Removing introduced hedgehogs from the Uists

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Abstract Hedgehogs (*Erinaceus europaeus*) are native to Great Britain but were introduced to the island of South Uist in 1974 and gradually colonised South Uist and Benbecula. In 1999 hedgehogs were confirmed in southern areas of North Uist. Hedgehogs eat the eggs and occasionally the chicks of waders, which breed at high densities in the Uists. Initial research by Royal Society for the Protection of Birds (RSPB) in 1998 suggested that predation by hedgehogs was having a significant effect on the wader populations in South Uist. In 2014, remote cameras were used on a sample of wader nests and found hedgehogs responsible for 52% of all predation in South Uist. The Uist Wader Project was set up in 2000 to remove hedgehogs from North Uist initially, but with a long-term aim to remove hedgehogs completely from the Uists. Various methods including lamping, trapping and the use of sniffer dogs were developed, trialled, and improved. We developed an Index of Abundance (IOA) of hedgehogs, using footprint monitoring tunnels. This IOA provides a means of confirming the impact of removal activities on the hedgehog population. In anticipation of scaling up, we carried out a removal trial on a two km² area at Drimore in South Uist. The trial demonstrated the effort required to reduce the abundance of hedgehogs from high density, 30 animals/km², to zero and enabled the project team to estimate the resources required to eradicate hedgehogs from Benbecula, North and South Uist. The North Uist phase should be complete by the beginning of 2018, with only eight hedgehogs caught in 2016 and just one in 2017. Two years of monitoring are planned between 2018 and 2020, to confirm eradication.

Keywords: dunlin, IOA, redshank, ringed plover, sniffer-dogs, translocation, trap, wader

INTRODUCTION

Wader surveys in the early 1980s showed that the Uists, off the west coast of Scotland, held high densities of breeding redshank (*Tringa totanus*), ringed plover (*Charadrius hiaticula*) and dunlin (*Calidris alpina*) (Fuller, et al., 1986). In recognition of the importance of the Uists, 14 Sites of Special Scientific Interest (SSSIs) and two Special Protection Areas (SPAs) for Birds were designated in the late 1990s. Shortly afterwards a decline was found in wader populations on the islands of South Uist and Benbecula that was largely due to egg predation by hedgehogs (Jackson, 2001; Jackson & Green, 2000; Jackson, et al., 2004). Hedgehogs (*Erinaceus europaeus*) are native to Great Britain but were introduced to South Uist in 1974–75 (Angus, 1993). In 1999, hedgehogs were starting to colonise southern areas of North Uist (Jackson & Green, 2000; Jackson, et al., 2004). Declines of waders recorded in South Uist between 1983 and 1998 were: ringed plover by -58%; dunlin by -65%; and redshank by -43% (Fuller & Jackson, 1999). In 2014, remote cameras were used on a sample of wader nests and found hedgehogs responsible for 52% of all predation in South Uist.

The hedgehog population on the United Kingdom mainland has been in decline since the1960s (Noble, et al., 2012). Hedgehogs are protected under Schedule 6 of the Wildlife and Countryside Act 1981 throughout the UK, but are classified as invasive non-natives in the Uists, as they are classified outwith their native range under section 14. Hedgehogs have no natural predators in the Uists, can breed five months out of the year, and can produce at least as many young per year as their population, as measured in the spring (Jackson, 2007). Initial research in South Uist on hedgehog behaviour and methods of locating them was carried out between 1997 and 2001 (Jackson, 2007). This work estimated the density of hedgehogs in different habitats in South Uist at 31.8 animals/km² for machair, 15.4 animals/km² for blackland and two animals/km² for moorland.

The Uist Wader Project was launched in 2000 as a partnership of Scottish Natural Heritage (SNH), Royal Society for the Protection of Birds (RSPB) and the Scottish Executive. The Project's objective was to safeguard the waders of the Uists from introduced hedgehogs. In order to achieve this it would be necessary to remove all the hedgehogs from the Uists, starting in North Uist.

MATERIALS AND METHODS

Study area

The Uists are part of the Outer Hebrides, located off the north-west coast of Scotland (Fig. 1). The Uists include six inhabited, low-lying islands, connected by causeways. The three main islands are North Uist (333 km²), Benbecula (81 km²) and South Uist (315 km²). The climate is wet and windy. Wind-blown shell sand has formed extensive machair habitats on the west side of these islands. These lime-rich coastal grasslands are grazed by livestock and cultivated with arable crops (oats, rye, barley and potatoes) on a traditional rotation (Angus, 2006). There are a few farms but most of the agricultural land is divided into small tenanted units, known as crofts, each with shares in larger common grazings. The other predominant habitat types in the Uists are moorland and blackland (an intermediate zone of mesotrophic grassland between machair and moorland).

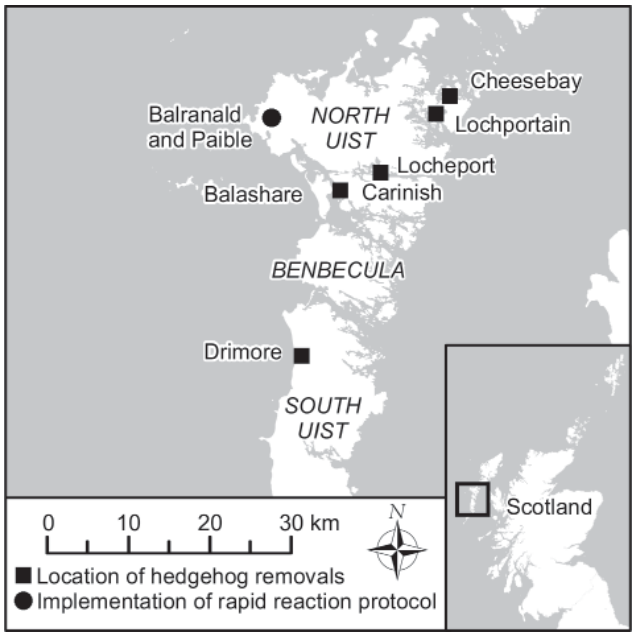

Fig. 1 Location map of the Uists in conjunction with mainland Scotland.

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In order to carry out any type of fieldwork in the Uists it was essential to have the full support of the local community, land owners, crofters and residents. Project staff spent time working with these groups to secure access to land and receive information relating to hedgehogs. Although access permission was always granted, there were constraints placed on some of the removal methods described below.

Population model

Based on initial research by Jackson (2007), modellers at Newcastle University developed a hedgehog population model in two phases (Shirley, et al., pers. comm. 2007; Shirley, et al., 2010). These individual-based, simulation models of the hedgehog population indicated that trapping and lamping would achieve total eradication of hedgehogs from the Uists within 30 years, at best, which represents eradication by 2040. The hedgehog population in the Uists was estimated from a combination of field data and the model to be around 3,900 in 2010, whereas this was estimated to be about 3000 in 2007, (95% confidence limits ±800). This highlighted the shortcomings of our initial methods and led to a new approach, using sniffer dogs and all year round removal of hedgehogs.

Hedgehog removal

There are three key methods of removing hedgehogs; lamping (spot-lighting), live cage trapping and searching with sniffer dogs. Lamping at night was very effective on short cropped machair turf. It involves three to five people transecting areas of land operating in a straight line about five to 10 metres apart, each using a 10–50 watt, 12 volt halogen spot-lamp to survey the ground for hedgehogs. Lamping was not effective in longer vegetation and the night work caused disturbance to local residents. Lamping as a method of hedgehog removal was gradually phased out due to its intrusive nature with regard to light and noise disturbance at night.

Live cage trapping was tried in 2004 and proved very effective at removing a large proportion of the population: 80–90% of hedgehogs over an eight week period. Trapping worked well in all types of habitat and replaced lamping as the main method of removing hedgehogs. The live cage traps used for hedgehogs are 180 × 150 × 480 mm, with a spring-loaded door, activated by a treadle plate. Traps are installed in large trap grids, designed to intersect the home range of each potential hedgehog. Two different trapping densities are used. Low density trapping (30 traps/km^2) is used when initially establishing a trapping route, where the underlying hedgehog population is expected to be zero (i.e. monitoring suggests no hedgehogs) or when the underlying habitat is not particularly suitable for hedgehogs, such as moorland and bog. Higher density trapping (50 traps/km^2) is used where a known hedgehog population exists and the underlying habitat is suitable. The traps are baited with fish, which is placed behind the treadle plate, but not obstructing it. Once operational, traps are checked every day. Throughout the project, trap placement was continuously improved through experience and research with habitat, location, cover, bait and trap sensitivity being the most important factors. Trapping proved to be an effective means of capturing a large proportion of a population, but not every animal, suggesting that some were trap shy.

Sniffer dogs are also used to remove hedgehogs. The dogs are trained to indicate the location of a hedgehog without harming it and are rewarded with a short period of play time with a favourite toy when successful. A specialist trainer was brought in for six days each year to guide the training process, encourage best practice and work with each dog handler on a one to one basis. Sniffer dogs can work effectively for periods of three to four hours and an experienced sniffer dog and handler can cover up to two km^2 per week in most weather conditions and across diverse vegetation. Dense vegetation and calm conditions result in narrower, more condensed search transects, while wind speeds between eight and 55 kph and short vegetation allow wider more expansive transects and hence greater area covered per unit of time. Wind speeds in excess of 55 kph progressively reduce the efficiency of dog searching due to the scent being dispersed too widely. Sniffer dogs and trapping complement each other as hedgehog removal methods, because dogs are more effective in boggy ground where traps simply can't be set and traps are more effective in areas where dens are located deep underground and hedgehogs only re-emerge at night. There were sometimes more restrictions on using dogs than traps in fields at lambing time but sniffer dogs could locate hedgehogs during the winter, when trapping is ineffective. The use of dogs was suspended, early on in the project, following the introduction of legislation banning the hunting of wild mammals with dogs, The Protection of Wild Mammals (Scotland) Act 2002. This greatly reduced the efficiency of removing hedgehogs at lower densities and added additional time and cost to the Project. Following careful legal interpretation of how dogs could be used to locate and 'flush' hedgehogs, the use of sniffer dogs was reinstated in 2010.

Between 2003 and 2006 all captured hedgehogs were euthanised, based on the best information available at that time. Advice from the animal welfare organisation, the Scottish Society for the Prevention of Cruelty to Animals (SSPCA), rejected translocation on welfare grounds and advocated hedgehogs were euthanised. The SNH board in 2002 stated that there was no scientific evidence or overriding conservation imperative to justify translocation of hedgehogs from the Uists to the mainland. During this time, the Project came under increasing pressure from animal rights groups and special interest conservation groups to stop killing hedgehogs and consider moving them to the Scottish mainland instead. The British public perceives hedgehogs as an iconic species, which is the gardener's friend, and there was strong media and public pressure against the cull.

New research carried out at Bristol University (Molony, et al., 2006) showed that translocation of hedgehogs resulted in low mortality if certain levels of veterinary care, feeding and general welfare were provided. Based on this work, the SSPCA advised that the hedgehogs' welfare would not be adversely affected by being translocated to the Scottish mainland. SNH then entered into a partnership with the animal care sector to translocate hedgehogs. Fieldworkers pass hedgehogs onto a 'carer', based in South Uist, for onward transport to an animal rescue centre on the mainland for release under established protocols. In response to improvements in the ability to identify and care for pregnant females and to locate dependant young, it became possible in 2012 to remove hedgehogs throughout the season, rather than only during the non-breeding season of three and a half months as done previously.

Monitoring

Monitoring between 2009 and 2010 simply involved checking traps and lamping, which equates to extending the removal methods until a period of two years has elapsed where no capture of hedgehog has occurred.

From 2011 onwards, three monitoring techniques were deployed: footprint monitoring tunnels, sniffer dogs and motion-activated cameras.

The footprint monitoring tunnels were made out of 150 mm plastic drainage pipe, cut to 560 mm lengths. A rectangular section 100 × 190 mm was cut out of the middle of the pipe to accommodate a plastic tray, 110 × 50 × 200 mm. The tray was then filled with one of three different substrates; clay, sand or carbon plate. The tunnels were dug into the ground and covered with turf to make the tunnel as much like a natural burrow as possible. The inside of the tunnel was fashioned to allow a natural walk through for an animal over the tray. These tunnels were dug into the monitoring area at a density of five tunnels/km² and their positions recorded using GPS.

Trained sniffer dogs were deployed to search at least 25% of the monitoring area following methods similar to their use for hedgehog removal. Hedgehogs located in North Uist were removed as re-release was not an option, whereas hedgehogs located in South Uist were released, since their removal would have no real impact on the overall population, which had reached its maximum carrying capacity.

Motion-activated cameras (model: Bushnell Trophycam HD max) were deployed at a density of 1.25 cameras/km². We set them to record 60 second video clips (1280 × 720 px) onto a 32 GB SD card. The camera was focussed on a 120 g 'tuna tin' with perforations in its top, filled with fish and dug into the ground so the surface of the can was level with the ground. This acts as an attractant to hedgehogs and a host of other animals, yet prevents them from removing the fish. The SD card needs to be changed every two weeks and the rechargeable batteries have a variable lifespan, of two to three weeks, depending on the rate of triggering.

Six sample areas representing the whole of North Uist were monitored between 2013 and 2014 using at least two different monitoring methods. Monitoring highlighted the areas where hedgehogs were present and allowed a more strategic and selective approach to checking the total area of North Uist.

Occupancy model

In the early part of the Project, progress was measured as 'number of hedgehogs caught per 1000 trap nights'. When trapping effort was applied over time, this measure generally showed a decline. However, we were unsure if this measure reflected the actual impact of removal activities on the hedgehog population, or if a significant number of animals remained undetected due to trap avoidance. In 2013, a two-year monitoring trial was established to estimate occupancy and the relative index of abundance (IOA) of hedgehogs across the Uists, and evaluate the effectiveness of the removal methods.

Between 2013 and 2014, hedgehog populations were assessed in 19 locations in the key areas for breeding waders, using footprint monitoring tunnels. Attempts were also made to assess populations using motion-activated cameras and sniffer dogs, but insufficient cameras were available and the sniffer dog data proved too difficult to interpret due to a number of factors including experience of dog and handler, wind speed, and topology of land.

Each plot (route) covered an area of four km² with a minimum of five monitoring tunnels/km² and was checked twice per week.

Various occupancy models were tested, and the Royle-Nichols single season, abundance-induced heterogeneity model (Royle & Nichols, 2003) was chosen as the most appropriate single season occupancy model. This is a two-parameter model that derives occupancy (ψ) from estimates of detectability r (the probability of detection per tunnel) and population density λ (the mean of the Poisson distribution), thus estimating occupancy in a way that accounts for hedgehogs being easier to detect when there are more of them. The following formulas represent the Royle-Nichols model:

1) $L(w) = \prod_{i=1}^{R} \left\{ \sum_{k=0}^{K} \binom{T}{w_i} p_k^{w_i} (1 - p_k)^{T - w_i} f_k \right\}$

2) $p_k = 1 - (1 - r)^k$

3) $f_k = \frac{e^{-\lambda} \lambda^k}{k!}$

Formula (1) represents the likelihood of detections, where W represents detections, R represents sites, T represents (route) locations. Formula (2) represents the site detection probability and (3) represents the probability density formula for a Poisson distribution, where both (2) and (3) substitute into (1). Note also how r and λ are incorporated into this model.

The plots were grouped together by year and modelled with a constrained detectability and unconstrained population density. Detectability was estimated, along with individual population density, for each location and year.

Footprint monitoring results were used in preference to camera monitoring results due to the limited data sample from the cameras compared to tunnels (Paul Ross, pers. comm. 2014).

Hedgehog removal trial

In 2014, we undertook a hedgehog removal trial to evaluate the effectiveness of the hedgehog removal methods. A research area of 1.78 km² was selected on Drimore farm in South Uist, which represented typical machair habitat with a probable high population of hedgehogs. A perimeter area of 1.3 km² surrounding this research area was also created to reduce the effects of dispersion and migration of hedgehogs following removal from the research area.

The research area was monitored using footprint monitoring tunnels, motion-activated cameras and sniffer dogs for a four week period to establish an IOA. The monitoring tunnels were evenly distributed at a density of five tunnels/km², motion-activated cameras at a density of five cameras/km² and sniffer dogs were operated at a rate of two km² per week. Hedgehogs were then removed from both areas using 50 traps/km² on the research area only, and sniffer dogs on both areas, for an eight week period. The research area was monitored for a further four weeks in the same design as the pre-removal monitoring, to establish whether all hedgehogs had been removed.

Scaling up to North Uist

Recent hedgehog removal efforts in North Uist were guided by the results of the monitoring work; areas that showed presence of hedgehogs were searched using a combination of trapping and sniffer dogs. The search effort was set using the results of the Drimore trial.

The removal phase is expected to be completed by spring 2018, and will be followed by a further two years of monitoring to confirm absence of hedgehogs. If a hedgehog is encountered during the monitoring phase a rapid-reaction protocol will be initiated.

Rapid-reaction protocol

A one km radius buffer around the sighting of a hedgehog will be searched for four weeks with sniffer dogs and 50 traps/km². If further hedgehogs are found, this process will be repeated.

RESULTS

Activites implemented in 2003 to 2008

Sniffer dogs were used only in 2003 during this period. Lamping and trapping were used as the main methods of hedgehog removal. Monitoring between 2009 and 2010 confirmed successful eradication.

Initial hedgehog removal: 2003–2008

Hedgehog removal started in 2003 in Locheport and Carinish in the southern area of North Uist (129 km²) and was completed by 2008. A further two years of monitoring were carried out to verify a successful eradication, which was declared in 2010. Fig. 2 shows the removal of hedgehogs and effort applied in Carinish and Locheport. Believing that North Uist was clear, the Project expanded the removal methods into Benbecula to continue working southwards. Good progress was made initially, but further hedgehogs were reported from new areas of North Uist; from Balranald in 2009 and Lochportain in 2012. Work in Benbecula was postponed whilst the trapping team was re-deployed to eradicate hedgehogs from these new areas.

Monitoring results – occupancy estimates 2013–2014

As expected, the lowest occupancy (ψ) estimates were in North Uist and the highest ones in South Uist.

The North Uist IOA monitoring results for 2013 and 2014 are shown in Table 1 and Table 2, respectively. Note that the route names do not correspond to the same areas between the two years. In 2013, Baleshare (represented by H1 & H2) showed no occupancy of hedgehogs, and Balranald (F1) showed a low level of occupancy. In 2014, Balranald (F1, M1, andG2) showed further dispersal of hedgehogs.

The South Uist and Benbecula occupancy results for 2013 and 2014 are shown in Table 3 and Table 4, respectively. Note that the routes K1 and B2 correspond between Tables 3 and 4. Fig. 3 shows these results spatially. The occupancy estimate of hedgehogs is relatively high for almost all parts sampled in South Uist and Benbecula.

All other parts of North Uist, Benbecula and South Uist were monitored by sniffer dog but due to a range of confounding factors it proved impossible to convert these data into a meaningful occupancy estimate. However, the sniffer dog monitoring did give a good overview of the distribution of hedgehogs across the Uists to complement the formal occupancy estimate results.

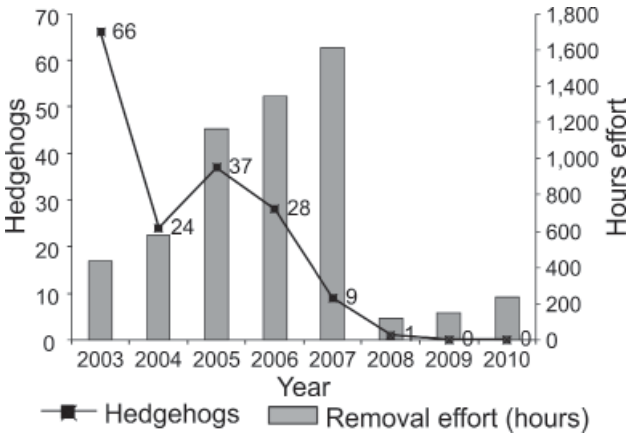

Fig. 2 Carinish and Locheport hedgehog removal and effort.

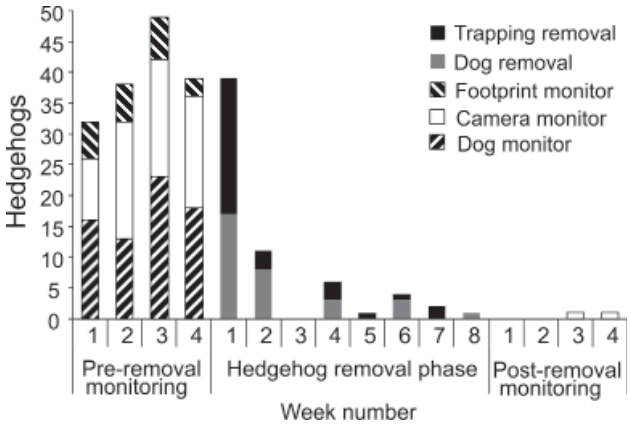

Fig. 3 Hedgehogs removed or detected, by method, for the Drimore trial.

Removal trial results (Drimore, 2014)

Pre-removal monitoring phase

Monitoring was carried out across the research area for four weeks between 7 April and 4 May. Table 5 shows the numbers of hedgehogs detected each week by footprint monitoring, camera monitoring and sniffer dogs. Using only the footprint monitoring data, it was possible to derive an occupancy estimate for this area of land during the four week monitoring phase, which is shown in row B2 in Table 3. In comparison to other sites monitored in the Uists, the Drimore site represented a high population of hedgehogs.

Removal of hedgehogs

This phase of operation involved removing hedgehogs from the research and perimeter areas using live cage traps and sniffer dogs over an eight week period between 5 May and 29 June. Two fieldworkers searched the area using sniffer dogs and operated 89 live cage traps. Table 6 shows that the same numbers of hedgehogs were removed from the research area by sniffer dogs as by trapping. Over the same period, hedgehogs were removed from the perimeter area by sniffer dogs alone, as shown in Table 7.

Post-removal monitoring

The final phase of the trial involved repeating the monitoring over another four week period between 30 June and 28 July to measure the IOA of the hedgehogs after the removal operation. Table 8 shows that only two hedgehogs showed up on camera during this period, both in the perimeter area. No hedgehogs were detected within the research area, providing an acceptable level of confidence that all of the hedgehogs had been removed. Fig. 3 summarises the numbers of hedgehogs detected by each monitoring method at all three stages.

Recent hedgehog removals in North Uist – scaling up to North Uist

Lochportain hedgehog removal

Lochportain, along with the neighbouring townships, is located on a peninsula on the east side of North Uist. In 2012 a hedgehog was found by a member of the public on the road close to Cheesebay (adjacent to Lochportain). Due to other commitments and limitations on staff resources the Project was only able to respond to this potential hedgehog population with a very limited removal effort in 2013, which yielded no hedgehog captures. The team returned to this area in 2015, with a concerted removal effort covering some 75 km², followed by monitoring in 2016. Fig. 4 shows the hedgehog removal and relative effort appliedin Lochportain.

Table 1 2013 – Royle-Nichols parameter estimates for hedgehogs in North Uist. Note: ψ represents the probability of occupancy, derived from $(1 - f_0)$, r represents the probability of detection per hedgehog / tunnel, and l represents population density as the mean of the Poisson distribution. Route name refers to four km² plot areas.

Route name	Naïve occupancy	Occupancy		Detectability		Population density	
		ψ	SE	r	SE	λ	SE
F1	0.046	0.073	0.322	0.142	0.027	0.076	0.077
F2	0.000	0.000	-	0.142	0.027	0.000	-
G1	0.000	0.000	-	0.142	0.027	0.000	-
G2	0.000	0.000	-	0.142	0.027	0.000	-
H1	0.000	0.000	-	0.142	0.027	0.000	-
H2	0.000	0.000	-	0.142	0.027	0.000	-

Table 2 2014 – Royle-Nichols parameter estimates for hedgehogs in North Uist.

Route name	Naïve occupancy	Occupancy		Detectability		Population density	
		ψ	SE	r	SE	λ	SE
F1	0.100	0.154	0.294	0.142	0.027	0.167	0.086
M1	0.025	0.041	0.333	0.142	0.027	0.042	0.042
G2	0.075	0.124	0.304	0.142	0.027	0.133	0.079
J1	0.000	0.000	-	0.142	0.027	0.000	-

Table 3 2013 – Royle-Nichols parameter estimates for hedgehogs in South Uist and Benbecula.

Route name	Naïve occupancy	Occupancy		Detectability		Population density	
		ψ	SE	r	SE	λ	SE
A1	0.286	0.582	0.145	0.142	0.027	0.873	0.347
A2	0.400	0.531	0.163	0.142	0.027	0.758	0.288
B1	0.130	0.241	0.264	0.142	0.027	0.275	0.164
B2	0.400	0.632	0.128	0.142	0.027	1.000	0.366
C1	0.286	0.405	0.206	0.142	0.027	0.519	0.223
C2	0.100	0.182	0.284	0.142	0.027	0.201	0.145
D1	0.000	0.000	-	0.142	0.027	0.000	-
D2	0.250	0.458	0.188	0.142	0.027	0.613	0.273
E1	0.300	0.446	0.192	0.142	0.027	0.591	0.255
E2	0.100	0.171	0.288	0.142	0.027	0.188	0.135
K1	0.050	0.080	0.319	0.142	0.027	0.084	0.085
B2	0.400	0.628	0.129	0.142	0.027	0.988	0.332

Table 4 2014 – Royle-Nichols parameter estimates for hedgehogs at Drimore in South Uist and Benbecula.

Route name	Naïve occupancy	Occupancy		Detectability		Population density	
		ψ	SE	r	SE	λ	SE
K1	0.050	0.105	0.311	0.142	0.027	0.110	0.111
B2	0.000	0.000	-	0.142	0.027	0.000	-

Lochportain was effectively cleared of hedgehogs over a 10 week period, which matched very closely with the Drimore removal trial. Migration to and from Lochportain was minimised by being located on a peninsula with a narrow isthmus.

Fig. 5 compares the Drimore trial and Lochportain removal. There is a strong similarity in the pattern of hedgehog removal even though the starting populations of hedgehogs and the area of land covered are very different. Both locations represent declining sequences of weekly captures ending at one or less over eight to 10 weeks. Subsequent monitoring on both sites demonstrated that no further hedgehogs were immediately present.

Balranald & Paible hedgehog removal

In 2009 hedgehogs were sighted in Balranald and Paible in the west of North Uist by members of the public. Trapping began in 2009, and sniffer dogs were introduced gradually from 2010, so that by 2013 all fieldwork staff operated a dog.

Fig. 6 shows that the bulk of the hedgehog population was removed between 2013 and 2015, with just a small number of hedgehogs removed in 2016. It also shows the relationship between trapping effort and the number of hedgehogs removed for Balranald and Paible.

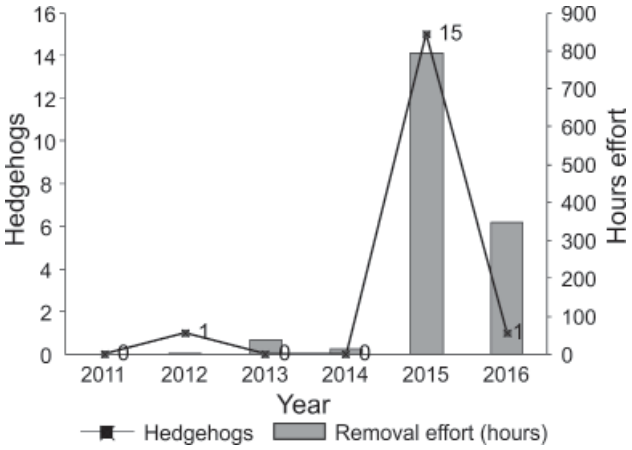

Fig. 4 Lochportain hedgehog removal and effort.

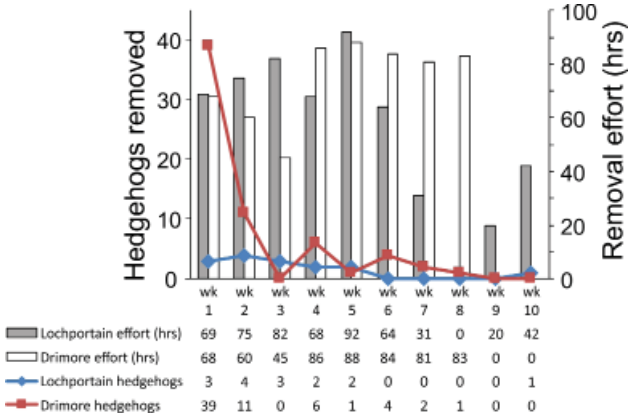

Fig. 5 Comparison of hedgehogs removed between Lochportain and Drimore.

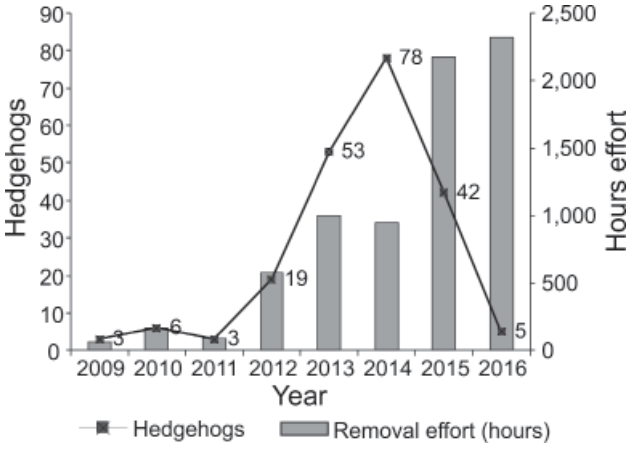

Fig. 6 Balranald and Paible removal and effort.

Table 5 Hedgehogs detected during the pre-removal monitoring phase at Drimore. Monitoring effort: two footprint monitoring checks per week per tunnel over 10 tunnels, five cameras running continuously and two sniffer dogs checking two km² per week.

Monitoring method	Week				Total
	1	2	3	4	
Footprint	6	6	7	3	22
Camera	10	19	19	18	66
Sniffer dog	16	13	23	18	70

Implementation of rapid-reaction protocol

The rapid-reaction protocol has been used only once. One hedgehog was located by a monitoring camera and then located and removed by a dog handler and sniffer dog in the area of east Balranald during April 2017. A search zone was established using a buffer of a radius of 1 km from the location of the hedgehog, as shown in Fig. 7. Four weeks searching using sniffer dogs and trap checks were carried out, but no further hedgehogs were located.

DISCUSSION

It is essential to have the support of the local community, not just to report sightings but also to persuade people not to move hedgehogs to new areas. Hedgehogs were clearly moved to discrete unconnected areas in North Uist, including Carinish, Locheport, Balranald and Lochportain. We had support from most land managers but we failed to reach all individuals within the wider community. Some people moved hedgehogs as they thought they would provide a helpful service such as controlling garden slugs or snails that host sheep fluke. Once we were able to discuss these introductions and the potential impacts with the individuals involved, they usually became more supportive. Any future removal project should include an education and promotion resource to assist with community engagement. There is also a need to secure full support and commitment right from the start of the project all the way through until eradication is confirmed.

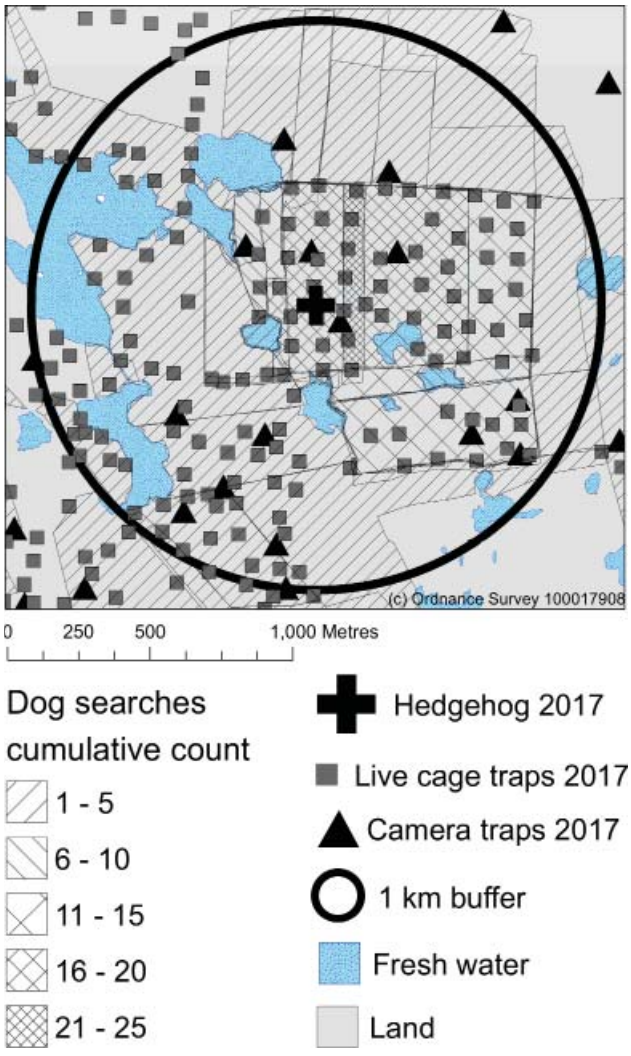

Fig. 7 Rapid-reaction protocol in response to hedgehog capture at Balranald.

Table 6 Hedgehogs removed from research area at Drimore during removal phase.

	Week								
Removal method	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Trapping	22	3	0	3	1	1	2	0	32
Sniffer dog	17	8	0	3	0	3	0	1	32
Total hedgehogs	39	11	0	6	1	4	2	1	64
Effort: trapping (hrs)	44	43	44	44	41	44	44	44	348
Effort: dog (hrs)	24	17	1	42	47	40	37	39	247

Table 7 Hedgehogs removed from perimeter area at Drimore during removal phase.

	Week								
Removal method	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Trapping	-	-	-	-	-	-	-	-	-
Sniffer dog	0	2	12	4	1	1	1	0	21
Total hedgehogs	0	2	12	4	1	1	1	0	21
Effort: trapping (hrs)	-	-	-	-	-	-	-	-	-
Effort: dog (hrs)	0	2	14	2	2	6	3	3	32

The methods used in eradicating hedgehogs from Carinish and Locheport were limited by the absence of sniffer dogs and a lack of clarity on the abundance of hedgehogs in any given area. For animal welfare reasons, hedgehog removal was restricted to the three and a half month non-reproductive period. These limitations meant it took approximately eight years to clear the area and verify it as clear. Balranald and Paible were also initially limited to the non-reproductive season and sporadic, exploratory efforts prior to 2013. However from 2013 onwards Balranald and Paible had a fully operational team of sniffer dogs and hedgehog removal progressed relatively quickly, with captures tailing off by 2016. Lochportain also benefitted from the use of dogs and from being on a peninsula. The introduction of monitoring, refined control methods and strategies meant that removing the Lochportain hedgehog population took just two years, compared to eight at Carinish. If there are obstacles or barriers to removal activities then it will reduce the effectiveness of removal and it will take longer to reduce the population to zero. Being able to work all year round made the Project much more efficient, reducing the predicted minimum time required for eradication of hedgehogs from the Uists from 30 to five years.

The Drimore trial demonstrated that hedgehog population density within a discrete area can be effectively reduced to zero by trapping and sniffer dogs over a relatively short period of time. The removal phase reduced the IOA from a high level to zero. The two hedgehogs detected on camera in the latter weeks of the post-removal monitoring were located in the perimeter area and it is assumed these were migrating into the research area. Comparing the Drimore trial results to the Lochportain eradication shows that it took roughly the same effort to remove 64 hedgehogs as it did 14 hedgehogs from an equivalent area. This suggests that eradication effort is determined by area of suitable habitat more than hedgehog density.

Table 8 Hedgehogs monitored during the post-removal monitoring phase at Drimore.

Monitoring method	Week				
	1	2	3	4	Total
Footprint	0	0	0	0	0
Camera	0	0	1	1	2
Sniffer dog	0	0	0	0	0

The Project needed to estimate the effort required to reduce the hedgehog population to zero over a given area of land and prevent re-colonisation from surrounding areas. The Drimore removal trial enabled us to assess whether the resource had been sufficient on every bit of land at Balranald and where to put in additional resource.

The near complete removal of hedgehogs from North Uist was achieved using an agreed strategy with proven methods of removal, which were shown to be effective. Being able to measure the effectiveness of the hedgehog removal methods used, and the effort required to clear a given area of land, enables a fairly accurate estimation of what timescale would be required to clear a specific area of land. There also needs to be a method of confirming that the population has been reduced to zero (Russell, et al., 2016). The IOA has been extremely valuable in that respect, particularly on areas such as Balranald, with complicated land tenure and constraints on using dogs whilst livestock are in fields at certain times of year.

In the early days of the Project we coloured maps by hand and filled in paper data sheets, whereas now we use graphic GPS, integrated to GIS systems, connected to relational databases. This increased data flow has facilitated a more adaptive approach to managing project activity. Scientific advice from a wide range of sources has been extremely helpful but needs to be combined with practical considerations.

Ideally it would have been desirable to have cleared the hedgehogs from South Uist to allow the waders to recover faster, but clearing North Uist first and then moving south made more strategic sense. Having successfully removed all of the hedgehogs from North Uist, the next step is to continue southwards and remove hedgehogs from Benbecula and South Uist. This will require clearing an area of almost 400 km². Using the results from the Drimore trial and the current removal methods, we estimated that this will take between five and 10 years and will require a team of 18 staff. It is estimated that this will cost between £3.5 and £5.0 million and, at the time of writing, SNH is exploring funding options with partners.

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