Biologically significant residual persistence of brodifacoum in reptiles following invasive rodent eradication, Galapagos Islands, Ecuador

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SUMMARY: Rat eradication resulted in prolonged presence of the anticoagulant rodenticide brodifacoum in exposed lizards, likely significantly contributing to the deaths of secondarily exposed raptors up to at least 773 days after bait application.

BACKGROUND: Invasive rodents threaten biodiversity on islands and over 447 successful *Rattus* spp. eradications have been implemented on islands worldwide, mostly using the rodenticide brodifacoum (Campbell *et al.* 2015, Russell & Holmes 2015). In the Galapagos Islands, a systematic rodent eradication programme commenced in 2007, with success on Rabida (499 ha) and 11 smaller islands in 2010. In 2012, ship rat *Rattus rattus* baiting commenced on Pinzon Island (PI; 1815 ha) where rat predation had halted recruitment of the endemic Pinzon giant tortoise *Chelonoidis ephippium* for at least 100 years.

ACTION: Bait containing 25 ppm brodifacoum was aerially applied to PI in late 2012. Secondary exposure risk minimization for 60 Galapagos hawks *Buteo galapagoensis* (GAHA) included live capture and captive holding, with release 12-14 days after baiting ceased. Telemetry transmitters were fitted to 32 GAHA before release.

CONSEQUENCES & DISCUSSION: Hatchling tortoise survival followed successful rat eradication from PI (Tapia Aguilera *et al.* 2015). Between 12 and 170 days after release, mortality of 22 tracked GAHA was recorded. Necropsy of these birds indicated anticoagulant toxicosis, with up to 379 ppb brodifacoum present in liver. In addition, a short-eared owl *Asio flammeus* carcass, found fresh 773 days post-baiting, had 577 ppb brodifacoum in liver. Monitoring of live-caught PI endemic lava lizards *Microlophus duncanensis* also showed residual brodifacoum in liver (Figure 1). The remaining PI GAHA population (n=10) were recaptured and placed into captivity in June 2013, subject to a repatriation plan based on sentinel release and ongoing residue monitoring of PI lizards.

A priori risk assessment predicted that, without captive holding as mitigation, high population-level mortality for PI GAHA would occur through secondary brodifacoum exposure via poisoned rats, with uncertainty regarding lizards as residue vectors. Ingestion of lizards carrying residual brodifacoum for prolonged periods were likely a significant contributor to unplanned mortality of released PI GAHA.

Recent data suggest reptiles are less susceptible to brodifacoum toxicity (Weir *et al.* 2015) than mammals and birds, and thus may be capable of carrying relatively high sublethal residue burdens. No population level poisoning mortality of PI lizards was observed, while monitoring confirmed population-wide exposure to brodifacoum. These omnivorous lizards represent a significant proportion of the biomass on PI, and were expected to ingest fragments of bait or invertebrates that degrade bait. The prolonged presence of residues in the lizard population suggests ongoing secondary exposure pathways (e.g. invertebrates, cannibalism), and/or relatively slow metabolic elimination of brodifacoum in these lizards. Residue recycling between lizards and invertebrates, possibly augmented by low residue elimination rates in lizards and reduced biodegradation of brodifacoum on PI, is a potential explanation.

Removing non-native invasive rodents from islands is a proven approach to protecting endemic biodiversity: anticoagulant rodenticides are currently the most reliably effective method to achieve this. Until alternative rodent-specific methods become available (Campbell *et al.* 2015), our data have important implications for planned use of anticoagulants in situations where reptiles could represent major residue transfer pathways.

REFERENCES

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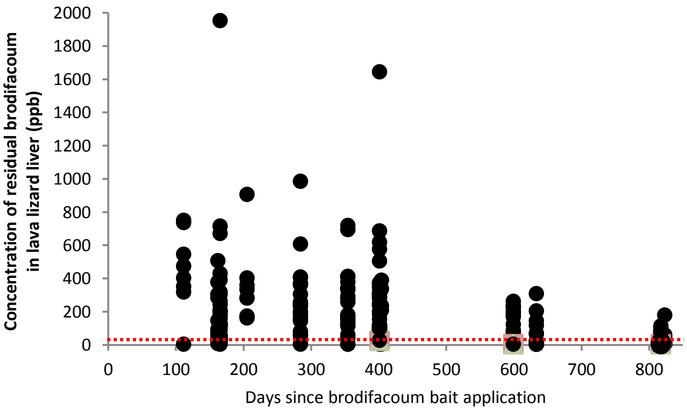

Figure 1. Concentrations of brodifacoum in livers of lava lizards (n = 270) sampled from Pinzon Island, Galapagos up to 850 days after application of brodifacoum bait. The analytical method limit of detection was 10 ppb, shown as a dotted line.

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