The Isles of Scilly seabird restoration project: the eradication of brown rats (*Rattus norvegicus*) from the inhabited islands of St Agnes and Gugh, Isles of Scilly

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Abstract As part of the Isles of Scilly Seabird Recovery Project, and directed by Wildlife Management International Ltd, the eradication of brown rats (*Rattus norvegicus*) from the inhabited islands of St Agnes & Gugh, Isles of Scilly was completed between October 2013 and April 2014 with the assistance of volunteers, and staff from the Royal Society for the Protection of Birds, Isles of Scilly Wildlife Trust and Natural England. Bait stations with cereal-based wax blocks containing bromadiolone at 0.005% w/w were established on a 40–50 metre grid over the island. With the presence of 85 residents on the 142 ha islands, this is the largest community-based brown rat eradication globally to date. Given the fact that a community is based on these islands, community engagement and advocacy was a vital and fundamental part of the eradication. Consultation for eradication began three years prior to the operation to explain the requirements for the proposed project and to assess support, but this built on many years of wider community engagement with seabird conservation. All of the residents supported the eradication of rats and vision of the project. The consultation and inclusion of the community in decision-making and management of the Isles of Scilly Seabird Recovery Project was a critical part of the operation and key to the success of the eradication. The community took ownership of the project and has committed to the on-going biosecurity requirements following the eradication of rats. The removal of brown rats from St Agnes and Gugh was a major achievement and provided the opportunity to restore the islands' communities of seabirds and other native species. This project provided an example of the effectiveness of ground-based rodent eradication techniques on an inhabited island and the lessons learnt during this operation can be used to help proposed eradications on other islands with communities and with terrain suitable for ground-based techniques.

Keywords: brown rat, community, eradication, Isles of Scilly, *Rattus norvegicus*, St Agnes and Gugh

INTRODUCTION

The eradication of invasive species from islands has become one of the most important tools in conservation in recent times. It offers the opportunity that, following an initial investment, significant long-term benefits can be achieved. The eradication of rats is a recognised prerequisite for the restoration of many seabird colonies on islands. Rodents have been successfully eradicated from over 700 islands around the world, including at least 10 UK islands (Moors & Atkinson, 1984; Atkinson, 1985; Taylor, et al., 2000; Zonfrillo, 2001; Towns & Broome, 2003; Appleton, et al., 2006; Howald, et al., 2007; Jones, et al., 2008; Bell, et al., 2011; Parks & Wildlife Service, 2014; DIISE, 2015; Thomas, et al., 2017; Bell, 2019; Bell, et al., 2019; Pearson, et al., 2019), However, most of these islands have been uninhabited. Many consider that islands with significant human populations, unreceptive communities or occurrence of livestock and domestic animals are unlikely to be feasible for eradication (Oppel, et al., 2011; Campbell, et al., 2015; Russell & Broome, 2016; Stanbury, et al., 2017). However, an increasing number of eradications are being considered on inhabited islands and the importance of the engagement and inclusion of local communities has been highlighted in a number of recent eradication and research projects, especially in regard to risk and benefit analysis (Eason, et al., 2008; Bryce, et al., 2011; Oppel, et al., 2011). It should be noted that the greatest conservation benefit to be gained from future eradications in the UK, and in other parts of the world, is predominantly from inhabited islands (Stanbury, et al., 2017). As such, it is vital that techniques and protocols developed during eradications on islands with even small communities should be assessed, utilised or adapted for these islands with larger communities.

The Isles of Scilly are a nationally and internationally important location for seabirds, particularly Manx shearwater (*Puffinus puffinus*), European storm petrel (*Hydrobates pelagicus*) and black-backed gull (*Larus fuscus*) (Lock, et al., 2006). Both Manx shearwaters and European storm petrels are amber listed under the United Kingdom Birds of Conservation Concern threat categorisation (Eaton, et al., 2015). A partnership of organisations (Royal Society for the Protection of Birds (RSPB), Natural England (NE), Isles of Scilly Wildlife Trust (IOSWT) and Isles of Scilly Bird Group (IOSBG)) produced the Isles of Scilly Seabird Conservation Strategies 2005–2008 and 2009–2013 which described the national and international status and context of the seabird populations on the Isles of Scilly and identified priority actions and strategic goals for management. These included current and future measures to improve the available habitat for seabirds through rat control and eradication (Lock, et al., 2006; Lock, et al., 2009). St Agnes and Gugh have a number of important land areas designated for seabirds as Special Protected Areas (SPA), Sites of Special Scientific Interest (SSSI) and Ramsar (Lock, et al., 2009). The eradication of brown rats (*Rattus norvegicus*) from St Agnes and Gugh was identified as a priority in these strategies as it would remove predation pressure on Manx shearwaters and storm petrels and provide the opportunity for other seabirds to colonise the islands (Lock, et al., 2006; Lock, et al., 2009). These strategies also recognised the social, economic and health benefits for the local community (Lock, et al., 2006; Lock, et al., 2009).

The Isles of Scilly Seabird Recovery Project (IOSSRP) was established in 2010 and was managed by a coalition of

In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) (2019). Island invasives: scaling up to meet the challenge, pp. 88–94. Occasional Paper SSC no. 62. Gland, Switzerland: IUCN.

groups including RSPB, IOSWT, NE, Duchy of Cornwall (DC), the Isles of Scilly Area of Outstanding Natural Beauty (AONB) partnership and a representative from St Agnes and Gugh, with support from the IOSBG. The IOSSRP partnership identified the need to assess the possibility of eradicating brown rats from St Agnes and Gugh to protect and enhance the islands' seabirds and protect Annet from re-invasion. Annet is the most important uninhabited island for seabirds in the Isles of Scilly as it has always been rat-free (excluding an incursion in 2004, probably from neighbouring St Agnes) and holds the main populations of Manx shearwaters and European storm petrels (Lock, et al., 2006). The partnership commissioned a feasibility assessment in 2010 (Bell, 2011). A formal IOSSRP Steering Group made up of representatives from all Project Partners was established in 2012. Wildlife Management International Ltd. (WMIL) directed the eradication with the assistance of volunteers and RSPB, IOSWT and NE staff. The eradication was completed between October 2013 and April 2014 (Bell, et al., 2014). This paper covers the technical aspects of the St Agnes and Gugh brown rat eradication and complements the Pearson, et al., (this issue) paper on the community aspect of the eradication.

STUDY AREA AND METHODS

St Agnes and Gugh

St Agnes and Gugh (49.89267°N, 6.34073°W) are two islands in the Isles of Scilly archipelago off the Cornish coast, in south-west England (Fig. 1). St Agnes (105 ha) and Gugh (37 ha) are connected by a rock and sand bar at low tide (Fig. 1). St Agnes and Gugh are separated from St Mary's by a deep channel (St Mary's Sound) that is 1.1 kilometres at the closest point (via stepping stone islands) or 1.3 km from shore to shore (Fig. 1). There are 85 residents, only two of whom live on Gugh. Brown rats were accidentally introduced to the Isles of Scilly from shipwrecks in the 1700s, and were widespread and abundant across both islands, as well as many other islands in the archipelago (Matheson, 1962; McCann, 2005). Tourism is one of the islands' major sources of income, particularly between April and October.

There are approximately 40 homes on the island, but at least 150 buildings (holiday lets, farm buildings, sheds, etc.) scattered across the whole island. There are six farms (including a chicken farm and dairy), a campground, a school, a restaurant, a pub, two cafes, a post office and store. There are cattle, chickens, ducks, geese, two ponies and pigs on St Agnes. Many families have pet cats and dogs. There is a main quay where passengers and freight are landed, and a smaller slipway used mainly by residents. These factors increased the number of challenges such as providing alternative food and shelter for rats, risk to non-target species and biosecurity.

Fig. 1 Location of St Agnes and Gugh, Isles of Scilly, United Kingdom.

The main habitats on St Agnes are farmland, mainly flower farms and low intensity cattle grazing, characterised by small fields with extensive hedges and stone walls, ponds, maritime grassland, invasive *Pittosporum*, rocky shores and sandy beaches (Parslow, 2007). St Agnes and Gugh are home to the only known populations in the British Isles of a number of rare plants, including least adder's-tongue fern (*Ophioglossum lusitanicum*) (Parslow, 2007).

Rabbits (*Oryctolagus cuniculus*), Scilly shrews (*Crocidura suaveolens cassiteridum*) and pipistrelle bats (*Pipistrellus* spp.) are the only other known species of mammal found on St Agnes and Gugh, apart from livestock and pets. House mice (*Mus musculus domesticus*) were present on St Agnes and Gugh, but have not been seen in at least 15 years, though mice are still present on most of the other main islands in the Scillies (Howie, et al., 2007).

Eradication operation

The eradication programme ran from 11 October 2013 to 11 April 2014 and included establishing the bait station grid, poisoning, monitoring and biosecurity establishment. This phase took 1,593 person days. Long-term monitoring ran monthly between May 2014 and December 2015. The final check, species monitoring, and rat-free declaration ran from 6 January to 18 February 2016. This phase took 250 person-days. All IOSSRP personnel wore blaze-orange hats (with the IOSSRP logo) to be easily recognisable to the community and visitors. Each operational task was undertaken and completed as follows:

Pre-eradication

Due to the presence of a community on the island and the selected method of bait stations, different pre-eradication preparation tasks were required compared to aerial baiting methods. Preparation tasks included, but were not limited to: consultations with the community about operational techniques; timing of each aspect of the project and confirming access to land and buildings; testing rats for resistance to rodenticides; getting the community to cease using rodenticides on the island six months prior to the eradication (i.e. to prevent bait aversion, avoid rats becoming accustomed to bait and to prevent resistance); removal of waste, alternative food and harbourage (including cleaning up farm sheds and other buildings on the island); establishing waste management systems for each household and business (including provision of rodent proof wheelie-bins and compost bins); application for an extension-of-use for rodenticide use from the UK Health and Safety Executive (HSE); construction of bait stations; and delivery of all equipment to the islands.

The University of Reading completed resistance testing and DNA screening of 26 rats trapped on the islands. Of these samples, resistance (L120Q mutation) was detected in one individual (Rymer, 2013). This resistance evidence confirmed the requirement for multiple toxin and bait formulations to ensure any problem rats could be targeted successfully. An extension-of-use permission from HSE was obtained to use specific rodenticides (difenacoum and brodifacoum) at specific locations outdoors if it became necessary to target any resistant rats towards the end of the eradication.

Over 1,500 bait stations were constructed by RSPB staff and volunteers in Penzance and these and all other equipment was delivered to St Agnes in September 2013.

Bait station grid

The bait station grid was established between 12 October and 7 November 2013. Bait stations were made from 750 mm lengths of 100 mm diameter corrugated black plastic drainage pipes, wired into the ground to prevent movement by animals and/or wind. Bait was placed in the centre of the station through the access hole that is covered by an additional short section of pipe and held in place by a 'crow clip' (a short piece of wire wrapped around the centre of the station devised during the Lundy Island rat eradication operation which prevents the crows and gulls removing the lids (Bell, 2019)).

Bait stations were placed out on a 40 m × 50 m grid. Positions were determined by electronic Geographic Information System (GIS) and loaded onto a hand-held GPS unit. Each station was marked by a bamboo cane or flagging tape to ensure visibility in thick vegetation or poor weather.

The entire grid of 962 tube stations was positioned across the island (with an additional 74 commercial Protecta™ lockable bait stations inside all private homes, holiday rentals, public buildings and on the quay) before being individually numbered and mapped using GPS and added to a GIS-linked database (Fig. 2).

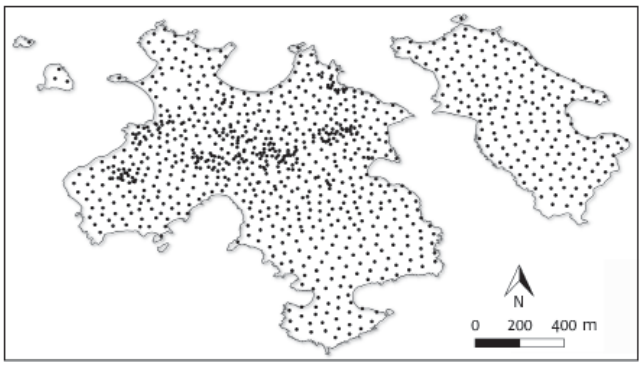

Fig. 2 Bait station grid on St Agnes and Gugh, Isles of Scilly. Bait station positions are marked by a black dot.

Poisoning

The main toxicant used was bromadiolone, Contrac™ (manufactured by Bell Laboratories), a 28 g, cereal-based wax block bait with 0.005% active ingredient. This bait was used between 8 November 2013–12 January 2013 and 27 January–8 March 2014 (Table 1). There were two alternative baits, both manufactured by PelGar International, available if any rats were detected that seemed to be avoiding or appeared to be resistant to the main bait: Roban Excel™, a 20 g cereal-based block bait with active ingredient difenacoum at 0.005% w/w that was used between 13–26 January 2014 (Table 1); and Vertox Oktablok II™, a 20 g cereal-based block with active ingredient brodifacoum at 0.005% w/w that was not required. Contrac™ and Roban Excel™ are dyed blue (or green/blue) to be less attractive to birds (Caithness & Williams, 1971; Hartley, et al., 1999; Weser & Ross, 2013), thus helping to further reduce risks to non-target species.

The poisoning operation commenced on 8 November 2013 and continued through to 8 March 2014. Baits were present in each station throughout the poisoning programme and replaced as required; when eaten by rats, by non-target species such as invertebrates and/or damaged by weather. Between 8 and 18 November 2013 there were eight blocks of bait in each station. This was reduced to four blocks between 19 and 25 November 2013 and reduced again to two blocks from 26 November 2013 to 26 January 2014 (Table 1). After 27 January 2014, only one block of bait was placed in each station. Existing undamaged bait blocks were left in the stations and the extra blocks were removed. All waste and partially eaten bait was collected and incinerated in a high temperature incineration facility at the end of the operation.

Bait was loose in the stations between 8 and 25 November 2013 (so that rats can take bait back to their burrows to feed nursing females or young) and after 26 November all bait was wired into the stations (which could be used to confirm the presence of rats due to teeth marks being recorded on partially eaten blocks in the stations) (Table 1).

Excluding the stations in the houses (which were checked once a week), all other bait stations on St Agnes and Gugh were checked and serviced at intervals between one to seven days (a total of 56 bait checks over 120 days) depending on the stage of the operation (Table 2). To present the data on bait-take gained from these varied bait station checks we grouped the data into 27 periods or checks (mean (±SEM) = 1.9 ± 0.2 days between checks, range 1–7 days) shown as days from baiting (Fig. 3).

Bait-take was recorded in field notebooks by bait station number and the species believed to have consumed

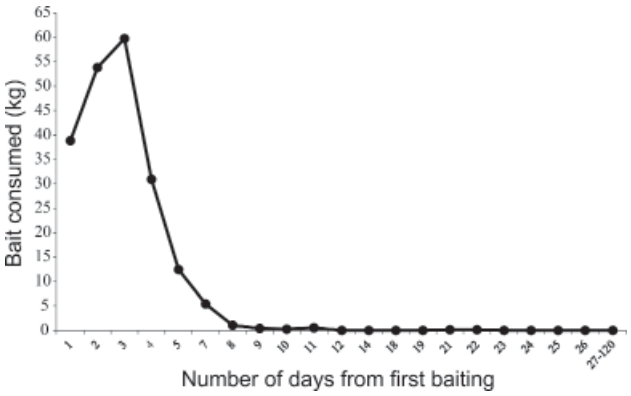

Fig. 3 Amount (in kg) of bait consumed by rats at each bait check (marked by black dot) during the brown rat (*Rattus norvegicus*) eradication on St Agnes and Gugh, Isles of Scilly.

Table 1 Baiting regime during the brown rat (*Rattus norvegicus*) eradication on St Agnes and Gugh, Isles of Scilly, United Kingdom.

Date	Bait type	No of blocks	Bait loose or wired into station
8–18 Nov 2013	Contrac™ (bromadiolone)	8	Loose in station
19–25 Nov 2013	Contrac™ (bromadiolone)	4	Loose in station
26 Nov 2013 to 12 Jan 2014	Contrac™ (bromadiolone)	2	Wired into station
13–26 Jan 2014	Roban Excel™ (difenacoum)	2	Wired into station
27 Jan to 8 Mar 2014	Contrac™ (bromadiolone)	1	Wired into station

Table 2 Number of bait station checks during the brown rat (*Rattus norvegicus*) eradication on St Agnes and Gugh, Isles of Scilly, United Kingdom.

Date	Checks per week
8–20 November 2013	6
21 Nov to 13 Dec 2013	5
14 Dec 2013 to 8 Mar 2014	3

or removed the bait. These data were entered into a GIS-linked database and maps showing active stations were produced in real-time to enable the team to effectively monitor bait-take activity and target any "hot spots".

Searches for carcasses were completed during all checks. Any carcasses that were found, were collected, necropsied to determine cause of death (where possible) and incinerated to reduce risk for non-target scavengers. It was expected that very few rat carcasses would be found on the surface as most rats die underground in their burrows. Five rat carcasses were found on the surface during the Lundy Island rat eradication and three during the Isle of Canna rat eradication (Bell, 2004; Bell, et al., 2006). Any non-target species that were collected during the operation were also necropsied and assessed for anticoagulant poisoning (i.e. blood in body cavity, bruising, discolouration of organs). Non-target species have been affected during other eradications: 77 non-target species' carcasses (greater black-backed gull *Larus marinus*, carrion crow *Corvus corone*, house sparrow *Passer domesticus*, short-eared owl *Afio flammeus* and rabbit *Oryctolagus cuniculus)* were found on the surface during the Lundy Island rat eradication and seven non-target species carcasses (wood mouse *Apodemus sylvaticus*, and pygmy shrew *Sorex minutus*) were found during the Isle of Canna operation. Of these, only 15 showed evidence of anticoagulant poisoning and the remainder had died of starvation (rabbit, shrew) or either natural (short-eared owl, crow) or unknown causes (greater black-backed gulls) (Bell, 2004; Bell, et al., 2011).

Monitoring

Three distinct periods of monitoring were undertaken as the project progressed. Intensive monitoring using 2,500 stations at 25 m spacing was carried out from 19 November 2013 to 8 March 2014 to detect rats surviving through the poisoning phase. This was followed by a 21-month period of long-term monitoring using 87 biosecurity stations and six rodent motels (wooden boxes designed to provide an attractive, alternative 'burrow' for rats during an incursion) from 9 March 2014 to 5 January 2016. These biosecurity stations were established at high risk areas on the island; around the coast, at the quay and other boat landing sites and at seabird breeding sites (Bell, et al., 2014). The final monitoring check, using 448 stations, was carried out between 6 January and 18 February 2016 (Bell & Cropper, 2016). WMIL and RSPB staff and volunteers carried out the intensive and final checks and IOSSRP staff, St Agnes and Gugh residents and volunteers maintained the long-term monitoring. Monitoring stations consisted of materials attractive to rats that would also clearly show teeth marks (e.g. chocolate, peanut or coconut flavoured wax, candles and soap), tracking tunnels and trail cameras (Bushnell™). All were individually numbered and any evidence of activity (e.g. teeth marks or foot prints) was recorded in field notebooks by station number and the species believed to have consumed or marked the monitoring item.

Monitoring items were placed inside and outside each station as well as halfway between each station during the intensive monitoring phase and final monitoring check. During these monitoring phases, each monitoring site was checked regularly 3–5 times a week (depending on weather), either separately or – during the poisoning phase – together with the poisoning bait station grid. Monitoring items were placed inside the biosecurity stations only during the long-term monitoring phase and these were checked monthly. Checks for active rat runs and activity at high-risk sites (i.e. stone walls, farms, seabird colonies, etc.) were also undertaken throughout all three monitoring phases. Any rat and non-target species sign found on any monitoring detection device at any stage of the monitoring phase was recorded and added to the database.

RESULTS

Bait acceptance and take

Bait acceptance was excellent with no evidence of bait avoidance. Green/blue rat droppings appeared within three days and rats accounted for 203.6 kg of Contrac™ bait taken (estimated 1,600–2,500 rats).

The bait-take pattern was typical of other rat eradication campaigns (Thomas & Taylor 2002; Bell, et al., 2011). It was very high in the immediate days after original baiting (checks 1–3) and dropped to a relatively low level eight days after original baiting (check 8) (Fig. 3). A small increase was recorded at day 21 after the original baiting (check 15) but dropped away, reaching zero bait-take on day 23 after the original baiting (check 17) (Fig. 3).

Throughout the poisoning phase, 62% of bait stations were visited by rats, with 42.7% active within the first three days of the original baiting. This level of activity was similar to the Lundy and Isle of Canna eradications which had 42.5% and 62% of bait stations visited by rats, respectively (Bell, 2004; Bell, et al., 2011). The high number of active bait stations during the first two bait checks shows that the rats quickly accepted the bait across St Agnes and Gugh. It is likely that the small grid size and intensive baiting regime targeted the rats effectively within a short timeframe.

The average number of blocks taken by rats was 4.3 (± 0.1) blocks per active station (range 0–41 blocks). Again, this level of activity was similar to the Lundy and Isle of Canna eradications which had 3.2 and 8 blocks taken by rats by per active station, respectively (Bell, et al., 2004; Bell, et al., 2011). This also indicates that rats were quickly removed from most sites across St Agnes and Gugh. As shown by Fig. 4, bait-take was not evenly distributed over both islands, with the greatest level of bait-take on the coastal areas of both islands and each of the offshore

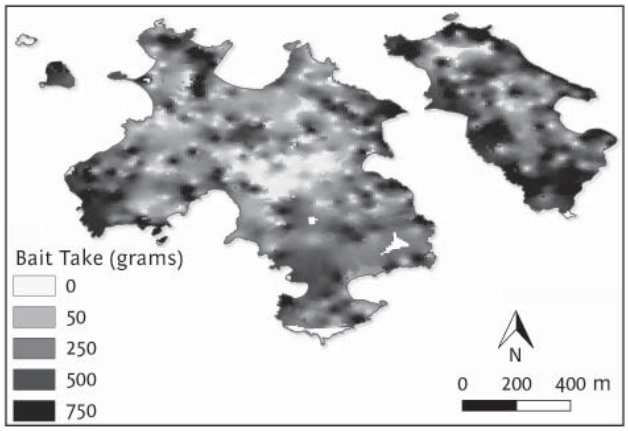

Fig. 4 Distribution of total bait-take (g) by rats consumed per station during the brown rat (*Rattus norvegicus*) eradication on St Agnes and Gugh, Isles of Scilly.

rock stacks connected to the main islands at low tide. The distribution of rats and density on Gugh was likely to be having an impact on Manx shearwaters and other seabirds and land bird and invertebrate populations present on St Agnes and Gugh.

There were 19 rat carcasses collected on the surface during the operation. These were collected and incinerated to prevent availability to non-target species.

There were low levels of interference by non-target species with nearly 54 kg of bait being consumed; cattle kicked up stations and ate a small amount of bait (1.4 kg), slugs and other insects consumed 51.9 kg and shrews consumed 0.4 kg. The weather conditions also complicated the operation and accounted for 3.4 kg of bait that had to be replaced due to the loss of 54 bait stations in storms. Carcasses of a water rail (*Rallus aquaticus*), a song thrush (*Turdus philomelos*), a blackbird (*T. merula*) and nine Scilly shrews were found. There was no evidence that any of these non-target species was affected by the rodenticide.

Monitoring

Monitoring for rat presence continued island-wide for two years after the end of the poisoning operation. The last rat was detected on chocolate flavoured wax on 29 November 2013 during the overlap between the poisoning and intensive monitoring phases and this rat was successfully targeted using the main bait, Contrac™, by 2 December 2013. No rats or sign were detected during any phase of the long-term or final check monitoring. St Agnes and Gugh were declared rat-free in February 2016.

Cattle, shrews and birds interfered with 899 monitoring stations (by eating the flavoured wax or soap, marking tracking plates or, in the case of cattle, by removing the monitoring wires) a total of 12,156 times between 21 November 2013 and 26 February 2014. There were 127 stations affected 1,384 times by cattle, 60 (82 times) by birds, 5 (8 times) by insects, 9 (9 times) by rabbits and 454 (2084 times) by shrews. Interference by birds, shrews and rabbits was limited to teeth or beak marks on the soap or flavoured wax or footprints on tracking plates. Cattle removed wires and ate flavoured wax and soap, so monitoring points had to be moved or hidden in those areas with cattle.

DISCUSSION

The success of the St Agnes and Gugh brown rat eradication shows that a well-planned, adequately resourced, well-executed programme, with the complete support of the community, local agencies and government and directed by an experienced operator with dedicated workers, can eradicate rats from inhabited islands using a ground-based bait station operation. The project on St Agnes and Gugh is the largest community-led (with 85 residents) brown rat eradication anywhere in the world. Most other eradications on inhabited islands either have smaller communities (e.g. Isle of Canna, 12 residents; Bell, et al., 2011; Rakino in New Zealand, 16 residents; Bassett, et al., 2016) or have staff or a military population (e.g. Bird, Denis, Curieuse and Fregate Islands in the Seychelles, Merton, et al., 2002; Lundy Island, Bell, 2004; Wake Island, Brown, et al., 2013) and have not had direct involvement of the community during and after the eradication or leaving the community responsible for all biosecurity measures (Pearson, et al., this issue).

However, the success of the eradication was dependent on the participation and support of the entire local community. The community maintained an integral role and was consulted extensively in the planning, preparation and implementation of the eradication programme. As such, it is vital that techniques and protocols developed during eradications on islands with even small communities should be assessed, utilised or adapted for islands with larger communities. The opinions and safety of local communities need to be a priority in any eradication planned for inhabited islands.

Stock and chicken feed provided a possible alternative food source for rats, but all the farmers were fully supportive of the project and stored all the unopened feed on pallets (with bait stations and/or traps underneath) or in rodent-proof containers and any opened feed was stored in large plastic, metal or wooden sealed bins. Where possible, farm buildings were kept clean to ensure fresh sign was quickly noted. All these methods meant that the sheds were cleared of rats and any roaming rats which re-invaded the area could be noted quickly. The presence of a large chicken farm could have been a major problem as their runs provide excellent rat habitat and alternative food. The owner of the chicken farm strictly managed his chickens and feeding regime throughout the rat eradication operation which made targeting rats and monitoring for any survivors on this farm easier.

Rubbish can be the most serious issue on an inhabited island wanting to eradicate rats. This was discussed comprehensively with the community before the project commenced. As a result, rat-proof wheelie bins and Green Johanna compost bins were provided to the residents and all rubbish was stored in these prior to removal to St Mary's. Rubbish was removed regularly (generally weekly) from St Agnes to St Mary's by the Isles of Scilly Council. In October and early November 2013, with the permission and assistance of residents, a number of sheds, farm buildings and outhouses were cleared and tidied by the IOSSRP team to ensure bait stations could be placed along all the walls.

St Agnes and Gugh were cleared of rats within three weeks (23 days from original baiting). Bait-take showed that the rat population appeared to be low (approximately 2,000 rats) and was not evenly distributed across the islands. There were high concentrations of rats on Gugh and around the coastal areas on St Agnes where the burrow-nesting seabird colonies are present, meaning rats were likely to have been having an effect on these breeding seabirds (Moors & Atkinson, 1984; Atkinson, 1985; Jones, et al., 2008).

The interference by cattle was another major factor affecting the operation, with cattle kicking up or crushing stations, but cooperation by the farmers to move stock around different paddocks, as well as altering the bait station positions, wiring the bait or lids into position in addition to the crow clip or weighting the stations down with rocks, meant this problem was quickly dealt with. Many of the monitoring stations were removed from, and then replaced back into, certain areas (such as Covean and Wingletang) as the cattle were rotated between paddocks.

Importantly, there were no known non-target species affected by this operation. Although a small number of Scilly shrews (n = 9) were found dead and necropsied during the eradication, proof of poisoning could not be confirmed (i.e. no symptoms of anticoagulant poisoning such as blood in body cavity, bruising or discolouration of organs). However, no liver or tissue samples were taken from non-target species for further analysis. It should be noted that, in certain cases, bait-take by shrews subsequently stopped in nearby stations suggesting these animals had died due to primary poisoning. Although there is no information on the LD50 for shrews, using LD50 data from other small mammals (voles and mice), it is likely that shrews would have to eat between 0.2–1.25 mg/kg to be affected by bromadiolone. This amounts to 0.001 blocks

of bait and this level of bait take by shrews occurred at 83 different stations between 22 November 2013 and 5 March 2014 suggesting that approximately 83 shrews may have been affected by the baiting phase (totalling to 0.4 kg of bait). However, it is thought that as Scilly shrews have small home ranges (< 50 m^2; Spencer-Booth, 1963; Rood, 1965), excluding those with a bait station in their immediate home range, most shrews would not encounter bait stations or poisoned invertebrates using the 40 m × 50 m grid. This means that even if a small number of individuals was killed, the overall population would survive. The risk to the shrew population was considered minimal, but the potential for a small number of individuals to be affected was acknowledged (Bell, 2011). Calculations of bait-take indicate that more shrews than anticipated may have been at risk, but extensive searches for carcasses and the necropsies performed do not support this; there was no definitive evidence of any shrew death being attributable to the rodenticide. Scilly shrew numbers have increased to population levels higher than those before the eradication (IOSSRP, unpublished data).

A large quantity of bait was consumed or damaged by slugs and other insects. Bait was changed often to ensure there was always the most attractive and palatable bait available to rats. Contrac™ was more durable than expected, compared to earlier experience on Lundy Island where it deteriorated within one to two days (Bell, 2004), meaning it lasted better in the St Agnes and Gugh environment. Occasionally it was difficult to interpret sign on the blocks during the important monitoring phase of the operation, owing to the nature of the block and ridges, but the Contrac™ bait successfully targeted all rats on St Agnes and Gugh within three weeks.

There was no evidence that any other non-target species were affected by the rodenticide, traps or monitoring tools used in the operation. Following necropsy of shrews and other non-target species carcasses (water rail, thrush and blackbird), there was no bait found in the stomach or symptoms of anticoagulant poisoning (i.e. blood in the body cavity, bruising or haemorrhaging or discoloured organs). Although 19 dead rats were found on the surface (1.1% of estimated rat population on St Agnes and Gugh), there was no evidence of any other animal scavenging these carcasses. There were no observations of pet cats, crows, gulls or raptors eating dead or dying rats on St Agnes and Gugh.

Weather also affected the eradication when storms removed or dislodged stations, but this generally was limited to coastal areas.

The eradication of invasive species such as rats from islands has become one of the most important tools in avian conservation worldwide. It was recognised that for the restoration and protection of seabird colonies on St Agnes and Gugh, the eradication of rats was required. This operation has already benefited key seabird species on the islands as well as the Scilly shrew as shown by comparisons between the pre- and post-eradication biodiversity monitoring. Manx shearwaters were recorded successfully breeding within one year of the eradication and 73 pairs were recorded in 2016 compared to 22 pairs and no fledged chicks in 2013 (Pearson, 2016). European storm petrels were first recorded on St Agnes in 2015, with 9 pairs in 2016, and the Scilly shrew population has increased to levels higher than the pre-eradication levels since rats have been eradicated (IOSSRP, unpublished data; Pearson, 2016; Thomas, et al., 2017).

Although eradicating rats from St Agnes and Gugh is a considerable and significant achievement, it is important to stress that keeping these islands rat-free will require constant vigilance and commitment from the whole community, partner agencies and visitors in order to prevent, detect and respond to any incursions. Prevention of an accidental rat re-introduction should be the primary aim. The greatest risk is via service and private vessels traveling between all of the inhabited islands in the Isles of Scilly, especially if delivering farming equipment, hay, stock feed, equipment or food to St Agnes. There is also a small risk from visiting yachts and general tourism. Permanent biosecurity stations have been established on St Agnes and Gugh; these will be maintained indefinitely by trained community members and IOSSRP personnel. A detailed biosecurity plan has been developed to prevent, detect and respond to possible incursions. Residents have been trained in these biosecurity measures, identification of rodents and rodent sign, and methods to reduce the risk of accidentally introducing rodents, demonstrating the commitment of the St Agnes and Gugh community to the restoration of their islands.

It is important to stress that the eradication of brown rats from St Agnes and Gugh is a valuable education tool to show other island communities that it is possible to safely eradicate rats without unduly impacting on the lives and habits of the local residents. The successful eradication of brown rats from St Agnes and Gugh demonstrates how the techniques of ground-based bait station operations can be utilised on inhabited islands throughout the UK and the world where this technique is feasible and where the community is involved and supportive.

ACKNOWLEDGEMENTS

This project was carried out with funding from EU LIFE (Scilly Isles LIFE Project 11 UK NAT 387), UK's Heritage Lottery Fund (HG-11-06880) and the Defra-funded Isles of Scilly Area of Outstanding Natural Beauty (AONB) Partnership Sustainable Development Fund. The Contrac™ bait, T-Rex™ and Protecta™ bait stations were generously donated by Bell Laboratories. The Roban Excel™ and Vertox Oktablok II™ bait were donated by PelGar International Ltd. Our heartfelt thanks go to the entire St Agnes and Gugh community for their support and enthusiasm throughout the project, supplying goods and services to the team, providing rat sightings, and for their willingness to implement new waste management and ongoing biosecurity procedures. We would also like to thank Sophie Thomas (RSPB), David Appleton (Natural England), Michelle Hawkins (Natural England), Peter Exley (RSPB), Tony Whitehead (RSPB), Trevor Kirk (AONB), Rebecca Steggles (AONB), Dave Mawer (IOSWT), Darren Hart (IOSWT), Dr. Alan Buckle (Reading University), Dr. Colin Prescott (Reading University) and David Rymer (Reading University). St Agnes Boating, The Isles of Scilly Steamship Company, St Mary's Boating Association, Bryher Boats and St Martin's Boating Association all provided boat transport. Samantha Sadighi, Great Green Systems Limited, supplied the compost bins for the St Agnes & Gugh community at a discounted rate. Special thanks to all the IOSSRP Seabird Taskforce Volunteers – Helen Brandes, Haydn Brooks, Alex Cropper, Bob Dawson, Lindsey Death, Neil Duffield, Paul Garner-Richards, Richard Halstead, Sarah Havery, Vickie Heaney, Jack Ibbotson, Cal James, Helene Jessop, Darren Mason, Tegan Newman, Will (Billy) Renny, Jack Roper, Rebecca Steggles, Colin Taylor, Toby, Rachel and Otto Taylor, Karen Varnham, Alastair Wilson, Will Whittington and Lewis Yates for their hard work, enthusiasm and support throughout the project. Extra thanks to Jenny Parker (RSPB) and David Flumm (RSPB) and their team of mainland-based volunteers who made the 1,500 bait stations.

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