OPTIONS FOR THE RECOVERY OF NESTING SEABIRDS ON JERSEY, CHANNEL ISLANDS

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EXECUTIVE SUMMARY

The recent establishment of the Jersey National Park on the island of Jersey, Channel Islands, and the acquisition of land at Plémont, St Ouen, by the National Trust for Jersey has created some unique opportunities for seabird and habitat restoration. Historically, the north-west coast from La Tête de Plémont to Douët de la Mer supported 200-300 breeding pairs of Atlantic puffin but which have dwindled today to less than 10 pairs at most. The decline has probably been a result of an overall decline in the species' southern range combined with the impacts of invasive species on Jersey including the brown rat, feral polecat/ferret, European hedgehog, European rabbit, and free ranging/feral cats. In addition, domestic dogs and agricultural stock (sheep and cows) could also prevent the re-establishment of puffins if not carefully managed at seabird nesting sites.

This document provides an overview of existing seabird recovery tools proven to re-establish breeding seabird colonies around the world. The primary focus is on the control of invasive vertebrates to increase the size and distribution of breeding colonies and reproductive success, and on hands-on species recovery techniques used to encourage seabirds to recolonise the area. However, during this study, it became apparent that much of potential seabird recovery area does not support suitable habitat for puffins or other ground-nesting seabirds. The sites are choked with dense stands of bracken fern, and this may be the primary factor currently limiting colony growth of puffins and other burrow nesting seabirds.

To understand more fully the impacts and interactions of invasive species, lack of suitable breeding habitat, and human disturbance on puffin colony re-establishment, we have recommended a pilot project combining species recovery techniques with research and monitoring. We recommend initial small steps to maximise opportunities for feedback into recovery project development. We recommend the development of Species Action Plans for puffins and other seabirds by working groups in order to guide recovery efforts, include local seabird experts and stakeholders, and ensure best practices.

ACKNOWLEDGEMENTS

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BACKGROUND AND CONTEXT

In 2016, the States of Jersey Department of the Environment, the National Trust for Jersey, and Durrell Wildlife Conservation Trust collaborated under the Birds On The Edge programme to investigate the possibility of actively restoring breeding seabird colonies to the Plémont area within the newly created Jersey National Park (**Fig. 1**). The study comprised a literature review to evaluate successful seabird recovery techniques implemented in the U.K. and worldwide, consultations with seabird ecologists and local wildlife biologists on Jersey, and a field site assessment to evaluate conservation techniques that could be effective for seabird recovery on the Plémont peninsula and north coast of Jersey.

The following report summarises the results of the field site assessment on Jersey, consolidates ideas from local seabird ecologists and wildlife biologists for seabird recovery obtained through discussion and consultation, provides a framework of possible activities to initiate seabird research and recovery, and makes recommendations to support seabird recovery planning for the Plémont area and adjacent coast. The primary focus is the restoration of Atlantic puffin (*Fratercula arctica*) as this species is globally Vulnerable (IUCN 2018) and Red-listed in Jersey (severe decline in the Jersey breeding population size of more than 50% over 20 years, Young *et al*. 2011). Also, due to its popularity the puffin is an ideal flagship species for Jersey with which to focus awareness about impacts to seabird populations and the actions that can be taken to re-establish them on the island. In addition, research and recovery activities discussed in this report are similar for other seabirds of interest including Manx shearwater (*Puffinus puffinus*), storm petrel (*Hydrobates pelagicus*), and razorbill (*Alca torda*), the latter of which is also Red-Listed. The restoration of seabirds will also benefit the coastal habitat and terrestrial birds, mammals, and reptiles in the area, and increase the biodiversity value and ecological integrity of the Jersey National Park.

Figure 1. The island of Jersey, Channel Islands, and the Jersey National Park (dark green).

The report to the Plémont Estates Ltd entitled *'Atlantic puffin* Fratercula arctica *and other seabirds at Plémont, Jersey, Channel Islands*' by Durrell Wildlife Conservation Trust (2008) provides detailed historical, biological, and ecological information about Jersey's seabirds and should be consulted for additional information. Given this, we have not given here a full account of the island's seabirds and have only replicated that information where it provided some background and context to this project (see Appendix A). This report also acknowledges ongoing puffin and other seabird surveys on Jersey and the recommendations made therein.

SEABIRD RECOVERY SITES ON JERSEY

Historically, puffins nested all along the north coast cliffs between La Tête de Plémont and Douët de la Mer, with a few birds found breeding just outside the pier at Grève de Lecq (Dobson 1952, Jones 1975) (**Fig. 2**). This historically occupied area is the recovery site for puffins and other seabirds considered hereafter. These sites provide the grass-covered sea-facing slopes that puffins prefer, where they will typically nest underground in burrows. If the soil is too shallow, puffins will also nest under rocks, in crevices, or in a natural cavity on vertical cliffs. In their southern range, nest prospecting begins in late March and egg-laying occurs from mid-April to mid-May. Incubation time is 39-45 days, the young remain in the nest for 34-50 days, and fledging occurs at night (Gaston and Jones 1998). In Jersey, Jones (1975) reported the first arrival at Plémont on March 28 and the last departure on August 02.

Figure 2. (*Left*) Google Earth map showing historical puffin nesting sites on the north coast of Jersey. (*Right*) view from Grand Becquet looking north-west to La Tête de Plémont, the grassy slope of Le Petit Becquet is in the foreground. Dark green vegetation is mostly bracken fern.

SEABIRD RESTORATION OPTIONS

To date, at least 128 seabird restoration projects have been implemented worldwide to protect 47 seabird species in 100 locales in 14 countries (Jones and Kress 2012). These projects have implemented a range of conservation techniques including control of predators and competitors, social attraction including use of decoys, acoustic playback, and artificial nest sites, and chick translocation. Factors influencing the success of these projects have included: 1) abatement of the original cause of decline or extirpation, 2) consistent funding, 3) adequate understanding of habitat requirements and breeding ecology of the focal species, and 4) pilot studies to determine the most effective restoration methods for the focal species. In addition, the availability of suitable habitat and the distance to seabird source populations are key factors in establishing new colonies (Kildaw *et al.* 2005).

Understanding the threats to seabirds within a regional, local, and historical context is critical to developing recovery goals. At-sea threats such as sea temperature rise, shifts in food distribution and abundance, extreme weather events, marine pollution, and fisheries bycatch require global and regional initiatives to reverse population declines. However, threats at breeding colonies such as introduced predators, nest site competition, human disturbance, and livestock grazing can be managed locally to increase seabird populations. Managing these threats has been proven to restore seabird colonies worldwide (see reviews in Jones *et al*. 2011, Jones and Kress 2012, Duron and Shiels 2017), and several initiatives could be developed to restore seabird populations to the north Jersey coast.

INVASIVE SPECIES IMPACTS

Invasive mammalian predators such as rats, mice, cats, mongoose, stoats, ferrets, and raccoon among others, are considered one of the greatest terrestrial threats to the persistence of seabird colonies around the world (Atkinson 1985, Jones *et al*. 2008, Croxall *et al*. 2012). Most seabirds have largely evolved to breed on remote islands or steep cliffs to escape predators. Thus, when predators are introduced to seabird breeding sites their impact is particularly severe. Non-native rodents (primarily *Rattus* sp. and *Mus musculus*) have been introduced to about 90% of islands worldwide (Atkinson 1985), and their impacts on seabirds is well documented. Direct and indirect impacts act on local, regional, and global populations result in species decline and extinction, species and colony extirpation, and ecosystem collapse (Croll *et al.* 2005, Towns *et al*. 2006, Hilton and Cuthbert 2010, Croxall *et al.* 2012). In particular, seabirds in the family Hydrobatidae and other small, burrow-nesting seabirds are particularly affected (Jones *et al.* 2008).

European hedgehogs (*Erinaceus europaeus*) are native to Western Europe but have been introduced to islands within Europe where they are not indigenous including, the Western Isles in Scotland, the Isle of Man, and Jersey. In the Uist islands (Scotland) hedgehogs have been responsible for an overall decline in shorebird numbers in the areas they occupy, and they have significant impact on shorebird nests (up to 60% destruction in some wader species) (Jackson and Green 2000, Jackson *et al*. 2004). In New Zealand where hedgehogs have also been introduced, predation rates on shorebird nests were as high as 51% at some sites, more than all other invasive predators combined (Jones 2017).

Ferret (*Mustela putorius furo*) (ITIS 2017) is the name given to the domesticated animal derived from the albino form of the European polecat (*Mustela putorius*). There is some debate as to whether the ferret was derived from the western European polecat (*Mustela putorius*) or the eastern European steppe polecat (*M. eversmannii*) or is a hybrid of both. Ferrets are variously considered to be a separate species, or the same biological species as the western polecat, or a subspecies of it, *M. putorius furo*; they do interbreed with western polecats in the wild and the resulting hybrids are sometimes indistinguishable from the wild polecat (see the CABI datasheet for more information on ferret as an invasive species https://www.cabi.org/isc/datasheet/74424). Ferrets were originally domesticated to hunt rodents and rabbits. In Europe ferrets are still used for rabbiting but have also become popular pets; lost or escaped animals is a typical introduction pathway for this species. Because ferrets are feral rather than truly wild animals, they exhibit reduced levels of aggression compared to their wild ancestor and thus tend to be found on islands where other predators are scarce or absent (Kitchener and Birks 2008, Poole 1972).

When present, European rabbits form a large part of ferret diet in the wild (Clapperton 2001, Bodey *et al*. 2011), but ferrets are opportunistic predators and quickly respond to changes in prey availability; at seabird breeding colonies ground-nesting birds can be the main prey item. In New Zealand diet analyses have shown that ferrets prey on yellow-eyed penguin (*Megadyptes antipodes*), sooty shearwater (*Puffinus griseus*), little blue penguin (*Eudyptula minor*), banded dotterel (*Charadrius bicinctus*), song thrush (*Turdus philomelos*), blackbird (*T. merula*), house sparrow (*Passer domesticus*), and skylark (*Alauda arvensis*) among others (Clapperton 2001). In the United Kingdom ferrets are invasive in the Inner and Outer Hebrides, the Orkney Isles, and the Shetland Isles where they threaten ground-nesting shorebirds and seabirds (Lever 1985). They have also contributed to the decline of seabird populations in the Azores (Pitta Groz *et al*. 2002).

While invasive species eradication (the complete removal of all individuals) is a common conservation practice today (Howald *et al.* 2007), in locations with large resident human populations and development, eradication is not feasible and only localised population control can be used to protect native seabirds (Igual *et al.* 2006). Invasive species control is best defined as the local limitation of the species' abundance (Duron and Shiels 2017). This can be achieved by several methods which have been successfully applied elsewhere. In this document, we focus on a discussion of controlling the abundance of the brown rat to reduce the impacts to seabirds, but the concepts can be equally applied to other invasive mammals present on Jersey.

INVASIVE MAMMALS ON JERSEY

Originating from northeast China, the brown rat (also known as Norway rats) was introduced to Europe in the Middle Ages and probably spread to the Channel Islands via ships and cargo; it has probably arrived more than once. In contrast, the house mouse is native to Europe but has spread worldwide with significant impacts to native biodiversity and seabirds. Feral ferrets and feral cats are listed as invasive alien species on Jersey (Cornish *et al*. 2011, **Appendix A**) and were historically introduced. Feral ferrets were reported on Jersey in the 1970s and may have since displaced the native stoat which was last recorded on the island in 1973 (Le Seur 1976). The European rabbit was introduced in the 13th century and the hedgehog was introduced in the late 1800s from England (Le Sueur 1976). In addition, free-roaming cats and dogs can have equally devastating impacts on ground-nesting birds and other wildlife (Woods *et al.* 2003). At least four small mammal species are native to Jersey (**Table 1**). The seabirds most threatened by invasive predators are the smaller, ground and burrow-nesting birds including Atlantic puffin, European storm-petrel, common tern and Sandwich tern, as well as numerous ground-nesting shorebirds and passerines.

Common name	Scientific name	Status
Jersey bank vole	*Myodes glareolus caesarius*	Endemic
Lesser white-toothed shrew	*Crocidura suaveolens*	Native
Millet's shrew	*Sorex coronatus*	Native
Wood mouse	*Apodemus sylvaticus*	Native
Mole	*Talpa europaea*	Native?
House mouse	*Mus musculus*	Native?
Stoat	*Mustela erminea*	Native/extirpated
Red squirrel	*Sciurus vulgaris*	Introduced
Brown rat	*Rattus norvegicus*	Introduced
Hedgehog	*Erinaceus europaeus*	Introduced
European rabbit	*Oryctolagus cuniculus*	Introduced
Feral ferret	*Mustela putorius*	Introduced
Feral cat	*Felis catus*	Introduced

Table 1. Terrestrial mammals present on Jersey, Channel Islands (excluding bats).

SEABIRD RECOVERY SITE RAT SURVEYS

Surveys were carried out between August 19 and 25 2017, primarily to determine the presence of brown rats at the seabird recovery site. A total of 41 live-traps were deployed across a linear distance of approximately 1.4 km (**Fig. 3**). Traps were active over seven nights (204.5 adjusted trap nights) with no rats captured. However, during the surveys, two untagged feral ferrets were trapped at Plémont, both at the ramparts at the 'neck' of the Plémont peninsula. Several bank vole were captured (but only in the smaller-sized trap) as well as several hedgehog and one rabbit. The full survey methods and results are reported in **Appendix B**. The lack of rats captured in the survey area does not determine species absence. Invasive rats are notoriously difficult to capture as they have a strong aversion to novel foods and environments. In addition, the abundance of natural foods, the species' reproductive cycle, seasonal habitat migration, and distribution patterns all influence capture success at a particular site. As the survey was carried out in peak summer, the abundance of natural food, including agricultural crops, was probably high. Absence of rats also does not represent a lack of impact on seabirds. Rats actively prevent seabirds from establishing breeding colonies in otherwise suitable habitat. This has been clearly demonstrated by the rapid recolonization of seabird sites and extirpated species after rat eradication (Regehr *et al.* 2007, Whitworth *et al.* 2015, Brooke *et al.* 2018). Because of their generalist foraging strategy and high adaptability to a range of environments, when seabirds are unavailable rats persist by feeding on other prey (and agricultural crops).

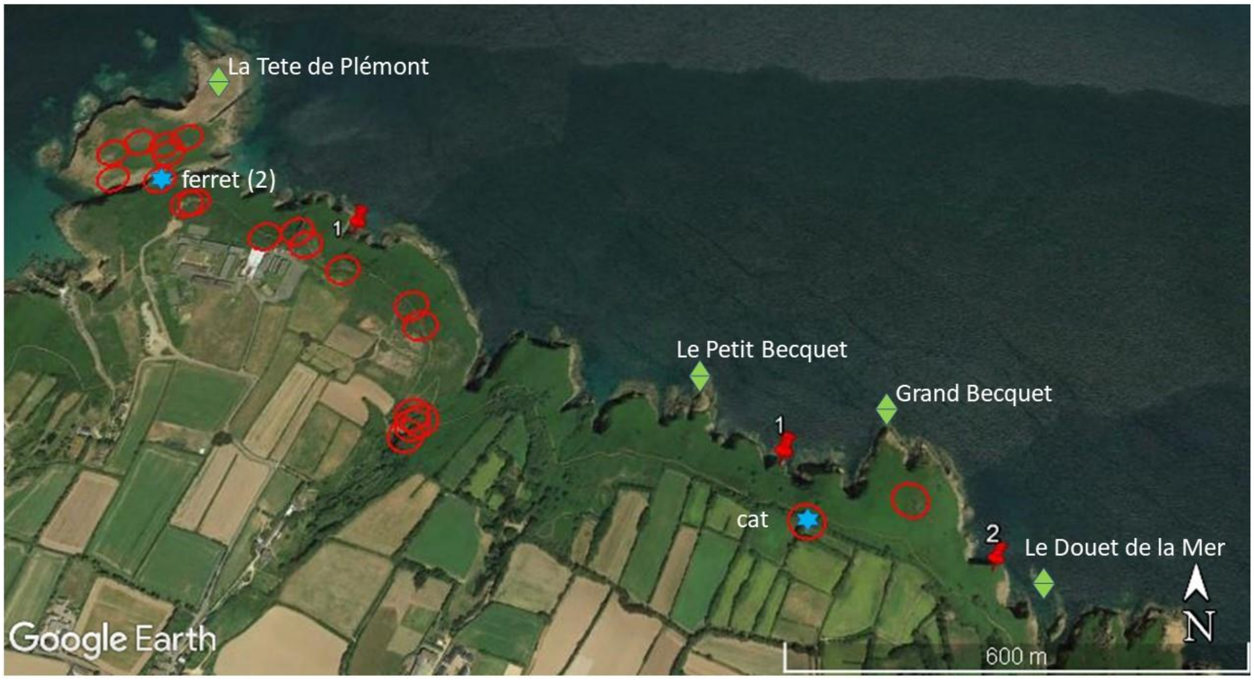


Figure 3. Google Earth image showing places mentioned in the text, trap sites, and 2018 puffin nest sites. Each red circle represents a 2,000 m^2 (0.2 ha) potential capture area of each trap or of a cluster of traps. Blue stars show location of two captured ferrets and a cat captured by a remote camera. Red location pins show the number of puffin nest sites monitored in 2017 (P. Sangan pers. obs.).

Remote Cameras

Three remote Bushnell trail-cameras on loan from Durrell Wildlife Conservation Trust were placed at trap-sites to monitor trap activity. However, while these cameras operated well in the daytime, most photos taken at night were completely obliterated by too much flash light. We tried to rectify this by diffusing or blocking parts of the flashlight and increasing the distance between the camera and the

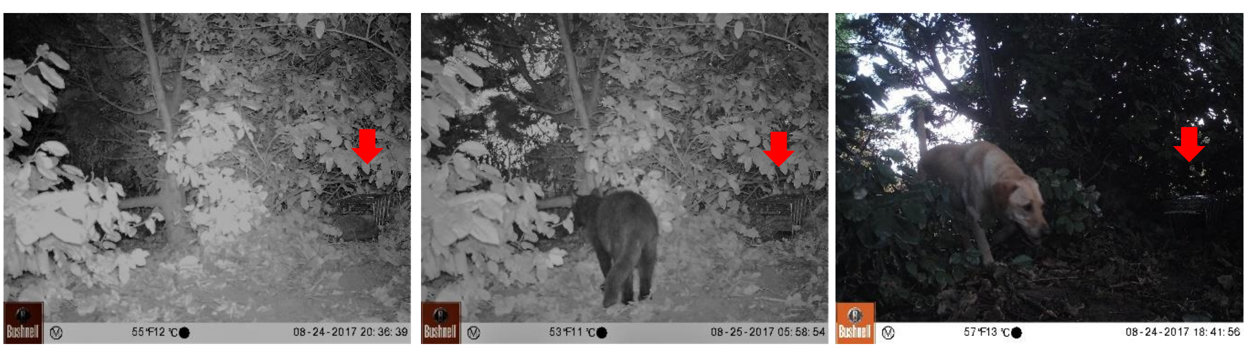


Figure 4. Bushnell camera trap images, Aug 24-25 2017. *Left to right*: hedgehog, cat, and dog. All images captured at the same trap (see Figure 3) placed in woodland/farmland edge habitat. Arrow shows the trap.

trap, but with no improvements to the photo quality. Of the few usable night-time images, both hedgehog and cat were detected (**Fig. 4**). The location of the cat was approximately 87m from a 2017 puffin nest site (**Fig. 3**) and 320m from the nearest farm (at the corner of Rue des Geonnais and Rue du Bouquet). During the day time, the same trap was visited by a golden Labrador. Other detections included wood pigeon (*Columba palumbus*), ring-necked pheasant (*Phasianus colchicus*), and wren (*Troglodytes troglodytes*).

RAT CONTROL - REDUCTION OF RAT POPULATION ABUNDANCE

More than 130 rat control projects have been implemented worldwide to protect native biodiversity, of which 34% were designed to mitigate impacts to seabirds (see review by Duron and Shiels 2017). Most rat control projects have used rat poisons (typically anticoagulants) or poisons combined with trapping, and fewer projects have used trapping alone. Rat control sites using traps have been significantly smaller (median 30 ha, maximum 210 ha) than with poison use (median 716 ha). However, the costs per unit area has not been different between methods but cost-efficiencies are significant with increasing areas under rat control.

Because of the apparent abundance of four species of native small mammals at the seabird sites, the use of poisons to control rats is not recommended. Given that rat control operations must be maintained in perpetuity (immigration from adjacent source areas is constant), non-target mortality of native mammals could be considerable. Rat-trapping is an alternative to poison use and can include snap-traps, live-removal traps, and more recent innovations such as the Goodnature A24 automated trap (see **Box 1**). The A24 rat traps are self-setting up to 20 times, thus reducing personnel-time needed for daily checks, and reducing personnel risk from handling live rats and accessing remote sites. They are approved for use in England for the purpose of killing rats and stoats only (Spring Traps Approval (Variation) (England) Order 2015). While up-front costs are more expensive than traditional traps, they may be a cost-effective option for Jersey's seabird sites.

Box 1. Volunteers in Wellington (New Zealand) are controlling pests at the Miramar Peninsula to give little penguins (*Eudyptila minor*) a fighting chance of raising their chicks. Little penguins are the world's smallest penguin and their nests are predated by rats, weasels, stoats, and hedgehogs. Backed by City and Regional Councils, a committed group of volunteers manage A24 Good-nature traps for targeted and localized pest control at penguin nest sites. The traps are labour-saving and easy to use so everyone can get involved. In one year, the groups' 35 A24 traps killed 200 pests. Volunteers are trained to use the traps and check them monthly. A digital strike counter collects data to feedback to the volunteers and maintain motivation as they can see the impact their work is having on controlling pests. In addition to protecting penguins, the group has found that the local tui birds are also increasing in numbers. Sources: Forest & Bird, Goodnature (2015). **www.goodnature.co. nz**

The design of a rat population control program at seabird recovery sites requires the identification of short-term and long-term goals for seabird recovery, and the intensity of rat control required to achieve them. For example, a rat control strategy can be designed to: protect single or multiple seabird species; target specific life-history stages (e.g. increased hatch success); provide whole ecosystem benefits; and establish new colonies or extirpated species. Rat control can be implemented seasonally to protect individual colonies, or continuously to provide whole ecosystem benefits. Determining the motivation and goals for rat control and identifying measures of success are is critical to developing a cost-effective strategy.

MAINLAND ISLANDS AND VIRTUAL BARRIERS

The *mainland island* concept was developed in New Zealand in the mid-1990s to protect native fauna and flora from the impacts of invasive mammals (Saunders 2001). Previously, the restoration of offshore islands including translocation of native fauna had been the primary strategy used to reduce the impacts of invasive predators. The mainland island approach implements intensive conservation management across a typically large area of land that is adjacent to areas not managed for conservation purposes. Mainland islands are typically directed at ecosystem restoration goals while also including the protection of threatened species from invasive mammals. While most established mainland islands are in New Zealand, the concept has been increasingly applied worldwide with some modification and adaptation to local conditions (See **Box 2**).

KA`ENA POINT, OAHU

Box 2. In 2011, a predator-proof fence 630m long was completed on the island of Oahu (Hawaii) to protect Laysan albatross (*Phoebastria immutabilis*) and other nesting seabirds. Feral dogs, feral cats, mongoose, black rats, and mice were removed from inside the 20-ha reserve and native vegetation out-planted. More recently, translocation of Laysan albatross and social attraction for black-footed albatross have been used to supplement the site. In three years, nesting wedge-tailed shearwaters increased by 45% (3,265 ± 827 to 4,726 ± 826), and young produced increased by 384% (614 ± 249 to 2,359 ± 802). In four years, Laysan albatross increased 51% (365-550 birds) and nests 121% (61-135). The entire project cost $637,595 including $290,000 for fence construction ($446/m) (approx. £288/m). Annual fence repairs and management of rodent incursions are critical to maintain the site predator free. (Young *et al*. 2013).

Some mainland islands use pest-proof fences to exclude a variety of invasive mammals, while others have no physical barriers but implement intensive removal to create a predator-free core area (**Fig. 6**) and/or a virtual barrier (Saunders 2001, Burns *et al.* 2012, Roy *et al.* 2015). Pest-proof fences can be highly sophisticated to exclude even mice, or more basic to exclude larger mammals such as feral dogs or goats. In New Zealand, several mainland islands are open access such as the Tawharanui Regional Park which integrates conservation, recreation, and farming activities (Maitland 2011). Worldwide, mainland islands have proved very effective in increasing local awareness of invasive species impacts and providing new opportunities for local tourism.

Figure 5. **Plémont headland** (La Tete de Plémont): (*Upper*) a hypothetical exclusion fence line (dash) across the Plémont neck (view from north to south) and into the east (*left*) and west (*right*) gulleys, and on a Google Earth image (*middle*). The headland is about 5 ha in area. Straight-line distance as shown is approximately 300 metres but accounting for terrain, could be up to 500 metres. (*Lower*) Plémont headland showing low (*left*) and high (*right*) tides. At low tide the headland is connected to La Grève au Lanchon beach facilitating access by terrestrial mammals.

Because the Plémont headland is separated from the mainland by a narrow isthmus (the neck), there is an opportunity to create a *mainland island* where the impact of invasive mammals on the headland's ecosystem could be reduced. However, the potential benefits of installing a predator exclusion fence at the neck is questionable given that at low tide, the headland is connected to the adjacent beach at La Grève au Lanchon (**Fig. 5**). In addition, a fence might prevent predators from naturally migrating out of the site, increasing potential impacts to native fauna. But, similar challenges have been encountered elsewhere and the frequency and duration of the low tides together with the management goals for the site should be considered when evaluating the value of an exclusion fence. A mainland island could also be created using a virtual barrier of traps (see **Fig. 6**). Initially, the headland would be cleared of predators through trapping and removal, and subsequently an array of traps to the south of the Plémont neck would capture any new animals as they attempted to invade the headland. Traps would be strategically placed and spaced between 25m and 100 m apart depending on the target species.

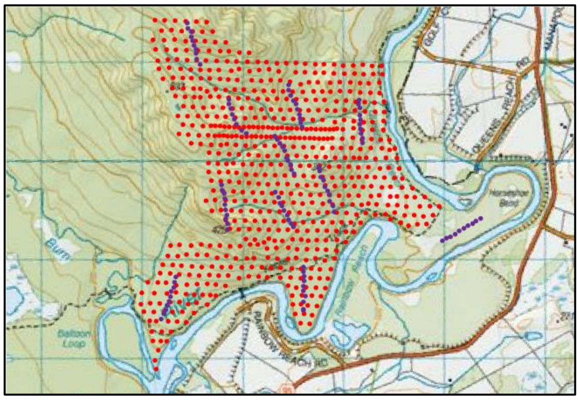


Figure 6. Hart's Hill, Kepler Track, New Zealand showing 600 ha of mainland protected by 670 Goodnature A24 rat traps in a 100m x 100m grid. The river is used as a natural boundary to help to control incursion of rats into the controlled area. *Source*: DOC-2582594 Rat control (100m x 100m) Harts Hill–Fiordland Project Report.

HABITAT IMPROVEMENT AT NEST SITES

Typically, puffins nest in long burrows on grass-covered slopes facing the sea. Puffins usually excavate their own burrows but will also use rabbit burrows, as well as rock crevices where there is insufficient soil (Gaston and Jones 1998). Many colony sites are heavily grazed by cattle or rabbits, or are even bare earth (Harris 1976). Burrow densities can range from as high as 3 to 4 per m^2 (Iceland and Canada), 0.6 per m^2 (Hermaness, Shetland) to 0.2 per m^2 (Isle of May) (Harris 1976).

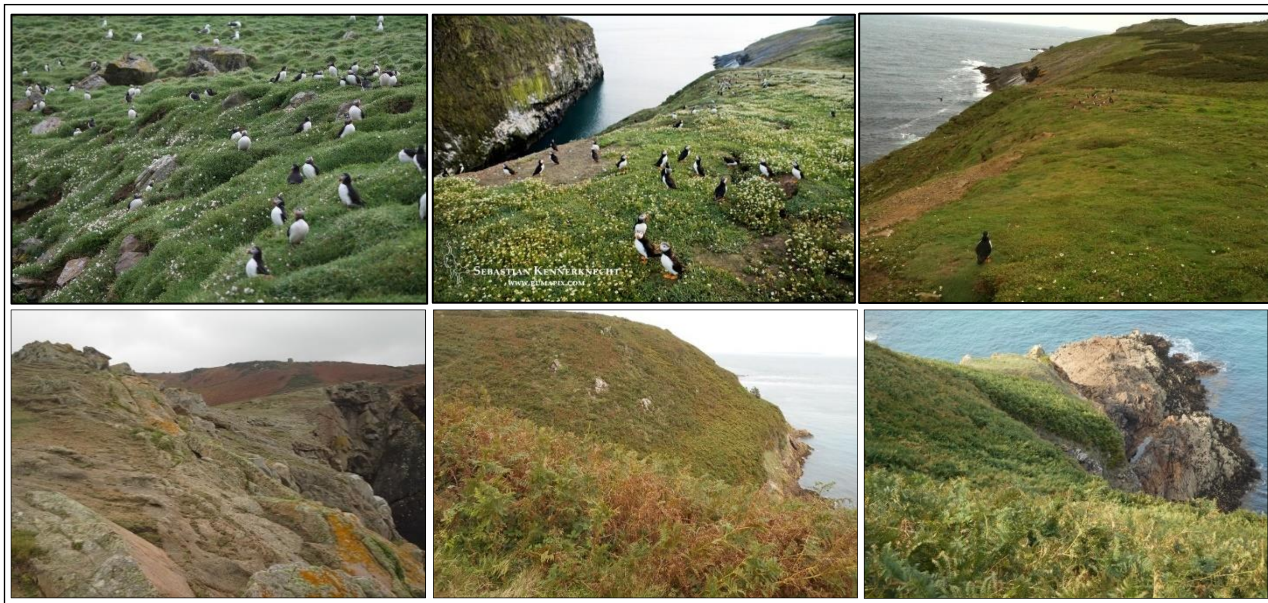


Figure 7. Comparison of habitat quality of an active puffin colony at Skomer Island (South Wales) (*upper*) and on the Jersey north coast (*lower*). *Lower left*: thin rocky soils at Plémont peninsula; (*middle*): bracken-covered slopes on the north coast; (*right*): grassy promontory that could be increased by removing adjacent bracken and other invasive plants. Photos (upper) (*left*) ©Kenji; (*middle*) ©Sebastian Kennerknecht.

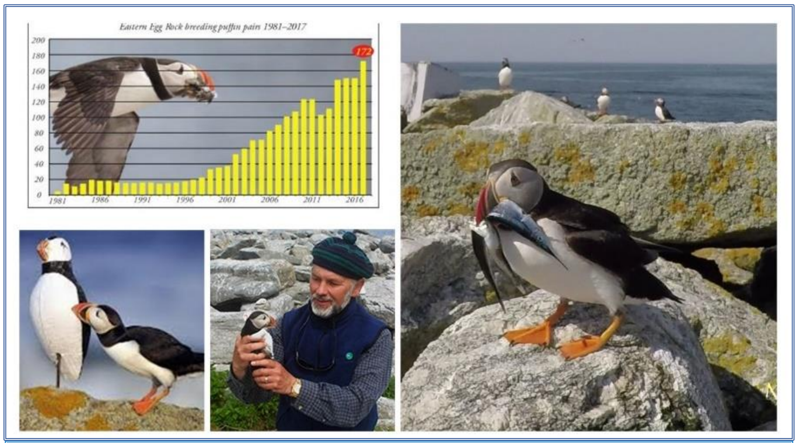
Colonial nesting seabirds are drivers of island ecosystems and play a major role in ecosystem functioning and community dynamics. Seabirds circulate marine nutrients from the sea to land as guano which fertilises the land on otherwise nutrient-limited islands. This supports above and below-ground biodiversity and has led to the characterization of 'seabird islands' (Mulder *et al.* 2011). Several studies have shown that the extirpation of historical island seabird colonies leads to significant vegetation changes and depletion of sub-surface invertebrate fauna (Croll *et al*. 2005, Fukami *et al.* 2006).

Extensive invasion by bracken and the thin, eroded soils on the Plémont headland (**Fig. 7**) may be the two primary factors limiting nesting habitat availability for puffins across the seabird recovery sites. The north-east facing slopes of the Plémont headland have a granitic and granophyte bedrock with poor soil development which may be insufficient for burrow nesting. In addition, any burrows available may already be occupied by rabbits. Cliff ledges and rocky crevices on the north coast may provide some nest sites, but the preferred short grassy slopes with deep soils are rarely present. This habitat may have been present at one time, but currently seems to be entirely invaded by bracken (*Pteridium aquilinum*). The bracken grows in dense stands often up to six feet tall along the north coast where it favours the acidic soils. The fern's density together with its underground rhizomes through which it spreads most likely prevents any potential occupation by puffins. Bracken management will be needed to create open areas with good soil depth to encourage puffin nesting and roosting. In the United Kingdom, bracken is primarily controlled using herbicides, mowing or cutting, hand-pulling, rolling, grazing by livestock (cattle, sheep, ponies) or burning with control of bracken as an objective. More discussion will be needed to develop a method appropriate for the seabird recovery sites.

ARTIFICIAL NESTS

Artificial burrows or nest boxes could be installed at recovery sites where the soil is too poor for natural burrow excavation and to protect birds from predation by larger pests such as free-ranging or feral cats and dogs, and from trampling by cattle and sheep. However, burrows and boxes are unlikely to protect birds from predation by rats and ferrets which can still enter them. Artificial nest boxes could be installed above-ground or dug below-ground where possible. While there seems to have been limited

Figure 8. Artificial seabird nest burrows and boxes. (*Upper left*) wood-concrete burrows for storm petrels, San Bonito Islands, Mexico (©Florian Schaefer and Yuliana Bedolla); (*lower left*) horned puffin feeding a puffling in a nest box, Seward, Alaska (©Carol Griswold); (*middle*) Atlantic puffin box, Petit Manan Island, Maine (©USFWS)**;** (*Right*) Manx shearwater, Ramsey Island, U.K. (©RSPB).



Box 3. In 1973 ***Project Puffin*** a pioneering project began to restore historical nesting colonies of Atlantic puffins to the Gulf of Maine. By 1885, puffins were largely extirpated from the Gulf due to hunting for feathers and food. Between 1973 and 1986, 954 puffin chicks were translocated to Eastern Egg Rock island from Great Island, Newfoundland, of which 940 fledged. Chicks were transferred at about 10-14 days old and hand-reared on-site in artificial burrows. Four years later, the first puffin chick returned to the island but it was 8 years before puffins began to breed. It would be 35 years before the colony reached 100 pairs, and today it stands at 172 breeding pairs. This success has been a result of the sustained translocations over 12 years (early returns were too few for colony establishment), the continued use of decoys and artifical burrows, advances in chick-rearing, and long-term research and monitoring to understand limiting factors. projectpuffin.audubon.org

use of artificial burrows for puffins (but see Lor 1991), they have been used for a variety of other ground-nesting seabirds including petrels (Procellaridae), penguins (Sphenisciformes), storm-petrels (Hydrobatidae), auklets (Alcidae), terns (Sternidae), and tropicbirds (Phaethontidae) among others (Fig. 8). Ultimately artificial nests can increase colony size, breeding success and adult survival, and have been used to protect nesting birds from predators, establish new colonies, and house translocated chicks (Priddel and Carlile 1995, Bolton *et al.* 2004, Carlile *et al.* 2012, Sherley *et al.* 2012, Bedolla-Guzman *et al.* 2016). Artificial nests lend themselves for close observation and research while minimizing human disturbance and can be fitted with digital technology including remote cameras and sensors. They are also widely to facilitate public outreach and engagement in seabird conservation.

SOCIAL ATTRACTION

Social attraction is a conservation technique that exploits seabird coloniality to encourage the establishment of new colonies. More than 95% of seabirds are colonial and are attracted to nest sites by the presence of conspecifics. Acoustic playback and decoys (models of adults, chicks, and eggs, sound recordings of non-aggressive vocalisations, mirrors, scent) are used to mimic an active colony and to lure prospecting seabirds to a new recovery site (**Box 3**). Acoustic attraction can be used for both diurnal and nocturnal species, but decoys have been used only for diurnal species. Decoys can be used in combination with mirrors that give the appearance of a larger and active colony (Parker *et al.* 2007, Mciver *et al.* 2010). While acoustic playback and decoys can be used independently, they are more commonly used together and often in combination with other recovery techniques such as chick translocation and nest boxes (Jones and Kress 2012). Overall, about 63% (of 68) of social attraction projects have succeeded in their objectives. However, there are mixed results for Alcids (auks), Procellariformes (petrels), and Hydrobatidate (storm petrels) with only 44% (of 18) success but this could be explained by the different objectives and success measures among projects.

CHICK TRANSLOCATION

Chick translocation has been used successfully to augment colonies or establish new colonies of several threatened seabirds (Priddel *et al.* 2005, Carlile *et al.* 2012) (see **Box 3**). Between 1997 and 2008, 1,791 chicks of eight burrow-nesting seabirds were translocated up to 240 km from their natal site to establish new colonies (Miskelly *et al.* 2009). This initiative has led to the development of translocation best practices and guidelines for several petrel and shearwater species (Gummer and Adams 2010, Gummer *et al.* 2014a, Gummer *et al.* 2014b). Typically, chicks are moved into artificial burrows or nest boxes, and are hand-fed up to fledging. Hand-rearing diets and techniques for many seabirds are now relatively well-known. This technique is ideal for species with high site fidelity but may not be suitable for species that have post-fledging parental care. Because most seabirds exhibit natal site philopatry, the transfer of very young downy chicks has been preferred to maximise opportunities for natal site imprinting. However, chick translocation is a very labour intensive technique and requires resident hand-rearers with daily access the translocation site. Chicks must be translocated each year for several years to ensure successful establishment and birds will not breed for several years after the first translocations. Predator control and limiting human disturbance at the site is also needed until the chick leaves the nest.

RECOMMENDATIONS

Recommendations presented here build upon recommendations made by Durrell Wildlife Conservation Trust in the report to Plémont Estates Ltd. (2008). Recommendations should also allow for the results from ongoing seabird surveys on Jersey and activities developed therein. While specific next steps are outlined below, we recommend the creation of an Atlantic Puffin Working Group to include partners and stakeholders from local government, the National Trust for Jersey, Société Jersiaise, and others. The Working Group would be responsible for developing a Species Action Plan to guide the restoration of Jersey's puffins, and which could be extended over time to include other seabirds. The Working Group should also include representatives from other Channel Islands given potential source populations of puffins on other islands and the benefits of a whole-archipelago restoration approach. We anticipate that the restoration actions discussed in this document and outlined below would be further developed by the Working Group within the Species Action Plan. In addition, further study of puffins as well as storm-petrel, Manx shearwater and razorbill at Plémont and along the north coast is critical to support recovery goals and actions. Lastly, funding sources would need to be identified and funds raised to support the project.

PUFFIN RESEARCH AND RECOVERY PILOT PROJECT

Given the uncertainty surrounding the exact causes of seabird decline on Jersey, the lack of evidence of historical breeding colonies of Manx shearwater and storm-petrel, and the extent of the conservation issues facing seabirds on Jersey (invasive predators and competitors, habitat loss to bracken and invasive plants, physical disturbance), we recommend further research on seabirds as well as on the invasive alien predators in Jersey including rats, ferrets, feral cats, and hedgehogs. Given the known biodiversity impacts of invasive ferrets in the U.K. and worldwide and given that two untagged ferrets were captured at the proposed seabird recovery site during the short study-period, we recommend that a greater understanding is obtained about the ferret population and the species' potential impact to native and threatened wildlife on Jersey. We recommend a pilot project in Jersey to test some seabird recovery techniques to encourage re-establishment of puffin colonies at Plémont and the north coast cliffs (Sangan pers. obs. for details of current puffin nest sites and potential restoration habitat on the north coast). Monitoring the outcomes of these activities will help to develop further activities and improve understanding of the factors limiting seabird breeding populations on Jersey. Outlined below are three options for pilot projects which are similar in approach but implemented at different sites and scales.

Option 1: Manage existing puffin nest sites

a) Protect known puffin nests from potential predation by invasive mammals (rodents, ferrets, hedgehogs, feral cats) and from physical disturbance by domestic animals and people.
b) Manage known nest sites (burrows, crevices) to minimize annual deterioration in quality and to maximise hatching and fledging rates. If needed, re-build or improve poor quality sites or replace with artificial burrows.
c) Prevent invasion of known nest sites by habitat-altering plants such as bracken, gorse, and shrubs.
d) Monitor known puffin nest sites with remote cameras to increase knowledge of reproductive behavior and success. Where artificial nest burrows are used, install a burrow camera.

Option 2: Increase puffin colony size on north coast cliffs

e) Increase nesting habitat availability. Remove bracken and shrubs to create new nesting habitat either contiguous with known nest sites, and/or close to known nest sites, and/or at historical nest sites (e.g. Le Petit Becquet, see **Fig. 3**).
f) Use artificial burrows and social attraction to establish new colonies/nest sites.
g) Implement invasive species control (rodents, ferrets, feral cats, rabbits, hedgehogs) and limit physical disturbance from domestic animals and people at new experimental colonies/nest sites.
h) Monitor nest sites with remote cameras.

Figure 9. Potential seabird recovery sites at Plémont peninsula. *White area (back)*: possibly suitable for Manx shearwater and storm petrel if artificial burrows were installed. *Blue area (foreground):* possibly suitable for puffins if bracken and other shrubs were removed. Artificial burrows may also be needed depending on soil depth.

Option 3: Create colonies of puffin, Manx shearwater, and storm petrel at Plémont peninsula

i) Select suitable restoration sites for each species on the north-east facing slopes of Plémont (see **Fig. 9**). Remove bracken and shrubs to encourage grass growth. Soil stabilization and other vegetation management techniques may be needed.

i) Install artificial burrows and deploy social attraction techniques to attract birds to new sites.

k) Implement invasive species control (rodents, ferrets, feral cats, rabbits, hedgehogs) and limit physical disturbance from domestic animals and people at new experimental nest sites.

l) Monitor nest sites with remote cameras.

SEABIRD RESEARCH

Annual surveys of the Plémont area and north coast cliffs is needed to understand the status and distribution of existing puffins at breeding sites and the factors limiting their reproduction on Jersey. In addition, monitoring the outcomes of recovery activities will be needed to inform future management and improve understanding of the factors limiting seabird breeding colonies on Jersey. However, because puffins and other seabirds currently nest on the sheer cliffs, they are extremely difficult to regularly monitor both from the land and sea. Additional technology such as remote cameras and audio recorders placed strategically across the area and at nest sites may help to improve our knowledge of seabirds and their use of the coastal areas. The technology supporting remote monitoring equipment for birds is increasingly sophisticated. Data collected by the device can be remotely downloaded and the site may only need to be visited once at device deployment and once at retrieval. While remote monitoring devices incur high initial costs, significant savings are made from reduced labour costs and reduced personnel safety risks.

APPENDIX A: PUFFIN DECLINES IN JERSEY AND THE CHANNEL ISLANDS

The 2008 report to the Plémont Estates Ltd entitled *'Atlantic Puffin Fratercula arctica and other seabirds at Plémont, Jersey, Channel Islands*' by Durrell Wildlife Conservation Trust provides detailed historical, biological, and ecological information about Jersey's seabirds. Given this, we have only replicated that information where it provided background and context, and we recommend that the report is consulted for supporting information.

The historical abundance of puffins in Jersey is not well known. The earliest records are from G.F.B de Gruchy (cited in Dobson, 1952) who estimated that between 1911 and 1914, 200-300 pairs nested along the cliffs from Plémont to Grand Becquet. However, by 1919 only about 20 pairs remained, and the population has not recovered since. Regular surveys carried out since 1969 to present day indicate that the population has fluctuated annually between about 10 and 40 pairs, and that in recent years there has been a steady overall decline (Mitchell 2004, Société Jersiaise records).

A similar pattern has occurred across the Channel Islands and all historical breeding sites in the species' southern range (**Table 2**). Between the late 1800s and mid-1900s, large colonies were described as nesting on the cliffs and offshore islands of Herm, Alderney, and Sark (see full account in Dobson 1952). Similarly, huge historical colonies were reported from Brittany and the Isles of Scilly, with thousands of birds also nesting in Devon (Lundy Island) and Cornwall. Today, Mincarlo Island (Isles of Scilly), Ile Rouzic (Sept-Iles), and Burhou island (Alderney) are the only significant colonies in the region, but between them support only a few hundred pairs. Remnant sites along the Cornish, Dorset, and Devon coasts and along the coasts of Brittany may still be intermittently used by a handful of pairs but most colonies have disappeared completely.

The exact causes of the puffin's southern decline are unclear, although many reasons have been cited for the species' decline elsewhere (BirdLife International 2017). The Channel Islands and Brittany are at the southernmost margin for breeding puffins and may only ever hold a fraction of the Atlantic population. However, large historical colonies at these southern sites suggest that conditions were once favourable. The 20th century saw some high impact localised events such as over-harvesting of birds from burrows by fishermen in the Channel Islands (Dobson 1952), unregulated sport hunting in the Sept-Iles that nearly eliminated the colony, major oil spills in wintering and breeding ranges including the Torrey Canyon (1967), Amoco Cadiz (1978), Sea Empress (1996), MV Erika (1999), and the Prestige (2002), mass mortality at breeding colonies from disease, and extreme weather such as the 2013/14 winter storms.

In the Channel Islands, nearly 70% of the breeding population apparently disappeared between 1969-70 (1,116 pairs) and 1985-88 (335 pairs), most of which was probably from the largest colony in Burhou. This decline was *despite* a 33% increase in breeding puffins overall across the rest of Britain and Ireland in the same period (Mitchell *et al.* 2004). While this decline mirrors the overall regional decline, the

Amoco Cadiz oil spill in 1978 probably contributed significantly as a total of 1,391 oiled puffins were collected from the region (Hope-Jones *et al.* 1978).

Puffins are a long-lived colonial species that lay a single egg and do not sexually mature until 4 or 5 years old. They have strong fidelity to their breeding sites, with young returning to the same colony to breed. Against a background of global threats such as sea temperature changes and food redistribution, this life-history strategy may significantly limit the species' ability to rebuild historical colonies.

Table 2. The primary southernmost colonies of Atlantic puffin, showing historical and current colony size. Unless otherwise stated, puffin numbers from 1969-2015 are reported as Apparently Occupied Burrows. Information sources are: Dobson 1952; Harris 1976; Mitchell *et al.* 2004; Bechet *et al.* 2016; and the JNCC Seabird Monitoring Programme online database.

	1878 - 1946	1950-1969	1970s	Operation Seafarer (1969-70)	SCR Census (1985-88)	Seabird 2000 (1998-2002)	2005-2015
Channel Islands				1,116	335	311	
Alderney cliffs & islets (Burhou)	countless thousands						97-168
Herm & adjacent islets	thousands	12 pairs					18 birds
Sark & L'Etac de Sercq	750 pairs	25 pairs					
Jersey	200-300 pairs, declined to 20 pairs in 1919	10 pairs	14 pairs		8		4 birds
Isle of Wight	300 - 350 birds	20 birds		4	-	-	
Dorset				35	-	26	
Portland Bill		35 pairs	17 pairs				
Cornwall		226 birds		233	66	33	
Lye Rock	3,500 birds (1942)	112 birds	24 birds				
Isles of Scilly	100,000 birds	60-100 pairs	87 pairs	100	106	121	
Devon				41	39	13	
Lundy Island	3,500 pairs	400 pairs declined to 41 pairs in 1969	100 birds				
Brittany							
Sept-Iles	10,000 - 15,000 pairs (end of 19th century) 7,000 pairs (1927-50)	2,500 pairs (1966) 400-500 pairs (1969)	350-400 pairs				112-185 (2008) 139-181 (2014)
Presqu'ile de Crozon	60+ pairs (1930)		3-6 pairs				
Archipel de Molene	130 pairs (1930)	30-50 pairs	12-13 pairs				
Baie de Morlaix et sur Ouessant							10 (2003)

APPENDIX B: RODENT FIELD SURVEY

METHODS

Field surveys for brown rats (*Rattus norvegicus*) were carried out between August 18 and 25, 2017. Live cage traps were used to reduce the risk to native mammals and other wildlife. A total of 41 traps were deployed across the Plémont headland, and along the north coast mostly adjacent to the public footpath (**Fig. 3**). Traps were mostly placed in 'clusters' each comprising between two and three traps to increase the probability of capturing a single rat at one trap-site. The minimum 'capture' area of each trap was approximately 0.2 ha (2000m^2)(25m radius from each trap), and the linear distance of the survey area was approximately 1.4km (**Fig. 3**). Most farmland rats occupy home ranges that are relatively stable, but about one-quarter will travel widely as transients. Ranging behavior varies greatly under different environmental circumstances. Macdonald *et al.* (1999) reported for males a linear home range of 678m (SD 535m) in full crop cover to 90m (SD 28.2) after crop harvest. Females generally had smaller home ranges from 85m in good food areas to 428m in a poor environment. Thus, in addition to capturing rats resident within the survey area, capturing non-resident rats traveling into the survey area was also possible.

The primary vegetation cover recorded across all 41 trap sites was bracken fern (35%), grasses (30%), blackberry (*Rubus* sp.)(28%) and gorse (*Ulex europaeus*)(21%). Along the coastal sites, the upper story was typically more than 60-180 cm (74%) in height and in the woodland sites (nine locations) the trees reached 10-13 metres. The lower story undergrowth was typically below 10-25 cm in height (80.5% of sites). On the exposed slopes along the northern coastline, the bracken was typically very dense and often taller than a person. Fruiting plants were recorded at 61% of trap sites and were typically *Rubus* sp., elder (*Sambucus* sp.) and ivy (*Hedera helix*).

Traps were placed on the ground and, where possible, wedged in-place to reduce trap movement; under branches, between rocks and walls, or with metal pegs. Traps were positioned at locations with sign of animal activity, with features attractive to rats, and which was out of sight to prevent human disturbance (Engeman & Whisson 2006). Placement included runways through vegetation, near burrows and holes in particular at the base of trees, adjacent to streams and walls, under brush piles, dense bracken, and fallen logs, rock piles, under fruiting/seeding plants, or inside derelict buildings. Given this, most traps were also protected from the wind, rain, and direct sun but when not, the trap was covered with vegetation (typically bracken fronds). Each trap was marked with a unique number (1-41), and a States of Jersey label stating the purpose of the trap and to whom it belonged.

Three trap types were used (**Fig. 10**): we deployed 30 Defenders rat and squirrel trap (STV088) (36 x 14 x 16cm, 1422g/n, 5 x 10mm mesh); 10 Defenders small live animal trap (dimensions 44 x 19 x 19cm, 1565 g/n, 10 x 10mm mesh); and just one unknown brand trap which was longer (19 x 60 x 20cm, 10 x 40mm mesh). All traps were single entrance, live-capture galvanized wire cage traps. The primary differences between STV088 and the other two traps were in the drop-down door mechanism and wire mesh dimensions; the smaller mesh size prevented native rodents from escaping when accidentally captured.

Figure 10. Live animal cage traps used for rodent surveys, Type A (38x14x16 cm) and Type B (44x19x19 cm). Trap type A was preferred. Photo shows trap type A in woodland edge habitat.

Prior to use, traps were soaked in a vegetable oil to mask the smell of new metal and increase their attractiveness to rats. This also helps to prevent rust and increase trap life. All traps also required modification of the door release hook to ensure that the trap door was not too sensitive or jam in-place. To reduce accidental capture of diurnal animals, traps were closed for most of the day; traps were baited and opened late afternoon, inspected the following morning and closed. Bait used was a mixture of peanut butter and oats which was replenished each afternoon when traps were re-opened. At each morning trap inspection, a record was made of whether the trap was open or closed (unsprung or sprung), if an animal was captured (yes/no), and the species captured. Anecdotal observations of other wildlife activity at the trap were also recorded. At the end of the surveys, all traps were cleaned and disinfected for storage.

Native small mammals and hedgehogs captured accidentally were released immediately after trap inspection. Accidental captures of feral ferret/ polecats were first scanned for transponders, then transferred to the relevant authority (the Jersey Society for Protection of Cruelty to Animals (JSPCA) for animals with transponders, or the States of Jersey for animals without).

Trapping was conducted under a permit issued to Durrell Wildlife Conservation Trust by the States of Jersey under the Conservation of Wildlife Law (2000) (permit number NE-LC-CR76).

RESULTS

No rats were captured across a total of seven survey nights and 204.5 adjusted trap-nights (**Table 3**). However, 14 captures of other species occurred (adjusted capture/trap night = 0.068): Jersey bank vole (*Myodes glareolus caesarius*) (6 captures); hedgehog (5 captures); rabbit (1 capture); and ferret (2 captures). Of significant note were the two ferrets captured; both inside the buildings located at the neck of the Plémont peninsula. Jersey bank vole were captured only in trap type B (**Fig. 10**) because they could not escape through the narrower mesh of this trap. Given the frequency and abundance of small mammal scat found inside the traps, that bait was missing from most traps in the morning check, and 23% of traps were sprung with no captures, we suspect that many of trap-type A were sprung by native small mammals but which subsequently escaped. Searches for rat sign (e.g. droppings, burrows, feeding sign, middens, vegetation damage, tracks) were made at trap placement sites, inside derelict buildings, and along public footpaths but no definitive sign was detected.

Date	SP	UNSP	not set	actual trap nights	adj trap nights	No. captures
19/08/2017	4	11	26	15	13	1
20/08/2017	9	32	0	41	36.5	0
21/08/2017	13	28	0	41	34.5	4
22/08/2017	6	32	3	38	35	5
23/08/2017	5	13	23	18	15.5	1
24/08/2017	11	30	0	41	35.5	1
25/08/2017	13	28	0	41	34.5	2
TOTAL	**61**	**174**	**52**	**235**	**204.5**	**14**

Table 3. Live-trap data August 19-25, 2017. SP=trap sprung; UNSP=trap unsprung. Adjusted (adj) trap nights follows Nelson and Clarke (1973) is actual trap nights minus half sprung value to account for partial trap night lost to a closed trap.

Tracking Tunnels

We constructed three tracking tunnels with used corrugated plastic available at the Jersey Zoo. Corrugated plastic is sold commercially as a building material under various names (Correx, Twinplast, Corflute, Proplex), and is available in different widths which determines strength and flexibility. Most of the material available was too thin and flexible to withstand field conditions or too thick to cut easily, and only one tunnel was eventually tested. Blue food dye was used as the 'ink' (Gillies *et al.* 2013). Only small rodent tracks were detected, and one footprint pattern was more distinctive (**Fig. 11**). With the right materials, the technique would be a useful non-invasive survey method for rodents and other small mammals in Jersey.

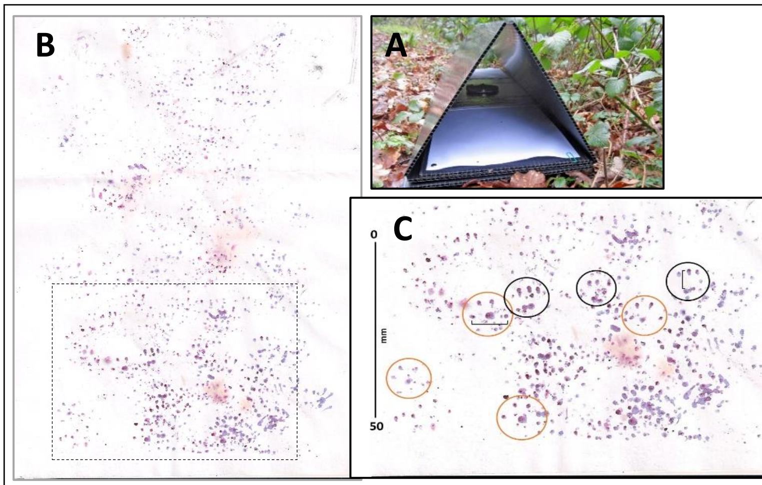


Figure 11. (A) tracking tunnel constructed from corrugated plastic. (B) 'inked' paper from Plémont with extensive small mammal tracks, dash area enlarged in (B) showing prints of fore feet (orange circles) and hind feet (black circles). Scale indicates span of fore print (inner right toe to left toe pad) is 8 mm, diameter of hind foot (centre toe pad to foot pad) is 5 mm. The foot span of brown rat is about 20 mm.

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