Can Non-Intrusive Geo-Physical Techniques Assist in Mapping Setts of the Eurasian Badger?

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Badgers and Roads

Atkins (Ecology) in Ireland is providing ecological design advice to the main contractor on the N7 Nenagh to Castletown road scheme. This involves advising on ecological matters relating to road construction, including the potential direct and indirect impact of the proposed road corridor on Eurasian badgers *Meles meles*. **The N7 road scheme runs for approximately 35 km through an area of predominantly lowland agricultural grassland in Counties Tipperary, Laois and Offaly, Ireland.**

Road impacts on badgers, in particular through disturbance, habitat fragmentation and road mortality are well documented (Harris *et al.* 1994, Forman *et al.* 1995, Roger *et al.* 1997, Clarke *et al.* 1998). Therefore, as per standard best practice (NRA 2006, HA 2001, *etc.*) pre-construction badger surveys were undertaken along the length of the scheme in 2004 (Hyder McCarthy Consultants 2005) and again in 2006 (Flynn Furney Environmental Consultants 2006). A follow-up pre-construction validation survey was also undertaken in 2008 to update the findings of previous surveys (Flynn Furney Environmental Consultants 2008). These studies identified a number of badger setts located inside and just outside the lands made available (LMA) for proposed construction and this informed the design of standard badger mitigation measures including mammal underpasses and mammal resistant fencing and badger gates [as per the *Design Manual for Roads and Bridges* (DMRB) (HA 2001) and National Roads Authority (NRA) Guidelines (NRA 2006)].

Badgers are protected under Irish law by the Irish Wildlife Act 1976 (as amended in 2000[1]). It is an offence under the Wildlife Act to intentionally kill or injure protected species or to wilfully interfere with or destroy the resting or breeding place of a protected animal. In assessing the risk associated with construction, the National Roads Authority has prepared guidelines (NRA 2006) for site works in the vicinity of badger setts. This guidance states that badger sett tunnels may extend up to c. 20 m from sett entrances and recommends that no heavy machinery be used within 30 m of a badger sett unless carried out under licence[2]. Furthermore it recommends that lighter machinery should not be used within 20 m of a sett entrance and that only light work, such as hand digging or scrub removal, should be undertaken within 10 m of sett entrances (NRA 2006). The DMRB considers c. 50 m (HA 2001) from a sett to be safe for machinery.

Those sett complexes located entirely within the LMA were excluded under licence [from National Parks and Wildlife Service; Department of Environment (NPWS), Heritage and Local Government], while for those outside the LMA it was unclear whether tunnels or chambers might extend underneath the LMA. It was therefore necessary to determine the extent of sett complexes at a number of locations[3] in order to determine i) whether proposed construction works might negatively impact upon them, or ii) whether the final road layout for construction would be impacted.

Sett Complexes

Badgers are common and widespread throughout Ireland (Smal 1995, O'Corry-Crowe *et al.* 1993, Sleeman and Mulcahy 2005, Delahay *et al.* 2008). They live in social groups mostly consisting of between two and six adults and their young (NRA 2006[4]). Territory size is on average 80 hectares (range of 25 to 200 ha). Recorded densities in East Offaly close to our study area are 0.7 groups/km^2 (O'Corry-Crowe *et al.* 1993).

Within each badger social group's territory there may be several setts of varying status and usage (HA 2001). Setts vary in size from simple single entrance setts to sett complexes with up to 40 or more entrances spread over 100 metres or more (NRA 2007). Generally, setts are categorised as main, annex, subsidiary or outlier setts, depending on factors such as number of sett entrances, patterns of occupation and connection to a main sett by well-worn pathways (Neal and Cheeseman 1996); an alternative strategy is to recognize only main or outlier setts. If not disturbed, setts can be used by successive generations over a considerable span of time. Furthermore, the influence of landscape, soil and bedrock type *etc.* on the size and design of any given badger sett, is such that the extent of a sett can be difficult to define accurately by examination of surface features alone. This is particularly so in Ireland where many sett entrances are in hedges, with tunnels radiating out under adjoining improved grassland where there are no visible sett structures [*e.g.* O'Corry-Crowe *et al.* (1993) found that most setts (55%) in their East Offaly study area were in hedges, which occupied only 3% of available habitat and that their location was little affected by soil type].

Non-Invasive Geophysical Techniques

As noted, the objective of this study was to determine whether any badger tunnels or chambers extend under lands made available for construction. In accordance with requirements arising from consultation with National Parks and Wildlife Service non-invasive geophysical survey techniques were used. While the possibility of using such techniques is highlighted on advertising material from a range of commercial geophysics companies, a review of the literature highlighted only a single published study; on St. Asaph Bypass, North Wales in 2003 (Nichol *et al.* 2003). This paper therefore outlines our experience of applying these techniques to mitigating impacts on badgers on the N7 road scheme in Ireland.

A combined approach of using Ground Penetrating Radar (GPR) and Electromagnetic (EM) techniques was employed to carry out this survey, together with a detailed assessment of surface features. With ground penetrating radar high frequency pulses of radio energy are transmitted into the ground. The transmitted pulses are reflected from material boundaries, building up a continuous cross section of the subsurface. Different frequencies are adopted in different situations, with high frequencies giving good spatial resolution of features and lower frequencies providing greater penetration to depth. Electromagnetic (EM38) Conductivity Mapping operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of this secondary EM field is calibrated to give apparent ground conductivity in milliSiemens/metre (mS/m).

Methods

Ground Penetrating Radar

In this study, Apex Geoservices Ltd were retained to undertake on site investigative works. The GPR survey was carried out using a MALA system, with a 500 MHz cart-mounted antenna, with a built-in odometer wheel. The data were recorded on the hard disk in the operating console and later transferred to a computer for processing and analysis. Notes were taken concerning the position of visible site details. GPR profiles were recorded across survey areas, with a nominal line spacing of 1 m. A time recording window of 56 ns was used giving a corresponding maximum usable depth of penetration of 2.8 m. Some areas were not surveyed due to obstacles such as trees or overgrown areas. All GPR profiles were surveyed using an RTK GPS system to 20 mm accuracy, in Irish National Grid co-ordinates.

In order to calibrate the system on site the location of known sett entrances and associated tunnels were surveyed. As each entrance had an associated tunnel radiating out from it, this provided an opportunity to survey for voids/tunnels in an area where badger tunnels were known to occur. A nearby culvert provided a further opportunity to calibrate the system on site.

The processing of GPR data was carried out using proprietary processing software (ReflexWin v4.5). The following processing was applied to the data:

- spatial relocation (data merge with RTK GPS data);
- temporal relocation (depth correction);
- amplitude recovery gain (time dependant);
- frequency bandpass filtering; and
- background noise removal.

Each GPR trace was analysed and the accurate location of the hyperbolic features were exported to the AutoCad plan drawing of the site with depth below ground level.

Electromagnetic Techniques

The equipment used was a Geonics EM38 Conductivity meter equipped with data logger. The instrument has an optimum depth of investigation of 1 to 1.5 m below ground. Conductivity values were recorded along all of the GPR profiles. Local conditions and variations were noted. The data were downloaded and contoured using proprietary software (Surfer v8.0). Variations in conductivity values were analysed in conjunction with GPR anomalies to identify subsurface voiding.

Result of the Badger Surveys

As noted, a series of pre-construction badger surveys were undertaken along the length of the scheme. Following finalization of the horizontal alignment of the scheme a total of six locations were selected for non-invasive surveys. For the purposes of this report we have presented the results of work from a single sett complex located along the southern boundary of the route. The sett entrance was located on the edge of an overgrown hedgerow, with one sett entrance clearly identifiable in the dense ground cover. Further field signs included a disused sett entrance c. 100 m to the north and evidence of prints and well used tracks.

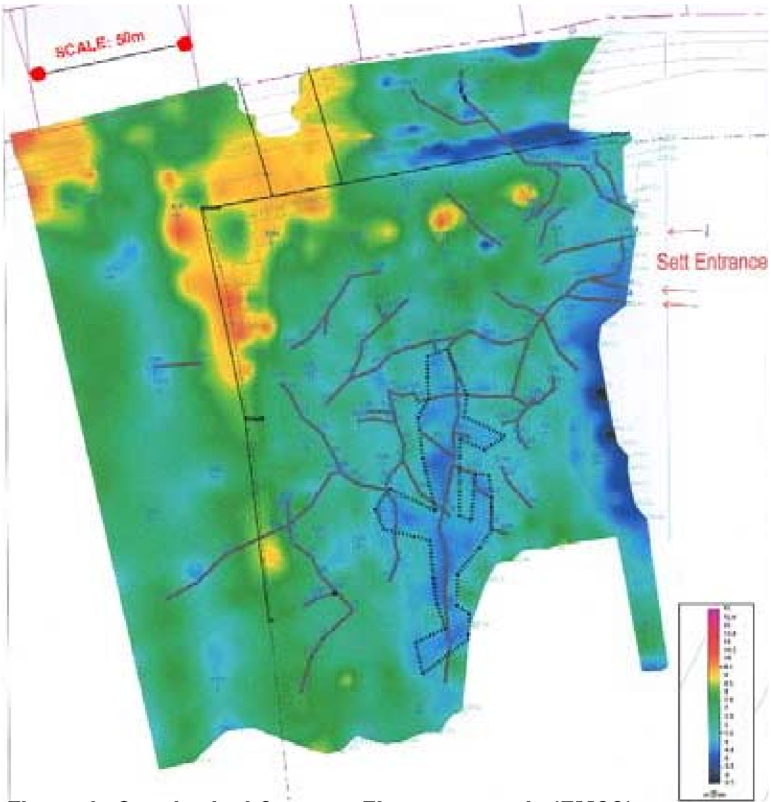

Figure 1: Geophysical Survey – Electromagnetic (EM38) survey results. Black lines indicate inferred tunnels. A central area is highlighted which reflects a core area of signal – potentially a concentration of tunnels and chambers.

As can be seen in Figure 1, three sett entrances were located along the eastern boundary of the sett complex; these were located at 13 m, 16 m and 17 m, respectively from the edge of site works. Each entrance allowed access to a single interconnected complex of tunnels. All structures identified in Figure 1 are between 0 m and c. 2 m below ground, within the known range for badger sett structures (Neal and Cheeseman 1996). However, a significant number were closer to 1 m in depth. The predominantly shallow nature of tunnels may however be explained by ground investigation results, which encountered groundwater intrusion at between 1.3 m and 3 m below surface level[5] in the environs of the sett complex. Using GPR depth readings a conservative core area of c. 22-24 m from the sett entrances can be mapped at depths of 0.5 m to 1.5 m. While the maximum axes lengths for the sett complex are 36 m (on the north-south axis) and c. 33 m (on the northeast-southwest axis), the shallow nature of some of these outlying tunnels likely indicates that these may be artefacts or perhaps old, collapsed tunnels. In a number of instances floating tunnels were also identified. As it is common for setts to be constructed at different levels, these may indicate sections of tunnel, which drop down below the maximum survey depth achieved in this study; though again a number of shallow floating voids are likely to be artefacts.

Discussion

Sett Architecture

The geophysical survey methods discussed above provide useful non-invasive tools for the investigation of the extent of badger setts in situations where direct investigative methods are not possible or are best avoided. In this study it emerged that the bulk of the sett complex was at a greater distance from the lands made available for construction than were the identified sett entrances. Thus unnecessary disturbance through digging and exclusion of badgers from the sett complex was avoided.

The study also highlighted the need to apply the NRA (2006) guidance, which states that badger sett tunnels may extend up to c. 20 m from sett entrances cautiously. As can be seen from Figure 1 local topography can influence the architecture of a sett; in this case very much biased in extent to the southwest of the sett entrances. Also in this case the outer tunnels do extend more than 20 m from the sett entrance. Thus when considering what type of construction works or site investigative works can be undertaken close to a sett the NRA categories should be used as guidance, but not as a definitive cut-off. Where doubt exists the advice of a qualified ecologist, who can review the context of the sett relative to ground conditions, local topography *etc.*, should be sought. It is in these cases that consideration could be given to the use of non-invasive geophysical survey techniques.

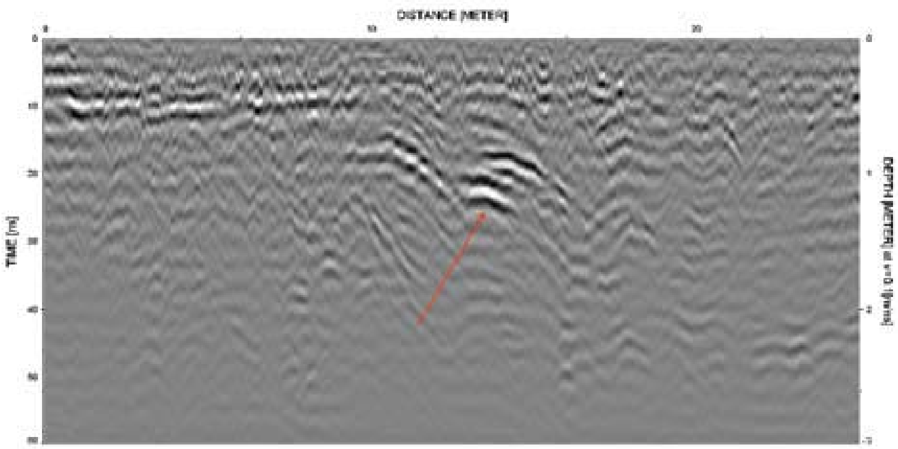

Figure 2: Example of Ground-penetrating radar (GPR) results – the distortion indicated by the red arrow is interpreted as a possible sett structure (tunnel).

Constraints to Consider

Clearly questions remain as to the widespread application of non-invasive geophysical survey techniques and when used, which method should be favoured. The first question is that of data validation. Due to the commercial constraints imposed on this work, it was not possible to validate the findings by undertaking a non-invasive survey of a sett proposed for excavation; those setts within the LMA already being excluded under licence. Such a study would allow for voids identified as putative tunnels to be validated as such. However, in this instance, a sett complex with known entrances from which tunnels were known to radiate, was used to ground truth work on site, as was a nearby culvert. It is proposed to undertake further such surveys in future projects where feasible.

In this study we utilised both Ground penetrating radar (GPR) and Electromagnetic Conductivity. GPR is influenced by both soil type and water content in the soil. The higher the clay content or the water content of soils within the survey zone then the shallower the depth to which the GPR can investigate. Made-ground, metallic objects or utilities can also distort results. Generally speaking bedrock depth is too great to influence results, though in areas of shallow bedrock, such as karst limestone this may be a consideration. Generally speaking the ground to be surveyed has to be reasonably flat, with ideally no hedge or tree roots that could be misinterpreted as voids, though can normally be discriminated (see for example the noise along the eastern side of Figure 1 – hedgerow). Ground conditions on many sites may therefore preclude its use.

In the current study, GPR was found to slightly out perform Electomagnetic (EM) techniques. However, in the current study EM38, which surveys to a depth of 1.5 m, was used (GPR surveyed to 2.8 m). An alternative strategy would, however, be to use EM31, which in horizontal dipole mode has a penetration depth of c. 3 m. It would be our intention to test EM31 at the next opportunity we have to investigate a sett.

While GPR can see the voids, EM gives you a measure of the conductivity. Generally a void gives a low conductivity reading; however, this could potentially be complicated if badgers are urinating within the sett complex; the salty nature of urine can give a high conductivity rating thereby cancelling out the anomaly. This effect may be more pronounced during the winter months when badgers are not coming to the surface to urinate and defecate.

EM signals are disrupted by the presence of metallic features with the resulting noise dominating the results. EM techniques should not be used in the immediate vicinity of fences and power lines where possible (an exclusion zone of 3 m for EM 38 and 10 m for EM31 is generally acceptable. GPR, however, is not affected by the presence of fences and/or power lines.

In the current study, the results of the GPR survey gave a good representation of the location of the tunnels and when viewed in combination with the EM data gave a clear interpretation, highlighting the value of an integrated approach to such studies.

While cost is a further consideration, in this study where we had a number of sites to visit the technique proved cost effective.

As noted, a large proportion of setts in Ireland are in hedges adjoining open agricultural lands; this methodology may therefore be more widely applicable in Ireland than perhaps in the UK.

Conclusions

Clearly, in certain cases this technique could be a valuable addition to the survey methods and mitigation options available to badger surveyors, as in this study where it assisted in defining a safe work area. Whilst the technique is now much easier to use in the field and is becoming more cost effective its precision must be further tested. In order for it to be more widely adopted a series of validated surveys would need to be undertaken under differing ground conditions. This would offer the opportunity to prepare best practice guidance for both ecologist and geophysical surveyors considering undertaking such work.

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Notes

[1] Wildlife Act 1976 (No. 39 of 1976) and Wildlife (Amendment) Act 2000 (No. 38 of 2000) - www.irishstatutebook.ie/

[2] Licences in Ireland are granted by National Parks and Wildlife Service, Department of Environment, Heritage and Local Government.

[3] In order to avoid disturbance of setts we have not included figures showing sett locations.

[4] Smal (1995) recorded an average group size of 5.9 adults per group in Ireland.

[5] Topsoils and subsoils in the environs of the sett complex comprised a mix of soft brown slighty sandy, slightly gravely clays. Gravels were fine to coarse and of various lithologies. In places the topsoil comprised black peaty clay with rootlets.