monitored for six months during 1992 found that badgers were the main predator (one was eaten by a fox). At one site (Ditchley, where badger numbers were highest), they kept the hedgehog population from reaching the same level as the other nearby sites supporting lower badger densities. The hedgehogs released at Ditchley that survived were also observed to stick closer to residential buildings, which were avoided by the badgers (so-called "enemy-free space"). A similar study conducted by Doncaster, Carlo Rondinini and Paul Johnson during 1994 yielded very similar results; hedgehogs were tracked moving substantially further and faster from unfavourable sites than from more favourable ones, and there was a strong tendency for the hedgehogs to settle in urban areas, rather than arable habitats. The authors suggested that the movement towards urban areas occurred because these were unoccupied by badgers.

Thus far, we have seen data from Oxford, but is this picture representative? It seems so. More recently, a joint study by researchers at the Central Science Laboratory in York and Southampton University looked at hedgehog density and distribution at ten sites in the Midlands and south-west England. The researchers, led by Richard Young at the CSL, found that hedgehogs were generally to be found in urban gardens and parklands; they were rare in pasture fields. Moreover, the biologists

observed that as the number of badger setts in an area increased, the likelihood of finding hedgehogs there decreased; this relationship was a linear one, with hedgehogs apparently excluded altogether from some areas with high badger densities.

Young and his team also found that it was the number of badger setts in a 2km (~ 1.5 mi.) area around their parkland study sites that seemed to affect whether (and how many) hedgehogs were present, rather than the local (larger scale) badger sett density or how far they were from the nearest badger activity (e.g. foraging). The authors suggest that hedgehogs experience high predation pressure -- i.e. a good chance of being eaten -- at high badger densities, and this may prevent (or severely limit) hedgehog movement between suburban patches; without movement between patches, numbers can't be replenished following mortality. Interestingly, the study also found that the average growth rates for hedgehogs were similar in areas of high and low badger density, suggesting that the exclusion of hedgehogs by badgers is predatory, rather than competitive. In other words, hedgehog numbers fell because they either avoided (or were eaten by) the badgers, rather than starving to death.

The above studies aptly demonstrate that hedgehogs and badgers don't make good neighbours. Nonetheless, not all studies looking at how hedgehogs respond to badgers have produced the same results; there have even been reports of badgers, foxes and hedgehogs feeding on the same lawn at the same time. Indeed, during the aforementioned study, Young and his colleagues failed to find a link between badger activity (i.e. foraging) and hedgehog occurrence, which suggests that the hedgehogs didn't avoid the playing fields where badgers were also hunting. Similarly, in a 1993 paper to the journal *Revue d'Ecologie: La Terre et la Vie*, Patrick Doncaster wrote:

"*Free-ranging wild hedgehogs (Erinaceus europaeus) radio-tracked in Oxfordshire showed no such response to predators. They foraged singly on exposed pasture with a random distribution of distances from cover, and yet they suffered significant mortality due to predation by badgers (Meles meles)*."

At the end of his 1992 *Proceedings* paper, Dr Doncaster suggested that, while we don't know how the hedgehogs caught on to the notion that there were badgers in the area, or what attracted them to other local hedgehog populations, "*they are likely to have been guided by their keen sense of smell*". It is smell that was to feature in another series of experiments, designed to test what impact badger odour had on hedgehog behaviour and physiology.

During the early 1990s, a joint team from Oxford University and the Centre d'Etudes Biologique de Chizé (Chizé Centre for Biological Studies) in France investigated the response of hedgehogs to predator odours. The team, led by WildCRU biologist Jane Ward, caught five wild hedgehogs from farmland around the village of Villiers-en-Bois in western France and put them -- along with 10 long-term captive individuals -- into a respiratory chamber so they could monitor their oxygen intake, which can be used to measure stress and general 'alertness'. The hedgehogs were then exposed to a predator odour (Eurasian badger faeces) and a non-predator odour (Roe deer, *Capreolus capreolus*, faeces). Ward and her team found that while the long-term captive hedgehogs showed no more response to the faecal solutions than to water (the control), the recently-caught animals increased their oxygen intake by just over 21% when exposed to badger odour and just over 1% when exposed to roe deer faeces. Twenty-one percent isn't a large increase in oxygen intake (when compared to, say, running), but it does suggest that hedgehogs can distinguish between the two odours, and recognise a potential threat. Indeed, having accounted for movement around the enclosure, the biologists concluded that the increase in oxygen uptake was an indication that the hedgehog was more alert to the possibility of danger.

Obviously, Dr Ward and her team were careful about drawing conclusions from such a small data set (only 15 animals), but their study did present two very interesting results: wild hedgehogs are clearly capable of responding to predator odour at low concentrations (1:1000); and hedgehogs held in captivity for long periods might "unlearn" their response to predator odour, which may pose problems upon release.

A complementary study to the aforementioned, published in the journal *Animal Behaviour* during 1997, saw three of the same authors (Ward, Macdonald and Doncaster) collecting hedgehogs from a badger-free golf course (and surrounding playing fields) in Oxford city. The hedgehogs were maintained in captivity and exposed to several odours in order to gauge their response. Unfamiliar non-predator odours took the form of Siberian chipmunk (*Eutamias sibiricus*) faeces and guano from Indian fruit bats (*Pteropodidae giganteus*), while badger faeces provided the predator odour. The scientists found that the response of captive hedgehogs differed from the individuals they tested in the field. Hedgehogs in the enclosure ate significantly more from the 'safe' (chipmunk) stations than from the 'unsafe' (badger odour) station. Hedgehogs in the field reduced their feeding time by 97% when exposed to the badger odour, compared with 50% when confronted with fruit bat faeces. The wild hedgehogs also moved around and sniffed more when badger odour was present. Interesting differences were found in the time the two groups stayed away from the predator-tainted stations.

The captive hedgehogs continued to avoid the feeder tainted with badger odour for the following two days. Despite reducing their foraging activity (often adopting a "fringe down" posture or seeking cover) for periods of up to 30 minutes when presented with badger odour, there was no evidence to suggest that the free-ranging hedgehogs avoided the site over a 24 hour period. The authors speculate that captive hedgehogs may show more prolonged avoidance because they can afford to: they have a superabundant supply of food and the safety of a cage. Conversely, free-ranging hedgehogs can't afford to give up a good feeding site for prolonged periods; they just avoid the immediate area (or are more alert) for a short period, during which time the danger will hopefully pass.

These studies on the effects of odour on foraging behaviour raise the interesting question of whether prey species respond to the odours of individual predators, or whether there is a generic component of all predator odours that they tune into. In a bid to prevent this section from becoming interminable, I shall not pursue the subject here. Sufficed to say that we're still not sure what it is about badger odour that rings alarm bells for free-ranging hedgehogs and why the response might be dampened after a prolonged period of captivity.

So, regardless of whether hedgehogs actively avoid the badgers themselves, the results of these studies tell us that -- in parts of Oxford, the Midlands and south-west England at least -- badgers seem not only capable of detrimentally impacting hedgehog numbers, but also of influencing hedgehog movements and distribution. The result is that hedgehogs move away from the pastureland on which

badgers forage, into gardens and parks that badgers less frequently visit. At this point, it should be underscored that badgers are invariably only one reason for this shift; changes to farming practices are widely considered to have resulted in much farmland being unsuitable for hedgehogs. Nonetheless, it does appear that badgers play a significant role in hedgehog distribution.

Too much of a good thing

Of late, with the recent cases of bovine TB reported by the media, badgers have provided a conversational topic almost as controversial as the hunting of foxes; nonetheless, badgers are still widely appreciated by the British public. Hedgehogs too are held in high regard by animal lovers. Indeed, in the latest issue of *BBC Wildlife Magazine* (September 2008), hedgehog came second in the poll of British mammals with 238 votes; 13 votes more than the badger and fox, which were held joint third place. With the potential that badgers -- quite unintentionally and without animosity -- possess for excluding hedgehogs from some prime worming habitat, do we know what the critical badger densities are? In other words, do we know how many badgers is too many for hedgehogs to survive in the area? (**Photo: Caught in the act! A badger eating a hedgehog, the body of which can be seen in the bottom left of the photo up against the wall.**)

Between June 1991 and August 1992, a team of biologists led by Thierry Micol at the Centre d'Etudes Biologique de Chizé looked at pasture fields and grass playing fields around Oxford city in order to gauge the badger density and distribution as well as the presence or absence of hedgehogs. Micol and his team discovered that the abundance of hedgehogs varied with the density of badger setts – the more setts, the fewer hedgehogs. The principal conclusion of the study was that hedgehogs were almost entirely absent from sites with 2.27 or more badger setts per 10 sq-km (~4 sq-mi.). The team also found that hedgehogs were significantly more abundant on urban playing fields (four per field, on average) than in pasture fields (averaging less than one per field). In their 1994 paper to the *Journal of Animal Ecology*, Micol and his co-workers conclude that:

"*… local variations in the abundance of hedgehogs can be related to the distribution of a principal predators* [badgers] *and a major food resource* [earthworms]*, and that isolation from neighbouring*

populations explains the absence of hedgehogs from a small proportion of sites which are otherwise suitable."

This subject is a very interesting one and serves to remind us that nature is full of intricate connections. It may well be that by protecting one species (badgers), we have inadvertently caused more problems for another (hedgehogs). More work needs to be done to establish how representative these data are and whether, as Farming Unions have suggested, culling badgers could be required in order to help halt the apparent decline in hedgehog numbers. Presently, we only have data to suggest that the culling of badgers can lead to an increase in the number of foxes (again, this is most likely through competitive release); and the number of TB infections!

Based on current evidence, foxes seem to have a far smaller impact on hedgehog populations than badgers, and -- baring, perhaps, the odd 'specialist' -- are seemingly undeserving of their reputation as hedgehog killers. Could it be that fewer badgers and more foxes could also mean more hedgehogs? This is anyone's guess. Nature is intricately complex and it is often simply impossible to predict the consequences of our actions; however well intended they may be. One thing's for certain: badgers are just one of a hedgehog's problems and, given the numerous other factors stacked against them and the problems associated with culling badgers, it would be imprudent to speculate without more empirical data on which to base our assumptions. In the end, there are some difficult decisions to be made and someone somewhere is going to be unhappy with them.