Monitoring Pesticide Use and Wildlife Exposure in Scotland
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Introduction
Scottish wildlife is exposed to a range of environmental contaminants, including rodenticides and plant protection products (PPPs). Potential exposure routes include consumption of rodenticide bait, ingestion of contaminated food or water and, for PPPs, dermal absorption and inhalation.

Methods
SASA surveys Scottish agricultural use of PPPs and rodenticides and also operates the Scottish Wildlife Incident Investigation Scheme (WIIS). In addition to investigating accidental and deliberate poisoning, WIIS has analysed wildlife carcasses, using LC-MS/MS, for sub-lethal residues of anticoagulant rodenticides since 2003 and for 70 currently approved PPPs since 2010. These surveillance schemes are operated to provide post-approval feedback to the pesticide regulation process.

Results
Approximately 1,400 tonnes of PPP compounds are applied to Scottish arable crops annually (Figure 1). In contrast, anticoagulant rodenticide use on arable farms is less than 0.1 tonne per annum (Figure 2).

Of 335 carcasses tested for PPPs only two buzzards contained residues (Table 1). In contrast, rodenticide residues were found in nearly all species tested (Table 2). Unsurprisingly, rodenticide exposure and residue levels were greatest in raptors and carnivorous mammals which prey on rodents; with red kites and foxes displaying notably high rates. However, it should also be noted that species do not regularly prey on rodents such as sparrowhawks and otters, also displayed around 50% exposure. Additionally, rodenticides were detected in 9% of herbivorous and insectivorous bird and mammal species, suggesting that predation of rodents is not the sole exposure route. The rodenticide residues detected in wildlife reflected reported agricultural use patterns, with the majority of use and detection being difenacoum and bromadiolone.

Discussion
Rodenticide residues are found in a range of Scottish wildlife, including many species which are subject to conservation and reintroduction schemes, such as Golden Eagles, White Tailed Eagles, Ospreys, Red Kites, Otters, Pine Martins and Scottish Wildcats. Despite application rates of PPPs being 10,000 fold greater than rodenticides, very few carcasses contained residues, highlighting the acknowledged difference in risk of exposure in relation to application rate. With the exception of red kites, very few cases of rodenticide related mortality were confirmed. However, lack of data about sub-lethal effects leads to concern about the potential impact on wildlife and questions whether the recommended risk management procedures are adequate to protect non-target species.