

Environmental Impact Assessment for the eradication of rodents from the island of South Georgia*

South Georgia Heritage Trust

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* This document covers both Phases of the South Georgia Habitat Restoration project. As such, it is part of a suite which describes and specifies Phase 1 of the Project. The other documents for this first Phase are the following Plans: Operational, Health and Safety, Biosecurity, Search and Rescue, Crash Recovery, Monitoring and Oil Spill Response. Together, these documents comprise the basis of the application made to the Government of South Georgia and the South Sandwich Islands by the South Georgia Heritage Trust for the work to be carried out, and upon which consent was given.

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NON-TECHNICAL SUMMARY

Introduced fauna and flora have profoundly damaged the natural ecosystem of South Georgia. Rat predation on seabirds and their eggs, overgrazing by reindeer and the introduction of alien plants and insects have altered the appearance and ecological function of the island.

The greatest threat to the terrestrial environment on South Georgia is the Norway (or brown) rat. Rats were most likely introduced by sealing vessels in the late 1700s, and now occupy virtually the entire north-east coastline and the northern quarter of the south-west coast of the main island, as well as some of the smaller islands. They have had a profound effect on all but the largest birds. In rat-infested coastal areas, South Georgia pipits and smaller petrel species have been eliminated, and populations of the endemic South Georgia pintail have likely been reduced. Most species of petrels are virtually confined to rat-free areas. Glacial retreat as a result of global warming presents additional threats, because ice barriers that currently isolate rat-free areas become less effective each year.

This Environmental Impact Assessment provides an evaluation of a large-scale eradication programme to eliminate rats and mice on South Georgia. Rodents are present on around a fifth of the land area of the island, mainly along the biologically rich and climatically favourable north coast. Their populations are physically divided into smaller independent units by glaciers, mountains and the sea. This facilitates a step-wise approach to eradication, allowing the process to be conducted over a period of several years, with clearance of discrete areas each season. Twenty one discrete eradication zones have been identified and supplementary environmental assessments will be prepared for each zone to deal with area-specific issues. This document will be updated during the project as more information becomes available.

A bait drop of the second generation anticoagulant toxin brodifacoum in cereal-based pellets will be distributed by helicopters using under-slung spreader buckets. This will be supplemented with hand spreading of baits in and around buildings and other areas inaccessible by air. Much of the interior of the island and the south coast will be unaffected by the baiting operations.

A terrestrial logistics base will be established at Grytviken. An operational team of around 11-15 people will be required, depending on the planned work each season. Fuel and bait depots (Forward Operating Bases – FOBs) would be located in outlying areas by ship to facilitate operations which are remote from Grytviken. At these sites a yacht on stand-by nearby during the treatment of that zone would provide accommodation for the operational team in the event of sudden bad weather, and would have a paramedic on board. FOBs will not be required for the first phase of the eradication, which will eradicate rats from Thatcher and Greene Peninsulas, the land on the west side of Mercer Bay (the Mercer baiting zone) and Saddle Island.

Alternative methods of conducting the eradication include a ship-based operation. A ship which could accommodate two helicopters would be very costly and would result in greater atmospheric emissions due to increased fuel requirements. A land-based operation with forward camps on land was initially considered but rejected due to the additional environmental impacts of the camps. Alternative poisons were assessed, but brodifacoum is the poison which has been proved most effective for helicopter spreading during other island eradication operations. Ground-based eradication techniques, such as trapping, bait stations and hand-spreading of baits would not be practical for an island-wide operation of this scale, but will be used for areas inaccessible by air such as in and around buildings. A possible

winter operation is discussed, but winter weather conditions on South Georgia are harsh and the potential for snow cover would diminish the operation's chances of success.

The potential environmental impacts of the proposed operation are considered, and where possible measures are proposed to eliminate or mitigate them.

Ethical considerations of using brodifacoum are assessed, but more humane methods for killing rats are not logistically feasible on South Georgia. Non-target species most at risk of directly eating the bait were identified as reindeer, brown skua, kelp gulls, South Georgia pintail and speckled teal. Reindeer may consume bait which may cause illness or death and would also reduce rat access to bait, thus jeopardising the operation. The eradication of the two reindeer herds on South Georgia is currently under consideration by the Government of South Georgia and the South Sandwich Islands, which has responsibility for this issue. Secondary poisoning due to feeding on poisoned carcasses is most likely for brown skua, snowy sheathbill and northern and southern giant petrels. Such losses should be sustainable at the population level, and numbers are predicted to recover on a scale of years. Searches for carcasses will be conducted each operational season, and results during Phase 1 of the operation will be used to inform operational methodology for Phase 2. Because of the multi-year nature of the work, the likelihood of irreparable damage to non-target faunal populations is very small indeed.

The baiting operation is likely to have negligible effects also on soil, water and vegetation as the toxin is not soluble and will break down to harmless products over a period of several months to a year. Similarly, effects on the marine environment are likely to be negligible due to the small amount of bait entering the sea and rapid break up and dispersal of the bait.

Physical disturbance and noise will be caused by the operation of the two helicopters and establishment and operation of FOBs as well as ground-based bait laying and monitoring activities. It is likely that king penguin, albatross and giant petrels colonies will be most affected by the helicopter overflights, necessitating particular care in the planning and execution of flights in their vicinity.

Atmospheric emissions will result primarily from the operation of helicopters and ships. Measures will be taken to minimise fuel requirements, to avoid fuel and oil spills and to have materials in place for clean-up should any accidental spills occur.

The production and disposal of waste, possible light pollution and impacts on heritage and wilderness values have also been considered, as well as biosecurity issues.

The potential environmental impacts of the project have been considered from the outset of planning, and will continue to play a key part in decision making. Environmental management of the project will include defining roles and responsibilities for general environmental management activities, implementation of the mitigation measures outlined in this EIA and environmental reporting. Monitoring of environmental impacts and outcomes will be an ongoing part of the project. Should significant and unpredicted impacts be observed, project plans will be modified accordingly.

The removal of rats from South Georgia is predicted to have very significant positive impacts on the island's environment. If the mitigation measures outlined in the EIA are taken, any negative environmental effects should be transitory and sustainable. Expected moderate reductions in populations of some native species as a result of the project due to primary or secondary poisoning should be rapidly overcome. A successful eradication will therefore significantly benefit the island ecosystem by allowing affected birds, invertebrates and vegetation to recover, thereby restoring native biological diversity. The eradication of rodents should result in millions of birds returning to breed on South Georgia.

1 INTRODUCTION

1.1 Purpose of eradication

Introduced, alien species are a major cause of the loss of native biological diversity worldwide, and their impacts are especially severe on island ecosystems. Invasive rodents are likely responsible for a high number of extinctions and ecosystem changes (Howald et al., 2007). The introduction and spread of Norway rats has been highlighted as the greatest and most immediate threat to the environment on South Georgia (Birdlife International, 2009).

The Norway rat has had a significant detrimental impact on South Georgia bird species, particularly the endemic South Georgia pipit, which is completely excluded by the presence of rats (Atkinson, 1985). South Georgia's blue petrels, Antarctic and fairy prions, diving petrels and the endemic South Georgia pintail have also been affected as these birds nest on open ground or in burrows allowing rats easy access to their eggs and chicks. Rats will also consume carrion and chicks from penguin rookeries (McIntosh and Walton, 2000). Rats eat native plants, seeds and seedlings, particularly tussac grass which provides habitat for breeding birds (Leader-Williams, 1985).

The purpose of the proposed eradication is to remove rats from all areas of South Georgia to allow affected vulnerable bird species and vegetation to recover, and to restore native biological diversity and ecological functioning. Failure to remove rats from South Georgia soon will result in further degradation of the island because climate change is reducing the effectiveness of glaciers as barriers to the spread of rats. In future, the entire coastline and all nearshore islands are likely to be colonised by rats unless they are removed from the parts of South Georgia where they now occur.

Following treatment of each zone, monitoring will take place to ensure that complete eradication of rats has taken place. If any survive in a previously treated area, this area will be treated again. Strict biosecurity measures are already in place to prevent the re-introduction of rodents to the islands (see Appendix 1).

1.2 Summary of proposed eradication method

Helicopters will be used to distribute the second generation anticoagulant toxin brodifacoum in cereal-based pellets. This will be supplemented with hand spreading of baits in and around buildings, other structures and areas inaccessible by air. This technique has been used for several eradications, including the largest successful operation to date on New Zealand's sub-Antarctic Campbell Island (113 km²; McClelland and Tyree, 2002).

Rats are not ubiquitous on South Georgia; around 80% of the island's surface area is free of them. The island can be broken into many discrete isolated units for eradication purposes, bounded by glaciers, mountains and the sea. Each land unit will be treated individually. The main rat infested areas are along the north-east coast. The total treatment area on South Georgia is estimated at around 1093 km² (Appendix 5), i.e. nearly an order of magnitude greater than that of Campbell Island.

It is proposed that the operation is undertaken in two phases. The first (trial) phase is to be the eradication of rats from three contiguous areas of land on the north coast (Greene, Thatcher and Mercer baiting zones) and Saddle Island. This operation will be followed by two years of monitoring to evaluate impacts and allow improvements to the plans for the

remainder of the island in Phase 2 (expected to occur in the years 2013-2015). Phase 1 will allow for the evaluation of lower bait application rates than most operations elsewhere and for the optimisation of logistics and operational procedures in the challenging conditions of South Georgia. This initial phase will also allow evaluation of effects of bait on non-target species.

Success of the project is defined as the total absence of rats and rat sign from South Georgia for a period of two years, the time estimated for a surviving population to return to readily detectable levels.

1.3 Background

It is likely that Norway rats were first introduced to South Georgia accidentally from ships when the island was the subject of intense commercial sealing operations in the late 1700s. Rats are established along the entire north coast and also on the south coast at the northern end of South Georgia. Many offshore islands remain rat free and are havens for ground and burrow-nesting bird species. Much of the south coast is also free of rats, but here the climate is severe, the vegetated coastal strip is narrow, and wildlife is less abundant. Steep peaks and glaciers provide natural barriers to the spread of rats from one part of the island to another. There is an element of uncertainty when attempting to define rat-free mainland areas, as scree and rocky slopes reach high up mountain slopes and rat sign has been reported on some glaciers and in high mountain passes (Christie and Brown, 2007). However, large glaciers on South Georgia are considered to be robust barriers to rats (Poncet et al., 2002; Poncet and Poncet, 2010).

South Georgia's glaciers have receded in recent years (Cook et al. 2010; Gordon et al., 2008) and if the current trend continues, rats will at some time be able to spread to parts of the island that they previously could not access (see South Georgia GIS <http://www.sggis.gov.gs>). During the ACAP survey in 2006/07 rats were found on Saddle Island and there were no pipits present (there were many birds in 1984). This implies that rats had arrived on the island in the last 20 years – bridging the 270m from the mainland, possibly facilitated by temporary ice bridges or bergy bits (S. Poncet, pers. comm.).

Globally, awareness of the problems posed by invasive species is growing, and guidelines have been produced by the International Union for Conservation of Nature (IUCN), which has an Invasive Species Specialist Group within the IUCN Species Survival Commission. The European Commission has funded the South Atlantic Invasive Species Project (SAISP), implemented by the Royal Society for the Protection of Birds (RSPB). The Government of South Georgia and the South Sandwich Islands (GSGSSI) is a partner in this project.

1.4 Previous control and eradication efforts on South Georgia

A successful trial eradication of rats from Grass Island on South Georgia took place in the year 2000 using 20ppm brodifacoum cereal based pellets spread by hand using a grid system to ensure complete coverage (Poncet, 2006a). The aim of the Grass Island trial was to determine the effectiveness of New Zealand eradication methodology in South Georgia.

Bait stations and snap traps are used to kill rats at Grytviken and King Edward Point (KEP). Until 2006, brodifacoum wax blocks were used in the bait stations but, due to the planned island-wide eradication programme, diphacinone poison is now used (D. Christie, pers. comm.).

1.5 Feasibility study

A feasibility study was undertaken in 2002 in conjunction with the New Zealand (NZ) Department of Conservation (DOC) (Poncet et al., 2002) to assess what local factors on South Georgia would necessitate changes to the standard methodology used for NZ eradications. The NZ DOC has extensive experience of eradications of a number of pest species, including Norway rats. This study recommended a summer eradication operation on South Georgia using aerial application of bait.

1.6 The environmental evaluation process

This Environmental Impact Assessment assesses the predicted and potential environmental effects of the proposed eradication of Norway rats from South Georgia. Impacts within the context of the overall eradication plan have been assessed.

This document includes:

- Description of the proposed eradication
- Alternative methods of eradication
- Description of the South Georgia environment (the treatment area)
- Assessment of actual and potential environmental impacts of the proposed operation on the environment and possible mitigation measures
- Outline of environmental management and monitoring activities

This EIA will be updated as further information becomes available over the period that this project will be active. Further supplementary assessments of each Baiting Zone will be required for Phase 2.

1.7 Expert evaluation and stakeholder consultation

The Environment Charter for South Georgia (see www.sgisland.gs) states that the GSGSSI will seek expert advice and consult openly with interested parties on decisions affecting the environment (guiding principle 5). The support of the public, non-governmental organisations and private organisations is an important precursor to implementation of the eradication plan.

The plans for the eradication as well as the environmental documentation were sent to the Island Eradication Advisory Group (IEAG) for peer review (February 2010). The IEAG is an expert group of eradication specialists and experienced eradication practitioners. Following this review, the EIA was made available to stakeholders via the South Georgia website (May 2010), before a final decision was made.

1.8 Domestic legislation

Legislation for South Georgia is the responsibility of the Commissioner for SGSSI. The extant wildlife legislation is the 1975 *Falkland Islands Dependencies Conservation Ordinance* along with the *Wild Mammals and Birds (Export) regulations* of the same date. A new *Wildlife and Protected Areas Ordinance* has been drafted and will be the subject of consultation before its enactment.

The 2001 Environment Charter highlights the Governments' commitment to the control or eradication of invasive species: "Guiding principles for the UK Government and for the Government of SGSSI ... 7. To safeguard and restore native species, habitats and landscape features, **and control or eradicate invasive species**".

Until the necessary legislation is in place, there is no legal requirement for environmental impact assessments to be undertaken before projects are approved on South Georgia. However, the Government is committed under the Environment Charter to ensure that environmental impact assessments of proposed activities, including consultation with stakeholders, are undertaken where appropriate.

The environmental impact assessment procedures which have been developed for the Environmental Protocol to the Antarctic Treaty, Annex I, form the basis of GSGSSI policy on EIA. The document *South Georgia: Plan for Progress* (Pasteur and Walton, 2006) provides further details of South Georgia environmental management policies.

1.9 International agreements

The *Agreement on the Conservation of Albatross and Petrels (ACAP)* (part of the *Convention on the Conservation of Migratory Species of Wild Animals*), states that “Parties shall take measures to the extent feasible to control and where possible eradicate non-native taxa of animals and plants, or hybrids thereof, that are, or may be, detrimental to populations of albatrosses and petrels” (Paragraph 1.4.2). The UK has signed ACAP on behalf of South Georgia.

The UK is a signatory to the *Convention on Biological Diversity (CBD)*, which states that “Each contracting Party shall, as far as possible and as appropriate: (h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species” (Article 8). The CBD has not been extended to SGSSI, but the GSGSSI support the principles of the CBD.

1.10 Project management structure

The project will be managed by the South Georgia Heritage Trust (SGHT). A Project Director will coordinate the detailed planning and implementation of the project, including all environmental components. An experienced field team, including specialist pilots, will undertake the eradication.

2 DESCRIPTION OF THE PROPOSED ACTIVITY

2.1 Project outline

The proposed eradication of rats from South Georgia will be a predominantly land-based operation using helicopters to distribute poison (brodifacoum) in cereal-based bait.

The operational centre will be at KEP/Grytviken. Temporary depots of fuel and bait (Forward Operating Bases – FOBs) will be used for more remote operations. A yacht will be used to support operations from FOBs.

The eradication will take place over several seasons. The metapopulation of rats on South Georgia comprises numerous sub-populations, each geographically isolated by areas of permanent ice or stretches of seawater. For the purposes of this eradication campaign, the area of land occupied by each sub-population is termed a ‘baiting zone’. Several zones (see Appendix 5) will be treated each season. In accordance with successful practice on Campbell Island (McClelland and Tyree, 2002), only one application of bait is planned for the majority of each Baiting Zone. A second application of bait will be made after 5-7 days along coastal, tussock habitat to ensure that all rodents,

including any mice, are killed. In the event that some rodents survive the initial treatment, a second treatment of the affected zone would be undertaken in a subsequent season.

The first phase of the eradication will take place on Thatcher and Greene Peninsulas (including the only areas of permanent human habitation on the island), land on the west side of Mercer Bay and Saddle Island. To determine that the proposed rodent eradication technique will work effectively on South Georgia, this initial phase of the eradication will involve an assessment of techniques, e.g. bait concentrations and Global Positioning System (GPS) mapping, to best suit the local conditions and environment as well as the effectiveness of logistics. Further assessment of the environmental impacts of the operation, such as wildlife disturbance and effects of baiting on non-target wildlife, will also be undertaken.

An Operational Plan (OP) has been prepared for Phase 1 of the operation (SGHT 2010a) and another will be developed in 2011 for Phase 2.

2.2 Area of disturbance

The eradication operation will take place mainly in the northern and north-eastern coastal areas of South Georgia (see red and orange shaded areas in Figure 1). All rat infested areas will be affected by helicopter overflights. A large part of the island is rat free and will therefore not be affected by eradication operations.

2.2.1 Operational base

The operational base at Grytviken will be where the main on-the-ground activities take place. Helicopters, equipment and bait will be stored in the existing engineer's shed at Grytviken. Jet A1 fuel will be stored in clearly marked 200-litre drums (a maximum of 150 drums will be required for Phase 1). All drums will be stored on a depot area outside any building.

The majority of the team will be accommodated in Larsen House at KEP and three people will be accommodated in the main BAS base, museum buildings or elsewhere. The footprint of the operational base and accommodation will be in an area already impacted by human activities.

2.2.2 Baiting Zones

A total of 21 independent baiting zones, bound by glaciers and the sea, have been identified (see Appendix 5). Estimates of the extent of vegetation, unvegetated ice-free ground and length of coastline for each zone have been made with an assessment of how robust are the glacier barriers (Appendix 5). Some of the barriers may have a greater risk of failure, particularly during the winter due to the freezing over of bays. Zones which should be treated during the same season have therefore been identified.

The largest zones are the Barff Peninsula (233km²), the area around the north-west coast (173km²) and the area around Stromness (163km²). Each one of these areas would be greater than the largest eradication to date on Campbell Island (113km²). Greene Peninsula (41km²), Thatcher Peninsula (95km²), Mercer Peninsula (16km²) and Saddle Island (1km²) are the zones planned for baiting in the first season.

2.2.3 Forward Operating Bases

During Phase 2, for locations which are not close to Grytviken, fuel and bait will be cached at FOBs in or close to the zones to be baited prior to the commencement of work each season. All FOBs will require a suitable flat area for storing fuel drums and bait pods (protective boxes for bait) and an area for two helicopters to land and be tied down

in the event of bad weather. FOBs will be within 800m of a beach which is suitable for landing Zodiacs or flat-bottomed landing craft. These FOBs will be out of range of possible damage by wave action and close to a yacht anchorage, but away from sensitive concentrations of seals and birds that would be significantly disturbed by helicopter operations.

A total of 24 FOBs have been identified (Poncet and Poncet, 2009). Fuel and bait will be moved to the FOBs by helicopter direct from a ship or from a nearby landing site (in the event that they were landed onto a beach by a sea truck). Fuel will be in sealed 200 litre metal drums. Bait will be housed in specially designed re-usable weather-proof plastic pods and securely covered with plasticised tarpaulins.

The FOBs will be a focus for likely disturbance due to helicopter landing and take off and the presence of team members loading bait into the bait hopper and conducting aircraft fuelling operations.

During operations using FOBs, a yacht will be on stand-by for safety purposes and to accommodate personnel should there be no operational requirement for the helicopter(s) to return to Grytviken. Emergency equipment including tents, food, stoves and fuel will be kept at each FOB in the unlikely event that personnel are unable to access the yacht or Grytviken due to bad weather.

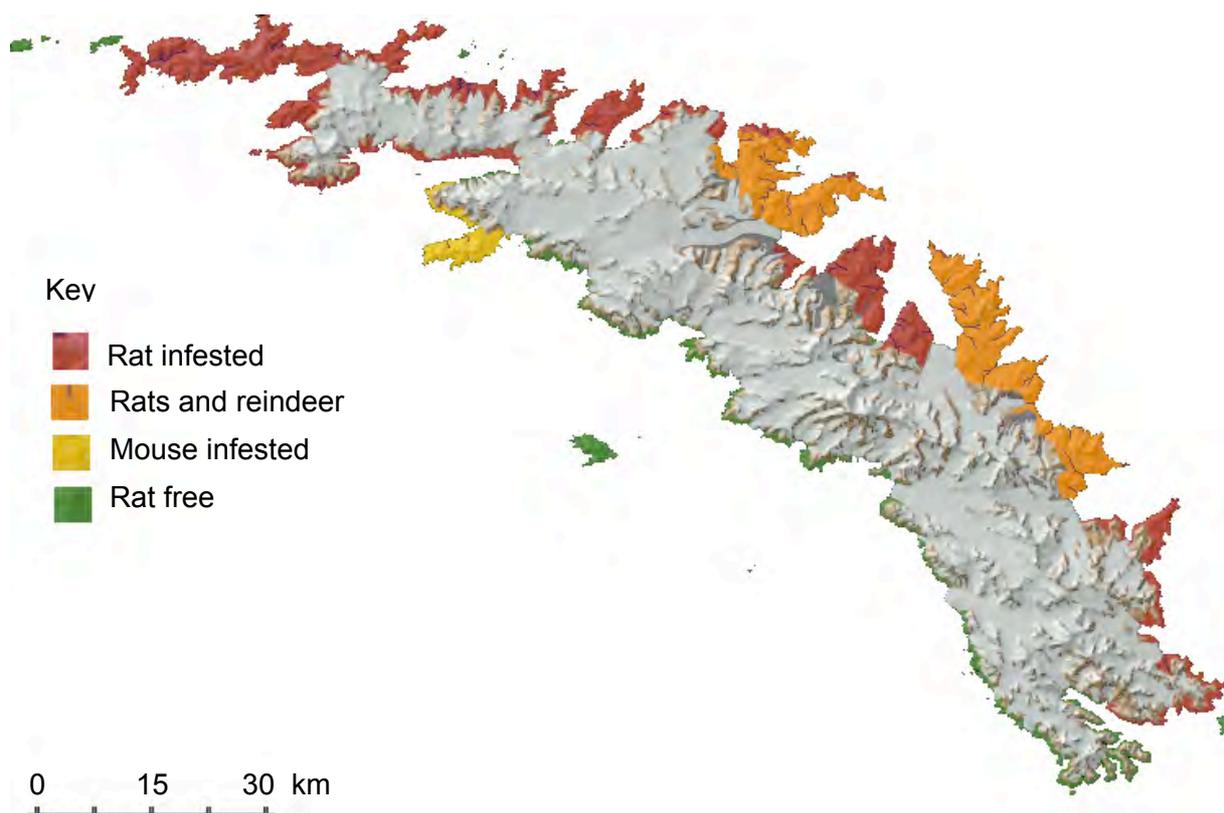


Figure 1. Map showing areas of rat, reindeer and mouse presence (from South Georgia GIS: www.sggis.gov.gs)

2.2.4 Monitoring

Monitoring will be used to investigate baiting impacts on both target- and non-target species. This will include monitoring for presence of rat sign and monitoring of the expected recovery of native wildlife populations following the eradication operation. Further details are given in section 6 and the SGHR Project Phase 1 Monitoring Plan (SGHT, 2010d).

These activities will involve team members conducting work on the ground in the treatment areas as well as the use of one or two rodent detection dogs. The dogs will be specially trained for this purpose and will work with their trainers.

2.3 Personnel requirements

The core operational team will consist of a Project Director, Assistant Project Director, Chief Pilot, Aviation Advisor, Helicopter Engineer, Accommodation Manager, Paramedic, GPS/helo tracking specialist and three Field Officers. Further personnel may be required depending on the scale of operation attempted each season, to a maximum of around 15 people.

2.4 Transport

2.4.1 Shipping

All equipment, helicopters and bait will be freighted to the Falkland Islands for onward passage to SG. Helicopters or a sea truck will be used for supplying FOBs directly from the transport ship.

A support yacht will be required during the operational periods during Phase 2 of the project to provide emergency backup to the project team due to the limited emergency and search and rescue facilities on South Georgia. The yacht would normally be anchored at an active FOB and will provide accommodation for the entire team when weather is good and a return to base at Grytviken is not required for other reasons.

2.4.2 Helicopters

Two twin-engined helicopters (Bolkow 105) will be used throughout. These will be shipped to South Georgia and use a hanger at Grytviken as the main base.

Fuel consumption for these aircraft is around 225 litres per hour and they have a range of around 324 nautical miles (600 km) and endurance of 2.7 hours. The maximum distance from Grytviken to any of the treatment areas is around 70 nautical miles, which is around 40 minutes flying time in a straight line. A discussion of alternative helicopters is given in section 3.7.

The helicopter altitude for bait spreading operations will be 150–500ft above ground level, but effective spreading at higher altitudes is possible in conditions of low or zero cross wind (P. Garden, pers. comm.).

2.4.3 Other vehicles

A tele-handler fork lift will be held at Grytviken to move cargo and supplies, and to bulk-load buckets when baiting is being conducted near the base. A lifting device may also be used at FOBs if a suitable loader can be sourced.

2.5 Use of Brodifacoum poison

The proposed toxin for the South Georgia rodent eradication is the second-generation anticoagulant brodifacoum. Bell Labs' Conservation 25W is produced as a compressed

cereal pellet containing 0.025g/kg (25 parts per million or ppm) of the toxin. The pellets are dyed green to make them less attractive to birds. Brodifacoum is absorbed through the gastrointestinal tract and acts by interfering with the synthesis of vitamin K dependent clotting factors in the liver, causing death by haemorrhaging.

The main advantages of using brodifacoum for rodent eradication on South Georgia are:

1. It is extremely toxic to rats. The LD₅₀ is 0.27mg/kg and the consumption of a single bait pellet is sufficient to kill most rats (Eason and Wickstrom, 2001). This reduces the risk of primary and secondary poisoning of non-target animals as a low concentration of brodifacoum can be used in the bait.
2. Onset of symptoms is several days after poison consumption, so rats have plenty of time to consume a lethal dose before feeling any ill effects. Bait shyness is therefore unlikely to develop and pre-baiting is unnecessary.
3. Rats normally take several days to die after ingesting a lethal dose of poison, gradually becoming weaker before they die. Many animals therefore die underground or in cover, thereby reducing the risk of secondary poisoning of scavenging birds.
4. Brodifacoum is insoluble in water and is therefore slow to leach from baits in damp conditions. When released it binds onto organic matter, becomes inert and is slowly degraded by soil microorganisms over a period of 3-6 months.
5. Brodifacoum is relatively safe operationally. Vitamin K1 is an effective antidote, but it has to be maintained for a relatively long treatment period.
6. The bait is generally effective for around 2–4 weeks after spreading, but this time may be reduced depending on weather conditions.

The above information is derived from the review of current knowledge of brodifacoum produced by the New Zealand Department of Conservation (Fisher and Fairweather, 2005). Further technical information on brodifacoum can be found in Appendix 2.

In a review of rodent eradication programmes around the world (Howald et al., 2007), brodifacoum was used in 71% of campaigns and 91% of the total area treated. Eradications using aerial broadcast made up 76% of the total area treated. There were 104 successful eradication operations for Norway rats and a failure rate of 5%.

2.5.1 Poison application method

Brodifacoum will be applied to the baiting zones using helicopters fitted with under-slung mechanical calibrated bait spreader buckets with petrol engine driven spinners to distribute the bait evenly to around 40m either side of the helicopter flight path (80m swath width, at optimum height). Helicopters will be equipped with second generation Global Positioning Systems (GPS) to ensure accurate coverage. The boundaries of the rat infested areas will be logged into the GPS software before bait spreading begins.

To ensure full coverage of coastal areas and rock stacks it is unavoidable that some bait, at the outer edge of application swathes, will fall into the sea. GPS guidance and the use of experienced pilots will minimise this.

Bait will be applied by hand in and around buildings, other structures and areas inaccessible by air.

2.5.2 Amount of bait and spreading density

There must be enough bait applied for every rat to encounter and eat a lethal dose. Steep terrain and possible loss of baits in rock crevices must be taken into account.

During fieldwork undertaken between Feb-April 2007 on South Georgia, 15 rats were fitted with radio collars and tracked. The results showed that rats have considerable ranges and travelled up to 150m a night. Field studies indicated that rat densities in non-coastal areas appear to be very low, with the main rat populations concentrated in coastal areas and around tussac (Christie and Brown, 2007).

It is proposed that the mean density of bait deployed will be lower than in other similar operations, due to the significantly larger scale of the operation on South Georgia and likely lower rat densities. Higher bait densities (up to 6.5 kg/ha) will be sown in coastal areas which have been identified as having the highest rat concentrations (Poncet et al., 2002; Christie and Brown, 2007), and where there is significant tussac cover. This will be done in two passes separated by 5-7 days to increase the chance of killing any mice which may be present. Lower application rates (2kg/ha) will be used for inland areas. The effectiveness of the bait spreading methodology will be assessed during and after the first operational season.

2.5.3 Source of bait and legal requirements

Due to its relatively short shelf life, new bait will be transported to South Georgia for each year of the operation. The bait manufacturer will be selected each year, and is Bell Laboratories (USA) for Phase 1 of the operation. The bait does not have a dangerous goods classification for transport. Any remaining at the conclusion of a season will be returned to Stanley for use in the Falkland Islands.

The Conservation 25W bait is designed for aerial application, and will be permitted for use by the South Georgia Government (M. Collins, pers. Comm.).

2.6 Duration of activity

The duration of the proposed eradication will depend on weather, but is likely to be four seasons, starting in 2011. One or more baiting zones will be treated each season.

2.6.1 Seasonality of baiting

Extreme weather conditions and potential for prolonged snow cover mean that a winter operation would have a significant risk of failure (Poncet et al., 2002). Consequently the proposed rodent eradication on South Georgia will take place from mid-February until May. The successful trial eradication on Grass Island took place during summer.

By mid-February, the most sensitive part of the breeding season for most animals on South Georgia is complete. The numbers of birds and seals present on the island is reduced and there should be no prolonged snow cover during this period. However, some wandering albatross will still be incubating eggs, king penguins and Wilson's storm petrel will be brooding chicks and many species' chicks will not have fledged. The mitigation of the potential impacts of the operation on these birds is discussed in section 5.

The alternative of a winter operation is discussed in section 3.8.

2.7 Site waste collection and disposal

All waste will be returned to KEP and disposed of in accordance with normal procedures at this site. General waste will be shipped to the Falkland Islands on either a GSGSSI or a British Antarctic Survey (BAS) ship for landfill disposal. Recyclable materials and hazardous wastes will be dealt with in accordance with the BAS Waste Management Plan (BAS, 2008) and shipped on a BAS vessel for recycling and disposal in the UK.

The project Waste Management Plan is shown in Appendix 3.

2.8 Project documentation

An Operational Plan (SGHT 2010a) has been prepared for the first phase of the rat eradication and deals with project management, staffing and living arrangements, purchasing, transportation, bait sourcing and broadcasting, helicopter operations, risk management and monitoring. Another O.P. will be prepared for Phase 2 in 2011.

In addition, site specific IEEs will be produced for each treatment zone. These will include information about the zone and the proposed eradication and monitoring activities within that zone, focussing on specific environmental issues not covered in this EIA.

A report will be produced at the end of each season, to include details of accidents and incidents, including environmental incidents, which will be fed into the planning for subsequent seasons.

A revised Rodent Distribution Areas and Boundaries Report (Appendix 5) gives updated details of the 21 proposed baiting zones. Operating Sites are described in the Baiting Zones and Operating Sites report (Poncet and Poncet, 2009). Information on biosecurity and waste management is given in Appendices 1 and 3 of the current document. The following Plans have also been prepared for Phase 1 of the project: Biosecurity (SGHT, 2010b), Oil Spill Response (SGHT, 2010c), Monitoring (2010d), Health and Safety (SGHT, 2010e), Search and Rescue (SGHT, 2010f) and Crash Recovery (SGHT, 2010g).

3 ALTERNATIVES TO PROPOSED ACTIVITY

There are three management options for rodents:

- maintain the current situation (do not proceed)
- control the population
- attempt eradication.

There are a number of alternative options for the proposed eradication: a ship-based operation (with a choice of ships); hand bait laying, using traps or bait stations as alternatives to the proposed aerial bait spreading by helicopter. Alternative poisons, alternative helicopters and alternative timing for the operation are also discussed.

3.1 Do not proceed

Rodents on South Georgia pose a threat to vulnerable ground-nesting birds and damage vegetation (see sections 4.4 and 4.5). With no action, rats are likely to increase their range on South Georgia due to the recession of glaciers (Cook et al., 2010) and cause more detrimental effects to the native biological diversity of the island. A future island wide eradication of rats is likely to be far more expensive as the eradication will need to cover a much greater area of South Georgia. In the future there may be improved, more reliable, cheaper eradication techniques which have more benign environmental effects (e.g. sterillants, pathogens or genetics). However, there is no guarantee that such developments will take place and these methods may also have risks associated with them (Howald et al., 2007).

Maintaining the current situation would require continued vigilance and action to prevent the spread of rats to new areas and ensure that the safe havens to wildlife that currently exist are preserved as well as possible. Additional biosecurity measures would be required to prevent the expansion of rats due to the recession of glaciers, but this would be very costly and virtually impossible to implement.

The option of “no action” is not consistent with GSGSSI policy or with the obligations within international agreements such as *ACAP* and the *Convention for Biological Diversity* and would result in continued degradation of a globally important island ecosystem.

3.2 Control the population

Controlling or reducing the population of rats, or eradicating in certain areas (for example the eradication on Grass Island), would likely produce short-term local benefits. However, any baiting without the use of helicopters would be very time consuming, labour intensive and costly. Also, rats may build up tolerance or bait shyness to the brodifacoum bait, which could compromise a future full eradication attempt.

Rat populations would quickly recover to their pre-treatment levels if ongoing treatment was not undertaken, and would very likely recolonise areas from which they had previously been eliminated. Long term pest control would have significant cost implications and the benefits to seabirds would only last as long as the rat population was kept under control. Controlling the population without complete eradication could result in the killing of far more rats overall, and endangering more non-target species as the operations would be ongoing. If an anticoagulant poison was used to control rats, then the poison may build up in the food chain.

An ecologically beneficial rat control program on the whole of South Georgia would be impractical due to the scale and number of rat infested areas, and far more expensive than an eradication programme.

3.3 Ship-based operation

Locating all the logistics on a ship is an alternative to a land-based campaign. This would provide the advantage that all cargo and personnel are on board the vessel and can be transported to each operational area. Helicopter flight times would be reduced and there would be no need to establish FOBs. This would reduce the risk of onshore fuel spills, bait spills, littering and wildlife disturbance. The ship would also provide emergency backup during the operation.

The use of a dedicated ship would increase the overall fuel consumption during the operation as the consumption of the ship (around 8 tonnes per day) would be greater than the extra fuel requirement for helicopters for a land-based operation. The fuel required to position the ship each season would likely be considerable, leading overall to greater atmospheric emissions than in a land-based operation.

The cost of a ship-based operation was examined in a scoping exercise in September 2009 by SGHT. The conclusion was that this option would cost an additional £4m at least, compared to a land-based operation, representing a supplement of some 70-80%.

3.4 Alternative land-based operations

Various options were considered for a land-based operation. The simplest from a logistical standpoint would be to use KEP/Grytviken as the only base, and have the

helicopters return here to refuel and refill bait buckets. The argument against this, and a strong one, is that the helicopters would spend a great deal of time commuting to and from remote locations, increasing risk to passengers, using lots of fuel and causing avoidable disturbance and pollution. It is likely that flying hours would double. Furthermore, where long helicopter ferry flights are required between the loading site and the operational area, bait pellets can become compacted in the bait bucket to the extent that they will not flow (P. Garden, pers. comm.). The most efficient use of helicopters would be obtained by having them commute the smallest possible distance between a supply depot and the baiting location. This argues for the establishment of a number of FOBs in or near baiting areas for fuel and bait. Remote working would require emergency cover/accommodation in the event of accident or sudden severe weather. Such accommodation could be provided by a land-based camp near the supply depot, but this would necessitate environmental disturbance and reduce operational flexibility.

The option which provides minimal environmental disturbance and significant operational flexibility is to establish supply depots near to an anchoring site for a yacht, and to have the yacht accommodate both the project's paramedic and indeed the entire team when return to Grytviken is not required for any reason. Such an arrangement will reduce helicopter commuting and increase readiness to operate whenever weather is flyable on some part of the island.

3.5 Alternative poisons

In order to eradicate rats successfully from South Georgia the following criteria must be met:

- Individual rats must be exposed and susceptible to the chosen toxin, and find the bait palatable
- Rats must be killed faster than they can breed
- The bait used should not allow any 'bait-shyness' to develop in the target species
- Adverse effects on non-target species must be avoided where possible, or mitigated
- Risks to human health must be avoided (and medical contingencies put in place)
- The method needs to be cost effective and logistically feasible on South Georgia
- There must be a minimal chance of reinvasion

(adapted from Brown et al., 2006)

3.5.1 *Alternative anticoagulant poisons*

Anticoagulant rodenticides are either classified as first-generation (multiple dose required) or second-generation (single dose required).

First-generation anticoagulants (warfarin, diphacinone, chlorophacinone, coumatetralyl) are generally less toxic and require a higher concentration and several feeds to be effective. There is a risk that first-generation poisons would not kill all of the rats and some may become resistant to the poison (Eason and Ogilvie, 2009). They are not effective for killing mice (Fisher, 2005).

Alternative second-generation anticoagulants such as bromadiolone, difencoum and flocoumafen act in the same way as brodifacoum and offer no significant advantages. These alternative toxins are not registered for aerial broadcasting, which is the preferred method for this eradication (Eason and Ogilvie, 2009).

Brodifacoum bait has been successfully used for several other sub-Antarctic rat eradication projects (Clout and Russell, 2006; Howald et al., 2007) and has also been

used successfully on Grass Island on South Georgia (S. Poncet, unpublished report). To try an alternative toxin could significantly increase the risk of failure of this operation.

3.5.2 *Alternative chemical poisons incorporated in bait*

Zinc phosphide is, worldwide, the most commonly used rodenticide after anticoagulants. An acute poison, it kills after a single dose by producing phosphine gas in the stomach (Mason and Litton, 2003). However, there is a high risk of bait shyness and pre-baiting is needed to accustom the rats to the bait. This would not be practical on South Georgia. Also, zinc phosphide becomes less effective when wet, is more toxic to birds than mammals and has no antidote (Eason and Ogilvie, 2009).

Calciferol / cholecalciferol / ergocalciferol (Vitamins D / D₃ / D₂) are acute poisons which interfere with the calcium and phosphate balance, causing death from kidney failure and/or the side-effects of soft-tissue calcification (Mason and Litton, 2003). Problems with palatability to rats and degradation outdoors as well as the lack of a suitable antidote (MAFF, 1996) make this poison unsuitable for use for this project.

Sodium monofluoroacetate (1080) is a widely used acute toxin registered for aerial application. However, primary and secondary non-target species deaths may result from 1080 use, there is no effective antidote, bait shyness is a problem with this poison and it is also highly water soluble (Eason and Wickstrom, 2001). The often wet conditions on South Georgia and the possibility that not all rats will take the poison render it unsuitable for this project.

3.5.3 *Combination anticoagulant and chemical poison: cholecalciferol + coumatetralyl (C+C)*

A combination of the first generation anticoagulant coumatetralyl and the poison cholecalciferol is being developed for controlling rats and mice (Eason et al., 2008). Bait containing 0.015% cholecalciferol and 0.03% coumatetralyl and is thought to be as potent as brodifacoum, with lower risk of secondary poisoning and long term residues in sub-lethally affected animals (Eason and Ogilvie, 2009). However, the bait has not yet been registered and is not tested for aerial application.

3.5.4 *Fumigant poisons*

Correctly carried out, fumigation (with sulphur dioxide, carbon dioxide, phosphine or cyanide gas) is an efficient rodent control method (Mason and Littin, 2003). However, this is only possible in enclosed spaces and for small scale operations and so is not a viable option for South Georgia.

3.5.5 *Persistence of toxins in the environment*

Table 1 shows the persistence of pesticide residues in the tissue or blood of non-target species. All of the second generation anti-coagulants have high persistence and have been shown to persist in the livers of live mammals (Eason et al., 2008). In mammals, sub-lethal brodifacoum poisoning has been shown to result in lassitude, anorexia and weakness (Fisher and Fairweather, 2005) and trials on chickens showed increased blood clotting times for up to a month following exposure to a single dose of brodifacoum (Bailey et al., 2005).

Although there is increasing concern about the use of brodifacoum for repeated operations in mainland situations due to the potential build up of the toxin in the food chain, aerial baiting of brodifacoum is generally accepted as the preferred poison in isolated regions (Eason and Ogilvie, 2009). As the South Georgia eradication is a single baiting operation (with two applications along coastal tussock areas) in each zone, in an

isolated environment, the potential for bioaccumulation is very much reduced. Even if residues remain in some animals for a number of years, the residues would gradually reduce with the turnover of population and eventually all of the toxin would break down in the environment.

Table 1. Persistence of alternative poisons in sub-lethally exposed target or non-target species (data from Eason et al., 2008)

Poison	Type of poison	Compound half life in tissue/blood	Persistence of residues
Brodifacoum	Second generation anticoagulant	130 – 300 days	> 24 months
Bromodiolone	Second generation anticoagulant	170 days	> 24 months
Flocoumafen	Second generation anticoagulant	220 days	> 24 months
Coumatetralyl	First generation anticoagulant	50 – 70 days	12 – 16 weeks
Diphacinone	First generation anticoagulant	3 days	6 weeks
Cholecalciferol	Acute toxin	10 – 69 days	12 weeks
1080	Acute toxin	<11 hours	7 days
Zinc phosphide	Acute toxin		12 – 24 hours
Cyanide	Fumigant poison		12 – 24 hours

3.5.6 Discussion

Conservation management may necessitate causing harm to individual animals or plants – but the end can justify the means. The eradication of rats from South Georgia would result in a highly desirable conservation objective, with the potential to achieve dramatic results. Brodifacoum is the only toxin that has a proven track record for island rodent eradications involving aerially broadcast bait and is currently the recommended bait for island eradications (Fisher and Fairweather, 2005; Eason and Ogilvie, 2009). It therefore offers the highest probability of a successful rodent eradication operation on South Georgia.

3.6 Ground based methods for rodent eradication

3.6.1 Trapping

There are several types of traps including sticky boards, live traps, snap traps and electrocution traps. Trapping avoids many of the potential adverse effects of toxin use, although birds may be killed in rodent trapping operations. Also, some rats could become trap shy, and failure to trap a single rat could mean the failure of the entire operation.

3.6.2 Bait stations

Using bait stations has the following advantages:

- Bait is kept dry, so the operation is not weather dependent
- Bait take can be monitored and unused bait can be removed
- A wide range of toxins is registered for use in bait stations
- There is a lower risk of non-target poisoning

3.6.3 Hand-laying toxic baits

The possibility of hand-laying bait was discussed following the trial rat eradication on Grass Island (Poncet et al., 2002). This would allow a greater level of flexibility for the use of different bait types, which can reduce the risk to non-target species.

3.6.4 Discussion

All ground based methods for rodent eradication would require foot access to all parts of the treatment area and large numbers of personnel, including specialist mountaineers to facilitate access to steep and dangerous terrain, resulting in greater cost and increased health and safety risks. Not all areas may be properly treated due to access problems and human error. In addition, trampling by personnel could cause damage to vegetation and bird burrows and disturbance to wildlife.

The terrain, even for the relatively easy Greene Peninsula, would likely require mountaineers and a large team which would greatly increase the cost and the risk of failure of the eradication (Poncet et al., 2002).

To attempt to poison all rats using bait stations or traps would require a vast number of these devices at substantial cost.

In order to achieve successful eradication of rats from South Georgia, bait must be available in all rat-infested areas to ensure that all rats are exposed to it. Ground-based operations are not practical or cost effective on such rugged and remote terrain and covering such a large area. This option is therefore rejected for the island wide project. However, hand baiting and traps will, of necessity, be used in and around buildings.

3.7 Use of alternative helicopter

Many helicopter types can be used for aerial baiting operations, ranging in size up to the large Russian Mil 8. The aircraft type does not affect the achievable swath width so the same flight time is required to spread bait over a given area, regardless of the size of the aircraft. Larger aircraft can carry more bait, but it has been found that pellets at the base of the bucket can become compacted and cease to flow if large bait quantities are carried. The ideal size of load is around 300-500kg, which can be carried by a medium-small helicopter (Garden, 2009).

Three helicopter types were identified as being particularly suitable for use in this operation: the Bell 206L LongRanger, the Eurocopter AS350B/A Squirrel and the Bolköw MBB 105. All have a carrying capacity of 6 people and similar noise levels during operation of 75-84dB (depending on maximum gross weight) at 500 feet above ground level (AGL) (P. Garden, pers. comm.).

Advantages of the Bell 206 is that it will fit into the maintenance shed at Grytviken without folding of the blades (the 3 blade Eurocopter & 4-bladed Bolköw would require their folding), it is easier to operate in bait spreading configuration (better visibility of bait bucket) and has a lower fuel requirement (160ltrs/hour compared to 225ltrs/hour for the Bolköw). The Squirrel performs better than the Bell 206 in high winds (Garden, 2009), and the Bolköw even more so due to a rigid rotor system. The Bolköw is the only machine with twin engines, which allows greater safety.

All factors considered, the Bolköw 105 was chosen for this operation, not least because it provided the best performance and greatest level of flight safety in the conditions of South Georgia.

3.8 Alternative operational timing

The timing of the operation is dictated mainly by the weather and by potential impacts on non-target species. While offering the operational advantage of more benign weather conditions, spring and summer are not suitable as they are the most sensitive times for breeding of non-target wildlife on South Georgia.

Many other sub-Antarctic rat eradication operations have taken place during winter months when rat populations are naturally at a low ebb, less food is available, consequently less bait is needed and rats are more likely to consume it (Poncet et al., 2002). However, there is snow cover to sea level on South Georgia for significant periods during the winter (see section 4.3). Due to reduced daylight hours and the risk that snow cover would prevent rats getting access to bait, a winter bait-spreading campaign here would have a substantial and unacceptable risk of failure (Poncet et al., 2002). Late summer to autumn has consequently been identified as the most suitable time for this operation on South Georgia (see section 2.6).

3.9 Summary of alternatives

1. The alternative of not proceeding is rejected as this is not consistent with GSGSSI policy or with obligations stemming from international agreements such as *ACAP* and the *Convention for Biological Diversity* to which the UK is bound. Recent developments elsewhere have demonstrated that rodent eradication on South Georgia is now possible, and could be achieved at manageable cost.
2. The *controlling* of rats on South Georgia, rather than eradication, is rejected because of the logistical and cost implications, and the fact that it does not offer a long-term solution to the problem.
3. The option of a ship-based operation, as opposed to a land-based one, is rejected for reasons of cost (far beyond the resources likely to be available) and because it would result in higher atmospheric emissions than the land-based equivalent.
4. Alternatives to the aerial dispersion of bait by helicopter were rejected as this method provides the only practical means to ensure total coverage of South Georgia and the only realistic prospects for success. The large area and difficult and steep terrain over much of South Georgia means that the alternative of ground baiting using traps and hand spreading would be impractical.
5. Alternative poisons to brodifacoum were rejected as this is the only toxin that has a proven track record for island rodent eradications involving aerially broadcast bait.
6. Alternatives to a small-midsized helicopter such as the Bolköw were rejected as they were not as robust, had only one engine (less safe) and would not perform so well in the high wind conditions frequently occurring on South Georgia.
7. Alternatives to an autumn operation were rejected as they offer a lower probability of success and/or could result in greater damage to native wildlife populations.

4 DESCRIPTION OF THE TREATMENT AREA

4.1 Location

South Georgia is a sub-Antarctic island situated around 1,400km east of the Falkland Islands. It is 170km long, 10-40km wide and ~50% of the land area is covered with permanent ice and snow.

The administrative centre, King Edward Point (KEP; 54°17'S, 36°30'W), is located in King Edward Cove, part of Cumberland East Bay on the northern coast of South Georgia.



Figure 2. Map showing location of South Georgia

4.2 Hydrology and glaciology

Ice-caps and glaciers cover over half the land area of South Georgia (Gordon and Timmis, 1992). The southern side of the main island is more heavily glaciated due to its colder south-facing position and greater precipitation. The terrain here is steeper and many glaciers drop to the sea from the ridge crests in a series of ice falls. In the far north-west of the island, where the mountains are less steep, the glaciers are wide and less crevassed.

South Georgia's larger glaciers currently create barriers to rat populations. However, recent studies indicate significant glacial retreat during the period from the 1950s to the present (Gordon et al., 2008; Cook et al., 2010). Out of 103 coastal glaciers, 97% were found to have retreated, with an average rate of retreat increasing from 8m per year in the 1950s to 35m per year at present. The glaciers on the north-east coast of South Georgia are retreating at an average rate of 60m per year, with individual glaciers (e.g. Neumayer Glacier) retreating at a rate of 384m per year (Cook et al., 2010). It is inevitable that continued global warming and glacier retreat, which has been accelerating since the 1990s, will allow rats access to areas from which they had previously been excluded.

There are around 20 freshwater lakes on the north eastern side of South Georgia (Trathan et al., 1996) as well as many smaller lakes and tarns around the island. Rivers and streams are widespread, particularly in summer when they are fed by snow and glacial meltwater.

4.3 Climate

South Georgia has a sub-Antarctic climate, characterised by deep depressions which originate in the Southern Ocean. Its severe climate is a result of its position around 200km south of the Antarctic Circumpolar Front (Pepper, 1954). Grytviken is on the more sheltered northeast coast of the island and has a mean annual temperature of around 2°C and total annual precipitation of around 1.5m. During winter, the area around Grytviken is completely snow covered with drifts up to around 1.5m (Pepper, 1954).

Temperatures on South Georgia have increased over the past 50 years, with a mean increase of around one degree, although the increase is greater in summer than in winter (J. Shanklin, pers.comm). Annual temperature variations for the period 2002-08 are shown in Figure 3.

Conditions are changeable and temperatures vary considerably from day to day. Wind speeds are generally high throughout the year, with monthly averages of 7–10 knots. Katabatic winds and violent squalls are a feature of South Georgia weather. Snow cover usually extends down to sea level during winter and sea ice may form in sheltered bays.

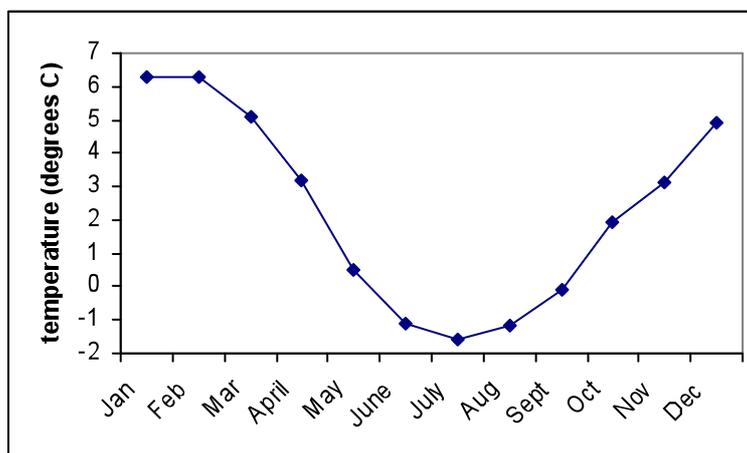


Figure 3. Average monthly temperatures at King Edward Point for 2002–08 [from <http://www.antarctica.ac.uk/met/READER/data.html>]

Weather will be an important factor in the eradication project as helicopter operations are only permissible within fixed limits on wind and visibility. Strong winds greatly affect the safety of helicopter operations and the accuracy of bait placement on the ground. Low cloud and fog will prevent helicopter operations. Operational planning must include an assumption of substantial down-time due to poor weather.

Rain may wash away distributed bait before it can be consumed by rodents, so baiting will be postponed prior to forecasted long periods of heavy rain. Baiting may need repeating under certain circumstances. Snow cover may prevent rats from accessing the bait. Forecasts from the BAS meteorologist at Rothera may be used to predict the occurrence of severe weather during operational periods. Further information is given in the OP.

4.4 Flora

Around 8.6% of the area of South Georgia is vegetated (sparse, partial or full cover); of this, 73% is rat-infested (Cook et al., 2010).

The vegetation on South Georgia is characterised by a coastal band of dense tussac, and inland festuca grassland and fellfield and herbfield vegetation communities (Scott and Poncet, 2003). There are no trees or shrubs and a limited number of flowering plants and ferns. Other vegetation includes moss, liverworts and lichen (McIntosh and Walton, 2000). Many plant species have been introduced. The vegetated areas of South Georgia have been mapped on the South Georgia GIS (<http://www.sggis.gov.gs/>). Vegetation is generally restricted to coastal areas and off-shore islands.

Areas with continuous vegetation cover which may provide year-round rat habitat are mostly a mixture of tussac with margins of bog and mire. Tussac grass (*Poa flabellata*)

grows to over 2m, is a major dietary component and habitat of rats, and is also important habitat for petrel and albatross colonies.

Rats eat the seeds, seedlings, flowers, fruit and foliage of many plants (Brown et al., 2006). This results in reduced general health of many plants and lowers their ability to thrive in what is already a very harsh environment. Rats may also facilitate the spread of introduced plant species.

4.5 Fauna

No terrestrial mammals, reptiles, amphibians or freshwater fish are indigenous to South Georgia (McIntosh and Walton, 2000).

Distribution maps for some of the fauna described below are available on the South Georgia GIS website (<http://www.sggis.gov.gs>).

4.5.1 Non-native mammals

4.5.1.1 Norway rats (*Rattus norvegicus*)

Norway (or brown) rats are omnivorous and globally widespread. They have caused, or contributed to, the extinction or restriction of native mammals, birds, reptiles and invertebrates through predation and competition. They also restrict regeneration of many plant species by eating seeds and seedlings. Rats are successful invaders because of their varied diet and high adaptability to novel environments. This allows them to prey on seabird eggs, chicks and adults while supplementing their diets with other island flora and fauna (Major et al. 2007).

Norway rats have an adult weight of around 300g and are up to 250mm in body length with a similar length tail. They have a brown/black upper head and body and are pale grey underneath. They have excellent hearing and sense of smell and taste, but poor sight. They live for around 9-18 months, achieving sexual maturity at 2-3 months and producing up to 7 litters of 8-10 offspring per year. Populations are therefore able to recover quickly after unsuccessful eradication attempts.

On South Georgia, Norway rats eat tussac grass, kelp, beetles, spiders, insects and birds' eggs, in addition to scavenging seal, penguin and reindeer carcasses. They also eat seeds, berries and roots. They generally prey on animals smaller than themselves, including ground-nesting birds such as pipits and the smaller burrowing petrels (McIntosh and Walton, 2000), but are capable of killing birds several times their body mass. Rat infested areas on South Georgia are shown in Figure 1 (section 2).

Rat fur etc. is frequently found in skua nests/food middens on other sub-Antarctic islands indicating that rats are likely to be a component of the skua diet (D. Brown, pers. comm.). However, the extent of skua predation on rats on South Georgia is unknown. Rats on South Georgia may also be consumed by kelp gulls. Skuas and gulls would therefore be at some risk of secondary poisoning if they consumed poisoned rats.

Norway rats nest in burrows and are often territorial. They climb with ease. Norway rats are good swimmers and, depending on water temperature and sea conditions, can swim around 1-2km (with intermediate rock islets, tidal flow, etc.) (Russell and Clout, 2005). In the cold environment of South Georgia their swimming range is likely to be a maximum of a few hundred metres.

Norway rats in a small study on Kapiti Island, New Zealand were found to range over an area of around 5.8ha (males) and 5.1ha (females) (Empson and Miskelly, 1999). Studies on South Georgia indicated a range over one night of 150m and indicated larger ranges

in areas away from the coast (Christie and Brown, 2007). The size of the home range has important implications for planning their eradication; the greater the range, the lower the density of bait pellets required to ensure that every rat encounters at least one. The consumption of a single pellet is adequate to kill all but the largest rats.

4.5.1.2 House mice (*Mus musculus*)

House mice have an adult body length of 75–100mm with a similar length tail, weigh 10–25g and have short light brown to black fur. They are good jumpers, climbers and swimmers.

On South Georgia, the only confirmed population of mice is in a rat-free area on Nunez Peninsula and the coast from Shallop Cove to Cape Rosa up to a glacier on the south coast of King Haakon Bay (Scott and Poncet, 2003; see Figure 1 in section 2). Pipit populations in this vegetated region are lower than expected (Cook et al., 2010), which may be connected to mouse predation.

The revised baiting zone report (Poncet and Poncet, 2010) includes an assessment of likely mouse presence in each of the 21 eradication zones. Unconfirmed reports of mouse observations and/or mouse sign have been made in the Northwestern eradication zone and Charlotte zone, though there is no supporting evidence. Presence of mice in the Grytviken, Stromness, Prince Olav and Barff zones is assessed as possible/likely. Other zones have been assessed as unlikely or unknown. Mice feed primarily on vegetation matter and inhibit plant regeneration by eating seeds and seedlings. They live in tussac grass and are known to predate invertebrates and the eggs and chicks of burrowing seabirds. On Gough Island mice have been shown to predate the chicks of large albatrosses (Wanless et al., 2007). Mice may also be responsible for the transfer of infectious agents to seals on sub-Antarctic Marion Island (de Bruyn et al., 2008).

A slightly different eradication methodology would be required for the removal of mice (e.g. bait density and possibly the number of treatments). These details would be included in the OP and site-specific IEE for the phase of the operation which includes the mouse infested areas.

Mice are often excluded from areas inhabited by rats, but populations of rats and mice are able to coexist if there is sufficient suitable habitat. On South Georgia there are no known areas of range overlap between these two invasive species, but it is possible that mice do exist at low densities in areas with rats. If this was the case, a predator-release effect may follow after rat eradication if not all of the mice were poisoned (see section 5.11). Post-treatment surveys must therefore include searches for mouse sign in addition to rat sign.

4.5.1.3 Reindeer (*Rangifer tarandus*)

Reindeer were brought from Norway to South Georgia in 1910/11 as a meat supply for the whalers. Two separate herds with a total of over 2000 animals now exist on the central north coast of South Georgia (see Figure 1, section 2). The GSGSSI are currently considering the management options for reindeer, including possible eradication (D. Christie, pers. comm.).

Reindeer are ruminants and eat mainly lichens, sedges and grasses. They have altered the vegetation on South Georgia by over-grazing the native grasses, causing damage to areas of tussac grass, greater burnet and some lichen species. The damage they cause to tussac displaces bird species that nest only in deep, dense tussac such as white-chinned petrels (Martin et al., 2009). In addition, the grazing of tussac damages

invertebrate habitat and may allow skuas greater access to predate burrowing petrels (McIntosh and Walton, 2000).

Reindeer are very likely to eat cereal-based rat bait, which may result in lethal or sub-lethal primary poisoning (see section 5.5.1). The poisoning of reindeer with brodifacoum would be an inefficient and unnecessarily inhumane way of eradicating these animals. Secondary poisoning of scavenger non-target species would also be likely. In addition, the consumption of bait by reindeer would reduce the availability of the bait to rats, thus risking the success of the rat eradication.

4.5.2 *Marine mammals*

A small number of Weddell seals (*Leptonychotes weddellii*) (<100) breed on beaches in Larsen Harbour, which is rat-free and will therefore be unaffected by eradication operations. Leopard seals (*Hydrurga leptonyx*) visit the island, but mainly during the winter months, so they are also unlikely to be affected by the proposed eradication. Crabeater seals (*Lobodon carcinophagus*) have been observed at South Georgia, but are rare.

4.5.2.1 Southern elephant seals (*Mirounga leonina*)

The population of Southern elephant seals on South Georgia is around 100,000 animals. Breeding is from September to November and they do not feed during this time. Following breeding, they remain on land to moult (January–April) and will be present on many beaches in the operational areas as they are widespread around the coast of South Georgia (see www.sggis.gov.gs). They are very unlikely to consume bait (see sections 5.5.1 and 5.6), but may be disturbed by helicopter overflights and FOB operations (see section 5.12.1).

4.5.2.2 Antarctic fur seals (*Arctocephalus gazella*)

The fur seal population on South Georgia is very large, probably in the low millions (A.R. Martin, pers. comm.). Antarctic fur seal pups are born from late November to early January and are suckled for about 4 months. Highest densities are on the beaches in December, and numbers steadily diminish thereafter. Females are mainly absent outside the breeding season, but some males remain ashore throughout the year. Fur seals feed on krill, fish and occasionally squid and are very unlikely to consume baits or eat bait infected carrion (see section 5.5.1 and 5.6). Some minor disturbance from beach landings and helicopter operations can be expected (see section 5.12.1), but no impact on health or reproduction is anticipated.

4.5.3 *Native birds*

South Georgia is a globally important site for many species of birds with an estimated 65 million nesting birds on the island. There are around 80 different recorded bird species, 31 of which breed on the island (Pasteur and Walton, 2006).

Nine breeding bird species on South Georgia are considered by the World Conservation Union (IUCN, 2009) to be threatened or near-threatened:

- | | |
|------------------|--|
| Endangered: | Black-browed albatross |
| Vulnerable: | Macaroni penguin, Rockhopper penguin, Wandering albatross, Grey-headed albatross, White-chinned petrel |
| Near-threatened: | Gentoo penguin, Light-mantled sooty albatross, South Georgia pipit (endemic) |

Northern and southern giant petrels were recently classed as “near-threatened”, until the second assessment of 2009 when their status was changed to “least concern”.

In addition, seven species are protected under the Agreement for Conservation of Albatrosses and Petrels (ACAP). They are the wandering albatross, black-browed albatross, grey-headed albatross, southern giant petrel, northern giant petrel and white-chinned petrel.

Tables 2–6 below indicate the expected breeding status of bird species on South Georgia during the proposed operational period of mid-February to May and their approximate populations (from Poncet and Crosbie, 2005 unless otherwise stated).

4.5.3.1 Penguins

Four species of penguin regularly breed on South Georgia: king, gentoo, macaroni and chinstrap (see Table 2). Macaroni penguins are the most numerous, but their numbers have declined significantly in recent years (Trathan et al., 1998). Rockhopper (*Eudyptes chrysocome*) and Adélie (*Pygoscelis adeliae*) penguins occasionally breed at South Georgia in very small numbers.

Table 2. Penguin species commonly breeding on South Georgia, their populations and breeding status during the proposed operational period (from Poncet and Crosbie, 2005)

Breeding penguins	Status during mid February - May	Est. population individuals
King penguin <i>Aptenodytes patagonicus</i>	Laying, hatching, brooded chicks	900,000
Gentoo penguin <i>Pygoscelis papua</i>	Fledging / empty colony	210,000
Macaroni penguin <i>Eudyptes chrysolophus</i>	Chicks (not brooded and fledging) / empty colony	2 million
Chinstrap penguin <i>Pygoscelis antarctica</i>	Chicks (not brooded and fledging) / empty colony	12,000

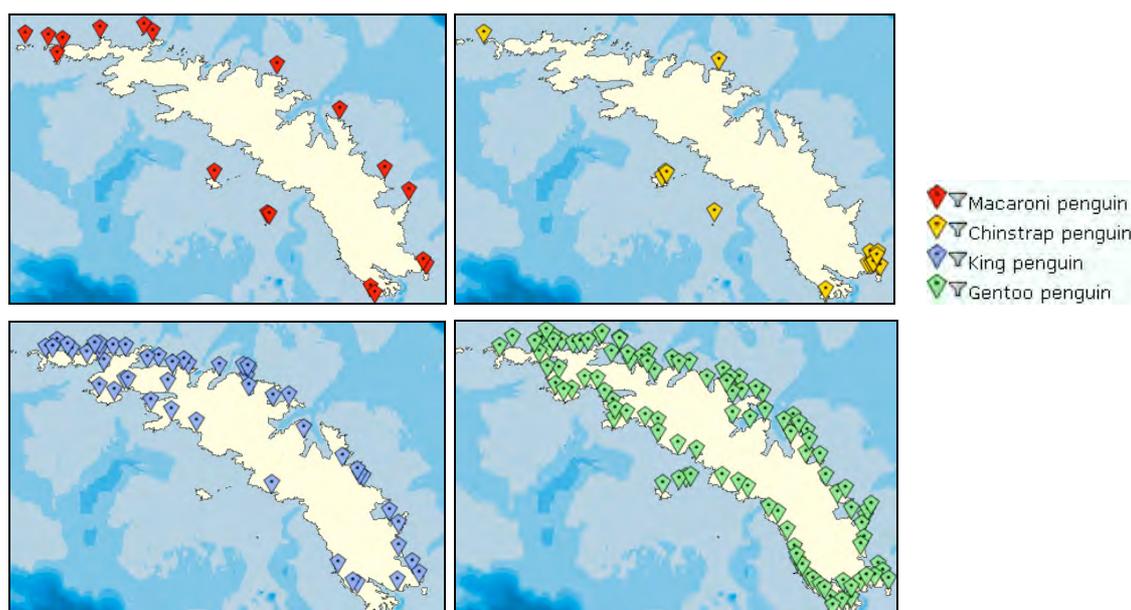


Figure 4. Distribution of macaroni, chinstrap, king and gentoo penguin colonies on South Georgia (from www.sggis.gov.gs British Antarctic Survey; data Poncet, 2007)

All of these penguins breed on land, laying, incubating and hatching eggs in colonies close to the coast. Breeding is complete by mid-February for all species except king penguins. King penguins breed over a two year cycle, and some hatching of eggs will be taking place during the operational period. Particular care is therefore required to avoid significant disturbance of king penguin colonies (see section 5.12.2.1).

Penguins are not expected to consume bait (see section 5.5.2.1) or be affected by secondary poisoning, but are likely to be disturbed by helicopter operations and possibly by falling bait (see sections 5.12.2.1 and 5.12.2.2).

4.5.3.2 Albatrosses

Wandering, grey-headed, black-browed and light-mantled sooty albatrosses all breed on South Georgia. The populations of the first three of these species are declining. Albatrosses feed at sea on squid, fish and krill, taking food from the surface or diving shallowly.

The breeding cycle for wandering albatrosses takes over a year from laying to fledging with a single egg being laid in each breeding attempt. Black-browed, grey-headed and light-mantled sooty albatross lay in October/November and fledged young birds leave the nest in April and May. Albatrosses will therefore be present and potentially impacted by the eradication operation (see sections 5.5.2.1 and 5.12.2.3).

Table 3. Albatross species commonly breeding on South Georgia, their populations and breeding status during the proposed operational period (from Poncet and Crosbie, 2005)

Breeding albatross	Status during mid February - May	Est. population individuals
Wandering albatross <i>Diomedea exulans</i>	Incubating, hatching and chicks present – not brooded	3,106
Black-browed albatross <i>Diomedea melanophris</i>	Chicks (not brooded and fledging)	151,000
Grey-headed albatross <i>Diomedea chrysostoma</i>	Chicks (not brooded and fledging)	96,000
Light-mantled sooty albatross <i>Phoebetria palpebrata</i>	Chicks (not brooded and fledging)	15,000

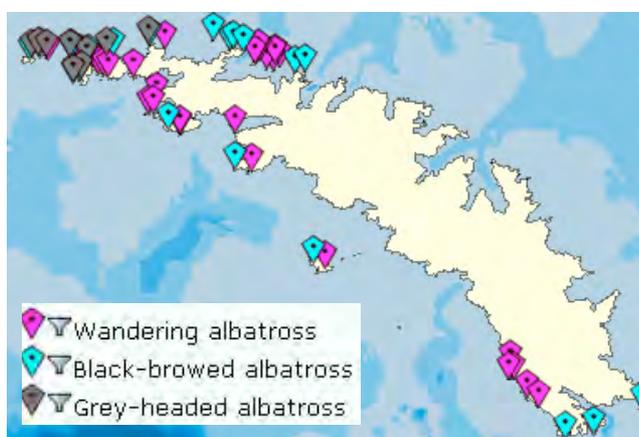


Figure 5. Distribution

of wandering, black-

browed and grey-headed albatross colonies on South Georgia (no data available for light-mantled sooty albatross; from www.sggis.gov.gs)

4.5.3.3 Petrels

Petrels are pelagic seabirds, returning to land only to breed, laying a single egg each breeding season. Petrels breeding on South Georgia include fulmarine petrels, shearwaters, prions, storm petrels and diving petrels.

Giant petrels are the largest petrels and are aggressive predators and scavengers. They feed on krill, squid and fish, offal from fishing vessels at sea, and carrion (mainly of seals and penguins). They may also kill other seabirds (including chicks of other species during the breeding season). They form loose colonies, laying a single egg in a rough nest built up off the ground. They may be susceptible to primary and secondary poisoning by brodifacoum bait (see sections 5.5.2.2 and 5.6.1.1) and are also vulnerable to disturbance (see section 5.12.2.4).

Table 4. Fulmarine petrel species commonly breeding on South Georgia, their populations and breeding status during the proposed operational period (from Poncet and Crosbie, 2005)

Breeding fulmarine petrels	Status during mid February - May	Est. population individuals
Southern Giant petrel <i>Macronectes giganteus</i>	End of chick-rearing; fledging	10,000
Northern giant petrel <i>Macronectes halli</i>	End of chick-rearing; fledging	8,620
Cape petrel <i>Daption capense</i>	End of chick-rearing; fledging	20,000
Snow petrel <i>Pagodroma nivea</i>	Fledging	6,000

Snow petrels nest in cavities and on cliffs. They feed mainly on fish and krill (Ferretti et al., 2001), and are exceedingly unlikely to come into contact with, or consume, toxic bait.

Cape petrels are colonial and nest on rocky cliffs near to the sea. They feed predominantly on marine crustaceans and some fish and squid and are therefore unlikely to be affected by brodifacoum bait poisoning.

Burrowing petrels

Burrowing petrels are very vulnerable to predation by rats (Jones et al., 2008). They spend little or no time above ground during daylight hours and nests are not visible or physically accessible from above ground (Martin et al., 2009).

Prion species include the Antarctic and fairy prion and the blue petrel. Prions nest in cavities under boulders or in burrows. They feed on crustaceans and small cephalopods.

South Georgia is the most important breeding site for white-chinned petrels worldwide (Martin et al., 2009). They dive for prey and forage on the ocean's surface, taking mainly krill and fish.

Storm petrels are pelagic and, like all the burrowing species on SG, come to land only when breeding. They emerge from the nest in rock crevices or small burrows only at night to avoid predation by gulls and skuas. They nest. Storm petrels are particularly vulnerable to predation by rats (De León et al., 2006; Jones et al., 2008).

Common diving petrels and South Georgia diving petrels nest in colonies on islands away from rats. Kelp gulls, skuas and giant petrels take considerable numbers of adults and young each year.

With the exception of the giant petrels, all petrel species described here feed exclusively on a marine diet dominated by fish, squid and crustaceans. They are very unlikely to eat bait or carrion and consequently are at low risk of primary or secondary poisoning from the toxic bait. The operation may result in physical disturbance to some petrels (discussed in section 5.12.2).

Table 5. Burrowing petrel species commonly breeding on South Georgia, their populations and breeding cycle status during the proposed operational period (from Poncet & Crosbie, 2005).

Breeding burrowing petrels	Status during mid February - May	Est. population individuals
Antarctic prion <i>Pachyptila desolata</i>	End of chick-rearing; fledging	44 million
Fairy prion <i>Pachyptila turtur</i>	End of chick-rearing; fledging	2,000
Blue petrel <i>Halobaena caerulea</i>	Breeding cycle complete	140,000
White-chinned petrel <i>Procellaria aequinoctialis</i>	End of chick-rearing; fledging	1.8 million (Martin et al., 2009)
Wilson's storm-petrel <i>Oceanites oceanicus</i>	Hatching and fledging	1.2 million
Black-bellied storm petrel <i>Fregetta tropica</i>	Fledging	20,000
South Georgia diving petrel <i>Pelecanoides georgicus</i> <i>common</i>	End of chick-rearing; fledging	100,000
Common diving petrel <i>Pelecanoides urinatrix</i> <i>exsul</i>	Fledging	7.6 million

4.5.3.4 Other breeding birds

Other breeding birds found on South Georgia are shown in Table 6. The blue-eyed (South Georgia) shag is a cormorant which feeds mainly on fish. Blue-eyed shags lay 2-3 eggs in October, fledging is from January to March and adults leave the colonies in April.

The snowy sheathbill nests in crevices or rocky ledges and is primarily a scavenger that eats eggs, small chicks, carrion, faeces, algae and invertebrates and any fish or krill discarded by other bird species. It is likely therefore to be vulnerable to primary or secondary brodifacoum poisoning (see sections 5.5.2.6 and 5.6.1.4).

Brown skuas scavenge and predate upon other seabirds and their young, eggs, fish, molluscs, crustaceans and rats and are therefore at risk of brodifacoum poisoning (see sections 5.5.2.3 and 5.6.1.2). They typically lay 2 eggs and often nest on elevated grasslands or in sheltered rocky areas next to penguin colonies.

Kelp gulls are mainly coastal gulls, which nesting in shallow depressions on the ground. They are omnivores and are therefore at risk of brodifacoum poisoning (see sections 5.5.2.4 and 5.6.1.3). They will scavenge molluscs, fish, crustaceans and other seabirds as well as seeking suitable small prey.

Antarctic (South Georgia) terns are an endemic sub-species and are numerous on South Georgia. They lay up to 3 eggs in a shallow pebble or shell-lined depression on the

ground within a colony and fledging is complete by the end of January (Poncet and Crosbie, 2005). Antarctic terns consume small fish and crustaceans and are therefore very unlikely to eat bait or poisoned rodents.

The South Georgia pipit is unique in that it is the island's only land-bird, only song-bird and only endemic avian species. This sparrow-sized bird nests mainly on offshore islands and in areas isolated by glaciers where there are no rats, building its nest from dry vegetation. It feeds on insects, spiders and other invertebrates. It is currently listed as NT (Near-threatened) by the IUCN owing to its small population and small range and the risk of introduction of rats to the areas which it inhabits. Following the recent invasion of rats on Saddle Island, it appears that the pipit breeding population on the island has been wiped out (S. Poncet, pers. comm.). Pipits have re-established on Grass Island, following the eradication of rats there in the year 2000 (S. Poncet, 2002). Pipits are unlikely to be exposed to bait or to poisoned invertebrates as they do not normally occur in rat infested areas.

The only other non-marine birds are the South Georgia (SG) pintail and the similar, but smaller, speckled teal. The SG pintail is an endemic subspecies of the yellow-billed (or brown) pintail (*Anas georgica*) and is currently listed as NT (Near-threatened) by the IUCN. The population of this taxon has been estimated at 2,000 birds (Prince and Croxall, 1996), but numbers could be substantially higher (A.R. Martin pers. comm.). The only area to be periodically surveyed is Bird Island, where some 250 birds are usually present during winter. The density of ducks on Bird Island is noticeably higher than in most parts of South Georgia, so this figure cannot be extrapolated to the archipelago as a whole.

SG pintails occur around the entire coastline of South Georgia, in areas with and without rats. The ducks feed on vegetation and sometimes on seal carcasses, making them the only carnivorous ducks. They nest in tussac grass. Eggs are mostly laid December-January. Most chicks fledge by late February, but some may do so as late as April. Primary moult of adult birds occurs from February to mid-April, and during this time the ducks are relatively immobile (A.R. Martin, pers. obs.). South Georgia pintails are at risk of primary and secondary poisoning (see sections 5.5.2.9 and 5.6.1.5).

Table 6. Other bird species commonly breeding on South Georgia, their populations and breeding status during the proposed operational period (from Poncet and Crosbie, 2005)

Other breeding birds	Status during mid February - May	Est. population individuals
Blue-eyed, (imperial, South Georgia) shag/cormorant <i>Phalacrocorax georgianus</i>	Very end of breeding cycle. A few unfledged chicks in Feb.	20,644
South Georgia pintail <i>Anas georgica georgica</i>	Breeding cycle mostly complete. A few unfledged ducklings in Feb.	Min. 2,000
Speckled (yellow-billed) teal <i>Anas flavirostris</i>	Breeding cycle mostly complete. A few unfledged ducklings in Feb.	20-30
Snowy (greater, American) sheathbill <i>Chionis alba</i>	Very end of breeding cycle. A few unfledged chicks in Feb.	4,000
Brown skua <i>Catharacta lönnbergi</i>	Breeding cycle complete	4,000
Kelp gull <i>Larus dominicanus</i>	Breeding cycle complete	4,000
Antarctic (South Georgia) tern	Breeding cycle complete	20,000

<i>Sterna vittata georgiae</i>		
South Georgia pipit <i>Anthus antarcticus</i>	Breeding cycle complete	6,000

The speckled teal is a South American duck which was first noted on South Georgia during the 1970s (Weller and Howard, 1972). It is possible that it had been present on the island for much longer, but was not recognised due to its superficial similarity to the South Georgia pintail. There is no recent evidence of the species breeding on South Georgia, and the population is currently small and thinly distributed, perhaps maintained by new immigrants (A. Martin, pers. comm.). The species feeds on fine vegetable matter, crustaceans, nematodes and arachnids (Weller and Howard, 1972).

The breeding cycles of the birds in Table 6 will be largely complete by the time the baiting operations commence. The disturbance of these species by helicopter overflights will therefore be less significant.

A range of other birds visit South Georgia, but do not breed on the island. Regular visitors include the Antarctic fulmar (*Fulmarus glacialisoides*), Antarctic petrel (*Thalassoica Antarctica*), Atlantic petrel (*Pterodroma incerta*), broad-billed prion (*Pachyptila vittata*), Grey petrel (*Procellaria cinerea*) and sooty shearwater (*Puffinus griseus*). Occasional visitors include the great shearwater (*Puffinus gravis*) and little shearwater (*Puffinus assimilis*). None of the above birds would be likely to land on the island, so they would be unaffected by baiting operations. Vagrant land birds also occur, but their numbers are very small (see Poncet and Crosbie, 2005).

4.5.4 Invertebrates

Invertebrates are the most abundant terrestrial fauna on South Georgia and include beetles, flies, spiders, earthworms, mites and springtails and many are at risk of predation by rats. About one third of the 230 species of arthropod fauna are endemic.

There are 70 species of freshwater invertebrate including cladocera, copepods, rotifers, annelids and nematodes (McIntosh and Walton, 2000).

The foreshores of South Georgia have limited invertebrate communities including bivalves, gastropods, annelid worms and prostigmatid mites. Species diversity is low due to the low temperatures and ice abrasion in winter and is generally typical of Scotia Arc and Antarctic Peninsula regions. Studies in the fjords and bays of South Georgia found that certain flatworms, nemertean, bivalve and gastropod molluscs, amphipod and isopod crustaceans, asteroid echinoderms and stalked ascidians were very abundant, but some normally common Antarctic higher taxa and species were notably absent or rare (Barnes et al., 2006).

The risk of primary poisoning of invertebrates is discussed in section 5.5.3.

4.6 Alien species and diseases

A wide range of alien species, including microbes, algae, fungi, mosses, lichens, vascular plants, invertebrates, fish, birds and mammals, have been brought to South Georgia by visitors. New taxa can also reach the island by natural means, carried on birds or attached to marine debris. Many of the species introduced to South Georgia have not survived, but some of those which have, such as reindeer, Norway rats and the grass *Poa annua* have altered natural ecosystems significantly.

The introduction and transfer of non-native flora and fauna to South Georgia is of great concern. The policy of the GSGSSI is to remove all non-native species where possible, and prevent further introductions or transfers from one part of the island to another.

4.7 Current usage

The main activities on South Georgia are tourism, fisheries and research. There are two centres of population: King Edward Point/Grytviken in Cumberland Bay and Bird Island in the north west of the archipelago.

4.7.1 Government administration

King Edward Point (KEP) is the main settlement on South Georgia. Government administrative activities are located at Carse House, with two Government Officers and a Deputy Postmaster who represent the GSGSSI on South Georgia.

The seas around South Georgia are one of the most important commercial fishing areas in the Southern Ocean. Each year, the GSGSSI issues licences to vessels to fish within the 200 nautical mile Maritime Zone. Fishery Patrol Vessels, chartered by the GSGSSI, patrol this area.

4.7.2 Research

The BAS operates research stations at KEP and Bird Island, both of which are occupied year round. BAS research vessels visit the islands around four times during the summer months. Visits are primarily for delivery of stores, collection of waste and transfer of personnel.

4.7.3 Tourism

Cruise ship tourism currently accounts for some 70 cruise ship visits per year (7,800 paying passengers in 2008/09 season). The size of cruise ship varies, but ships with more than 500 passengers are no longer permitted to visit South Georgia, which may lead to a reduction in the overall number of visitors in coming seasons. Shore landings usually last for 2–3 hours and tourists are supervised by guides. Most tourist visits occur during the summer months between November and March.

There are usually 20–25 yacht-based visits per season (25 in 08/09 season). This includes smaller, private vessels and larger commercial, chartering vessels. Yacht and expedition visitors are more likely to stay for longer and go for walks to the local peaks and bays, as well as undertaking research, camping, mountaineering and kayaking.

All of these vessels visit KEP, usually at the beginning of their visit, for customs clearance and briefing. The only land-based tourism facility on the island is the South Georgia Museum at Grytviken. There are no accommodation facilities for tourists on the island, although climbing and scientific expeditions are permitted to camp.

Visitor management plans have been prepared for the most visited sites on South Georgia (see section 4.8.2).

Tourist and expedition visits will be carefully managed during any baiting operations (see section 5.4).

4.7.4 Military

Royal Navy ships visit South Georgia regularly to undertake patrols and hydrographic survey work. The Royal Air Force undertakes aerial surveillance for illegal fishing, and local flying by helicopter is undertaken from navy vessels. Other military activities include foot patrols, search and rescue exercises and scientific and conservation support. The

Government Officer liaises with military vessels at South Georgia. Military authorities will be notified of the rat eradication plans well in advance of baiting operations.

4.8 Environmental Management

Environmental policies and procedures are set out in *South Georgia: Plan for Progress* (Pasteur and Walton, 2006), which is available in printed form and on the South Georgia website (www.sgisland.gs). This includes policies on conservation of flora and fauna, visitor and fisheries management and scientific research.

4.8.1 Specially Protected Areas

Specially Protected Areas (SPA) have been designated on South Georgia to limit access to places that are environmentally sensitive or of heritage value. Permits are required from GSGSSI to enter these areas. Permits will be needed by Project staff for access to Paryadin Peninsula and the coastline around Cape Rosa and Nunez Peninsula in support of mouse eradication.

4.8.2 Visitor Management Plans

Visitor Management Plans have been prepared for St Andrews Bay, Cooper Bay, Gold Harbour, Salisbury Plain, Cape Rosa, Godthul, Shackleton Walk and Fortuna Bay. They give site specific information about sensitive wildlife and precautions which should be taken to minimise impacts in these areas. The plans are available on the South Georgia website (www.sgisland.gs).

4.9 Heritage sites

The whaling stations at Grytviken, Ocean Harbour, Leith, Husvik, Stromness, Prince Olaf Harbour and the whaling storage depot at Godthul are visible reminders of the whaling years (1904–65). Ruined whaling and postal huts also remain on South Georgia. A large number of other heritage sites have been identified including whaling and sealing remains, shipwrecks, early research sites and military remains (Pasteur and Walton, 2006).

The *Prohibited Areas Ordinance, 2010* and *Prohibited Areas Order, 2010* have recently been published in the *GSGSSI Gazette*. The *Order* prohibits access to Husvik, Leith, Stromness and Prince Olaf whaling stations without prior permission from the Commissioner. This is due to health and safety concerns and also to protect the heritage of the whaling stations. During the rodent eradication project all of the whaling station buildings, which are a haven for rats, will need to be baited. Appropriate permits will be required. The whaling stations contain asbestos and some of the buildings are insecure (see section 5.4.3).

4.10 Baseline monitoring information and ongoing research

Meteorological measurements are made at KEP every 6 hours at the Automatic Weather Station and monitoring of the marine environment in King Edward Cove is undertaken by BAS researchers.

Information on flora and fauna was collected as part of the South Georgia Environmental Mapping Report (Scott and Poncet, 2003). This provides a baseline with which future changes can be compared. Additional information is being collected for ACAP surveys and for the South Georgia Global Information System (GIS; see www.sggis.gov.gs), including recent surveys of introduced plant and invertebrates (Osborne et al., 2009).

4.11 Future environmental reference state in the absence of the proposed activity

In the absence of the proposed activity, likely changes to the environmental reference state of South Georgia include:

- Spread of rats to new areas due to recession of glaciers and subsequent reduction in bird populations and damage to native flora
- Continued degradation of South Georgia plants due to rat presence
- Spread of mice to new areas
- Increases in rodent populations due to more benign temperatures resulting from climate warming

5 ASSESSMENT, MINIMISATION AND MITIGATION OF LIKELY EFFECTS ON THE ENVIRONMENT

5.1 Introduction

The following section identifies the likely impacts on the environment of the proposed rodent eradication as described in section 2. The potential effects on the environment, and minimisation and mitigation of these effects during the proposed operation, are as follows:

- Positive effects on human health, vegetation and native wildlife populations
- Ethical considerations
- Potential effects of operation on human health
- Potential for primary poisoning of non-target species
- Potential for secondary poisoning of non-target species
- Potential effects of bait on soil, water, marine environment and vegetation
- Potential effect on mouse population
- Physical disturbance and noise
- Atmospheric emissions
- Fuel and oil spills
- Waste

Measures to reduce negative effects are outlined in boxes below each section where applicable. These measures will be applied through the OP and related procedures (see section 8).

5.2 Potential positive effects of the proposed operation

The primary outcome of the proposed operation will be a reversal of the detrimental impacts on the ecosystem brought about by the introduction of exotic rodents to South Georgia. This will include an increase in the breeding range and population size of many seabirds, and a restoration of the ecosystem processes that are driven by large seabird colonies. The population of the endemic South Georgia pipit is likely to increase to many times its current level as more habitat becomes rat free. Substantial positive impacts on invertebrate and plant communities are also expected, as for other similar eradication operations (i.e. Towns et al., 2006). The operation will begin the process of reversing two centuries of damage to native fauna and flora, and should result in a substantial increase in the number of seabirds breeding on South Georgia.

Once rats have been removed, many previously rat-infested areas are almost certain to be recolonised by prions, diving petrels, storm petrels, blue petrels and pipits which currently persist on the satellite islands and the areas of the mainland remaining free of rats. Pipits quickly recolonised Grass Island following the eradication in 2000 (S. Poncet, pers. comm.). Other bird species such as white-chinned petrel, South Georgia pintail and speckled teal populations are also likely to increase.

Island ecosystems elsewhere have responded quickly following previous rat eradications. Almost immediately after rats were eradicated on Campbell Island, the Campbell Island snipe began successfully recolonising the island from an offshore islet (Miskelly and Fraser 2006). The removal of introduced foxes in the Aleutians led to major recovery in island bird populations (Ebbert and Byrd, 2002).

Invertebrates are an important part of the diet of Norway rats, and their populations are expected to recover significantly following the eradication operation (Pye and Bonner, 1980). Previous studies have indicated that particularly the larger bodied, flightless invertebrate populations benefit from the removal of rats (Brown et al., 2006).

The removal of rats is expected to result in a stabilisation of vegetation communities and an increase in plant diversity, as demonstrated by a number of other eradication programmes (Brown et al., 2006; Towns et al., 2006). Tussac should benefit from better general health and seed survival and other species with edible seeds or berries are also likely to benefit.

Rats are a known pest and cause damage to property, food and water supplies and may carry and transmit diseases harmful to humans. Viral and bacterial diseases may be transmitted to humans via rats from birds and seals (Kerry et al., 2007) or from contact with human waste or faeces. Rats may also transmit disease to South Georgia wildlife. The removal of rodents will therefore benefit the people living and working on South Georgia as well as the wildlife.

5.3 Ethical considerations of poisoning

Poisoning rats using the anticoagulant brodifacoum leads to death by haemorrhaging, the average time between exposure and death of Norway rats being 7.2 days (Mason and Littin, 2003). Symptoms include lethargy, weight loss, laboured breathing and haemorrhaging from numerous sites both internally and externally (Littin et al., 2000).

Brodifacoum poison can cause discomfort and pain which lasts several days. It also interferes with abilities to forage, resulting in weight loss and dehydration (Mason and Littin, 2003). Data from human cases provide further evidence that anticoagulants can cause pain and distress (see section 5.4). Brodifacoum also poses a risk of primary and secondary poisoning to non-target animals (see sections 5.5 and 5.6).

Animal welfare concerns the minimisation of pain, suffering and distress to animals. Killing for conservation reasons should be justifiable and as humane as possible. Mellor and Littin (2003) suggest six major principles to guide the design and execution of ethically sound vertebrate pest control:

1. The anticipated benefits and harms of any pest control programme must be clear.
2. Control must only be undertaken if the benefits are realistically achievable.
3. Methods that most effectively achieve the benefits must be used.
4. Methods must be used in the most effective way.
5. Whether or not the benefits were achieved must be evaluated at the end of any programme.

6. Follow-up steps must be taken to ensure that the benefits are maintained once initial control has ceased.

Alternative methods for killing rats were considered in section 3.5. Some of these are considered more humane than brodifacoum poisoning, but none are suitable for an eradication of this scale, and they could only be considered for partial control or eradication of small areas. In the longer term this may result in causing more suffering to rats, as many more may be killed over a longer period of time.

The aim of the proposed eradication is an island-wide clearance of all rats, which will mean that no poisoning will be necessary in the future and also that rats will no longer be able to take eggs and vulnerable chicks of ground-nesting birds.

The poisoning will cause pain and suffering to the existing population of rats and probably to a number of individuals of some non-target species for the duration of the baiting operation. However, the eradication of rats from South Georgia will stop the ongoing pain and suffering which the rats cause to the wildlife they predate. The outcome of a well-planned and executed rodent eradication with effective ongoing biosecurity on South Georgia would therefore justify the means.

5.4 Potential effects of operation on human health

5.4.1 Poisoning due to exposure to brodifacoum

The risk to human health is very low in a well-planned and controlled baiting operation (DOC, 2007). Due to the low concentration of toxin in the bait and its delayed effect, brodifacoum is considered to be only of low acute toxicity and only a slight hazard to humans (WHO, 2009). Large numbers of pellets would have to be consumed to produce harmful effects.

There is no clearly defined LD₅₀ dose for humans. As little as 1–2mg of brodifacoum can reduce blood clotting in humans, but a more average LD₅₀ dose would likely be around 15mg (Fisher and Fairweather, 2005, Brown et al., 2006). However, there is wide variation in susceptibility, and people suffering from anaemia or liver disease, or who are taking prescription anticoagulants are more susceptible to brodifacoum poisoning. Brodifacoum is toxic by ingestion and by inhalation of dust. Absorption through the skin is also possible, but at very low levels (less than 0.5%) compared to oral doses (DOC, 1997).

The onset of toxicity takes days in acute cases. In minor poisoning cases there may be no obvious signs of poisoning. In moderate cases symptoms include increased bruising rates and excessive bleeding from cuts, occasional nose and gum bleeds, blood in faeces or urine, a pale mouth and cold gums, and general weakness. Signs of acute poisoning are severe gastrointestinal bleeding and massive haemorrhage (usually internal) resulting in shock. Brodifacoum is a slight skin irritant and a mild eye irritant. It is classified as non-mutagenic and unlikely to be carcinogenic (Fisher and Fairweather, 2005).

Vitamin K1 is recognised as an effective treatment, but it has to be maintained for a relatively long treatment period. The manufacturer's information for the brodifacoum bait to be used on South Georgia is given as Appendix 2.

At Grytviken, bait will be loaded into the spreaders using a tele-handler, but 2-3 operators will be working in the area to operate the tele-handler, guide the spreaders onto the platform and open the bait containers. Bait loading procedures are described in the OP.

Protective overalls and gloves should be worn when handling pellets and when operating around aircraft and appropriate dust masks will be worn to avoid inhalation of bait dust. Contact with skin should be avoided and hands should be washed before eating food.

A lifting device may also be used at FOBs if a suitable loader can be sourced, but if not bait would be loaded into the spreaders from paper sacks by hand. Manual handling of bait would require particular care, to avoid injury to personnel.

The effects of brodifacoum on soil and water quality are discussed in section 5.8.

5.4.2 Risks associated with working in and around helicopters, working in remote environment and at FOBs

Personnel working on the project will be working in harsh weather conditions, in remote places and in and around dangerous machinery.

5.4.3 Risks associated with entering former whaling stations

In addition to health risks from the poison brodifacoum, hand spreading of bait in whaling stations may result in putting the health and safety of personnel at risk due to the presence of asbestos and wind-blown debris. Also, some of the buildings in the whaling stations may be unstable.

Minimisation and mitigation – effects on human health

- All personnel on South Georgia to be informed about eradication project and health implications
- No tourist visits permitted during the bait application process to areas where bait is being spread
- The Medical Officer at King Edward Point to be provided with details of the proposed operation and supplied with Vitamin K1
- Measures to be taken to ensure that toxin does not enter domestic water supplies (see section 5.8)
- Project personnel briefed on safe bait handling procedures, working around helicopters, field safety and emergency procedures
- Appropriate protection provided for all personnel handling bait including overalls, rubber or PVC gloves and appropriate dust mask.
- Care should be taken to avoid spillage of bait or damage to bait containers
- Personnel entering whaling stations required to wear appropriate safety equipment (see OP and Health and Safety Plan)
- Used bait containers should be reused or disposed of carefully (see Appendix 3)

5.5 Potential for primary poisoning of non-target species

Primary poisoning may be caused by the direct ingestion of brodifacoum baits by non-target species leading to either sub-lethal exposure or death. Native non-target deaths, and residues, have been reported in a wide range of species after the use of brodifacoum in other areas (e.g. Eason and Spurr, 1995).

On South Georgia, the vast majority of native wildlife takes its food from the ocean and is therefore unlikely to be attracted to the cereal bait.

The Grass Island eradication operation identified the following species on South Georgia to be potentially at risk of poisoning during a rat eradication attempt (Poncet et al., 2002): brown skua, South Georgia pipit, snowy sheathbill, kelp gull, South Georgia pintail and speckled teal. All of these birds, apart from the pipit and speckled teal, were resident on Grass Island during the trial eradication. A census was taken before and after the poison application and no loss of birds was recorded (Poncet et al., 2002). However, the chances of finding poisoned carcasses in the dense tussac, assuming that they had not been taken by scavenging birds, are extremely low.

Monitoring of non-target species in the Falkland Islands following a rat eradication programme in 2001 found no dead birds on Top, Bottom and Outer Islands. However, there was evidence of one scavenged rat, with a quantity of plucked rat fur found amongst the tussac. This indicated that at least one rat was probably taken by a predatory or carrion-feeding bird (Brown et al., 2001).

The species most at risk from feeding directly on cereal-based baits containing brodifacoum are those that are naturally inquisitive and have an omnivorous diet: giant petrels, snowy sheathbills and kelp gulls. Background information on South Georgia fauna is given in section 4.5.

On South Georgia bait will be spread at much lower rates over most of the treated area than has been undertaken in other similar projects (see section 2.5.2). Consequently there will be lower densities of bait accessible to non-target species, thus reducing the probability of primary and secondary poisoning.

The methodology of the rat eradication on South Georgia involving the sequential baiting of different areas over a number of years will greatly reduce the chance of significantly damaging populations of non-target animals on South Georgia overall. Even if some are killed in the baited areas in one season, those in the unbaited areas will in general be unaffected. Reductions in wildlife populations due to the baiting will be made up over time by immigration from non-baited areas.

5.5.1 Potential for primary poisoning of non-target mammals

Brodifacoum is a broad-spectrum toxin and is toxic to most terrestrial vertebrates (Fisher and Fairweather, 2005).

If reindeer were to be present in baited areas, they would be likely to consume cereal bait and become ill or die. Fatal primary poisoning of reindeer may lead to secondary poisoning of carrion feeders. The consumption of bait by reindeer would also reduce the amount of bait available for rats and creates an increased risk of failure of the eradication. Eradication of the non-indigenous reindeer prior to baiting the two areas where reindeer herds exist is being considered by GSGSSI (D. Christie, pers. comm.; Christie and Brown, 2007).

Antarctic fur seals and southern elephant seals showed no interest in consuming cereal-based baits during aerial bait trials on Macquarie Island and are therefore not considered to be at risk from primary poisoning (DPIPWE, 2009).

5.5.2 Potential for primary poisoning of birds

Direct poisoning of birds through ingesting brodifacoum baits has been recorded for a number of species during eradication projects. Populations of four indigenous birds (fernbirds, pukeko, Stewart Island weka, and western weka) were severely reduced at some sites where brodifacoum baits were broadcast on New Zealand islands (DOC, 2007). On Kapatī Island during an eradication using brodifacoum, non-target bird deaths

were recorded, but post-eradication monitoring indicated that the toxin had no adverse effect on breeding in the survivors (Empson and Miskelly, 1999). On South Georgia, and in the Falkland Islands, kelp gulls were observed eating and then actively seeking bait (D. Christie, pers. comm.).

During the baiting of Macquarie Island to remove rabbits and rodents in June 2010 a substantial number of kelp gulls may have succumbed to primary brodifacoum poisoning (DPIPWE, 2010). The number found dead plausibly represented one bird for each nesting pair on the island, though the size of the breeding population is poorly known (DPIPWE, 2010). Only a small proportion of the island was baited, and it is probable that more gulls would have been killed if the operation had been completed.

Table 7 (section 5.7) shows an assessment of the risk to bird populations of significant primary poisoning, defined as causing the death of >20% of all individuals in a baiting zone. The basis for those assessments is as follows:

5.5.2.1 Penguins, albatross and petrels

With the exception of king penguin, wandering albatross and Wilson's storm petrel, the main breeding season for these birds will be complete by the time operations commence. However, there will still be some chicks (not brooded) and fledging birds present on the island. All of these birds have a marine diet and are therefore unlikely to ingest bait.

Baits from an aerial eradication may fall on or near to wandering albatross nests and inquisitive chicks may show an interest in the baits. However, as chicks are confined to the nests, they unlikely to be able to access sufficient bait to cause poisoning.

Tests carried out on Macquarie Island with non-poisonous pellets found that penguins, petrels and albatrosses showed no interest in the baits as a food source (Ormonde, 2007; DPIPWE, 2009) and the risk of significant primary poisoning of these species is assessed as negligible.

5.5.2.2 Giant petrels

Some giant petrels will be at their nest sites during the baiting period as it coincides with the end of chick rearing. Bait trials were undertaken in 2007 on Macquarie Island to assess the probability of primary poisoning of both Northern and Southern giant petrels. The birds scattered during bait spreading, but settled within the bait area afterwards and showed no interest in the bait (DPIPWE, 2009). As giant petrels feed mainly on carrion, significant primary poisoning is considered to be a low risk.

5.5.2.3 Brown skua

By the time the baiting operation starts in mid-February, skua chicks will be fledging. During bait trials on Macquarie Island in 2005, skuas showed no interest in bait (DPIPWE, 2009). However, around two thirds of the skua population on Enderby Island consumed bait and died when two aerial applications of brodifacoum bait were spread on the island (Torr, 2002). It is thought that their interest may have increased due to the multiple application of bait. The population was assessed to have recovered to pre-baiting levels after around 8 years. No significant effects on skua populations were recorded following brodifacoum poisoning operations on Hawea Island (Eason and Spurr 1995).

The risk of significant primary poisoning of the brown skua population on South Georgia is assessed as low-medium.

5.5.2.4 Kelp gulls

During bait trials on Macquarie Island in 2005 (DPIPWE, 2009), kelp gulls ate a small amount of non-toxic bait (0-16 out of 100 baits were consumed in total in an area with densely laid out baits). During a trial on South Georgia in 2007, kelp gulls were seen to consume non-toxic bait (Christie and Brown, 2007). The LD₅₀ of New Zealand kelp gulls has been recorded at 0.75mg/kg (Eason and Spurr, 1995), so for a large kelp gull weighing 1kg, around 10 pellets would need to be consumed to have a lethal effect on 50% of birds. Kelp gulls consume large amounts of food, are attracted to cereal and could easily eat whole baits, so fatalities due to primary poisoning should be expected. Following the aerial application of brodifacoum on Rat Island, Alaska, over 200 glaucous-winged gulls were found dead and preliminary research indicates that they may have consumed baits (Woods et al., 2009). Kelp gull mortalities have also been reported for other island eradication operations involving aerial spreading of brodifacoum including that on Campbell Island (McClelland, 2001) and Macquarie Island (DPIPWE, 2010). These mortalities may have been caused by a combination of primary and secondary poisoning (see section 5.6.1.3). Significant primary poisoning of kelp gulls is therefore assessed as high risk. The availability of gull carcasses to other non-target scavengers may result in secondary poisoning (see section 5.6).

Kelp gulls are common and geographically widespread. Losses of even most of the population would almost certainly be recovered through intrinsic population growth and/or immigration on a scale of years.

5.5.2.5 Blue-eyed (South Georgia, imperial) shag

The blue-eyed shag has a marine diet and is unlikely to consume cereal baits. Testing of Macquarie Island shags in 2006 by the Tasmanian Parks and Wildlife Service resulted in no bait pellets being consumed (DPIPWE, 2009). The risk of significant fatal primary poisoning to South Georgia shags is assessed as negligible.

5.5.2.6 The snowy (greater, American) sheathbill

Sheathbills are scavengers and eat a wide variety of food, the vast bulk of it of animal origin (Burger, 1981). There is little information about their possible susceptibility to primary brodifacoum poisoning. They are inquisitive birds and would be expected to show an interest in bait, but would probably find it easier to consume when partially disintegrated. Uptake of poison is therefore likely to be fairly low, but some birds could be susceptible. There will still be ample natural food available during the baiting period such as fur seal pup carcasses and faeces, which would reduce the likelihood of poison uptake. The risk of fatal primary poisoning of a significant number of birds is therefore assessed to be low.

The snowy sheathbill is geographically widespread and any losses are likely to be swiftly replaced though immigration or natural population growth.

5.5.2.7 Antarctic (South Georgia) terns

Antarctic terns feed exclusively at sea and are therefore not considered to be at risk from primary poisoning. This is supported by the aerial bait trails on Macquarie Island in 2007, where Antarctic terns showed no interest in cereal baits (DPIPWE, 2009). The risk of primary poisoning of Antarctic terns is therefore assessed as negligible.

5.5.2.8 The South Georgia pipit

The endemic South Georgia pipit breeds in rat-free parts of the mainland and off-shore islands, but routinely occurs at low density in areas with rats. Some birds may therefore

come into contact with bait. New Zealand pipits have been observed to take bait from bait stations (Eason and Spurr, 1995). However, pipits are insectivores and are therefore unlikely to eat the bait material. They would not be able to consume whole bait pellets because of their size. The risk of significant primary poisoning of South Georgia pipits is therefore assessed as low.

5.5.2.9 South Georgia pintail

This duck is endemic to South Georgia, and therefore of particular concern. A substantial proportion of the population breeds in rat-free areas, which will not be treated with bait. However, all birds are likely to be within 10 km (less than 15 mins flying time) of a baited area at some stage during the campaign.

Some other island eradication campaigns have resulted in waterfowl casualties. A 60% (31/52) mortality of the endemic New Zealand paradise shelduck (*Tadorna variegata*) was reported on Motuihe Island after 0.02g/kg brodifacoum bait was aerially distributed followed 10 days later by a second aerial baiting at application rates of 8kg/ha and 3.5kg/ha respectively (Dowding et al., 1999). The second baiting may have significantly increased the probability of mortality, due to the sustained exposure to bait over a period of time. The amount of bait spread on Motuihe Island is substantially higher than that planned for South Georgia.

The LD₅₀ for mallard ducks is 4.6mg/kg, which means that 203g (68 three gramme pellets) of 0.025g/kg bait would need to be consumed by a duck of average weight to have a 50% probability of death (Fisher and Fairweather, 2005).

Trials undertaken on Macquarie Island to assess whether black ducks would consume bait pellets indicated no evidence of direct bait consumption. The likelihood may increase if the pellets had disintegrated, but the ducks would need to consume large amounts of matter to ingest a lethal concentration of brodifacoum (DPIPWE, 2009). During and after the first (truncated) phase of toxic baiting 19 black ducks and a mallard were found dead on Macquarie Island, very probably as a result of primary poisoning (DPIPWE 2010), so at least some of the population did indeed eat large numbers of pellets.

There is no information specifically on the susceptibility of South Georgia pintail ducks to poisoning by brodifacoum bait. However, as information from previous operations suggests that there is a risk of poisoning to other duck species, South Georgia pintails may be susceptible to primary poisoning from cerealised brodifacoum. If baiting is conducted during their period of primary moult (February to early April), when the ducks are at maximum physiological stress, cannot fly and do not feed in the open during the day, it would seem likely that cereal baits may be more attractive to them. Mobility of ducks is greatest from April onwards and during this period birds could access recently baited areas, regardless of where they bred or moulted.

Even if a substantial proportion, say half, of all pintails on SG were to be killed, it is likely that the population as a whole would survive. The pintail was clearly able to withstand losses due to hunting during much of the 20th century, though hunting pressure was localised and mostly limited to discrete areas along the north coast. Nevertheless, because dabbling ducks find cereal attractive to eat, are mobile and can consume large quantities of food quickly (storing it in their crop) the spreading of toxic cereal over areas of South Georgia could plausibly wipe out the entire taxon (Martin, 2008).

Fears that baiting on South Georgia poses a high risk to the taxon were somewhat allayed when trials on a captive flock of this species (Appendix 4) showed that the ducks were not attracted to green cylindrical bait pellets, either in their intact form or after

weathering had turned them to pulp. Although captive birds may not behave exactly in the same way as their wild counterparts, this trial indicates that pellets very similar to those to be used in Phase 1 of the SG project are unlikely to be very attractive to SG pintails, and that baiting the relatively small Greene, Thatcher and Mercer zones is unlikely to cause mass mortality. Consequently, careful monitoring of the first season's work should be a sufficient safeguard and will inform subsequent phases of the operation (see Appendix 4). A subsequent trial in 2010 with cylindrical pellets died blue produced a different result (A.R.Martin pers. comm.), with the pintails learning to eat the mush after the pellets had lost their physical integrity with weathering. Consequently, green pellets will be used on South Georgia.

The possibility of taking some wild birds into captive care to protect the species during the second phase of the eradication has been considered (Martin, 2008), is plausible, and remains an option if the mortality of SG pintail from the first phase of the eradication is greater than expected.

5.5.2.10 Speckled teal

It is likely that speckled teal will react in a similar way towards cereal baits as other ducks, though as a smaller bird than the South Georgia pintail it is even less likely to consume whole bait pellets. This teal is a recent immigrant to South Georgia, being first recorded in 1971, and the population today may well be maintained through constant immigration. The species is widespread in Patagonia and also present on the Falkland Islands (Weller and Howard, 1972). The speckled teal on South Georgia has not evolved into a different taxon from the parent stock. Whilst the population of these birds on the island is small and therefore vulnerable, in the worst case scenario of all birds being killed, the population could be naturally re-established with immigrants from the Falkland Islands or South America (Martin, 2008). Monitoring during the first phase of the eradication will assess the likely risk to speckled teal.

5.5.3 *Potential for primary poisoning of invertebrates*

Brodifacoum is reported to have very low risk to invertebrates at the concentrations which will be used on South Georgia (Fisher and Fairweather, 2005). No traces of brodifacoum were found in invertebrates following baiting operations on Red Mercury Island (Morgan and Wright 1996). However, during bait testing on Macquarie Island, invertebrates started to consume baits after the onset of spring (DPIPWE, 2009). Although residues do not appear to persist in arthropods beyond a few days, during this time there may be an additional risk of secondary poisoning to birds who may consume them (Hoare and Hare, 2006). The potential secondary poisoning of birds due to consumption of poisoned invertebrates is discussed in section 5.6.2.

Minimisation and Mitigation – primary poisoning of non-target species

- Design bait pellets to be as unattractive and unpalatable as possible to likely avian consumers
- Monitoring of South Georgia pintail ducks during first field season, including ringing and radio tracking a number of ducks to inform future phases of operation
- Depending on outcome of monitoring during first phase of eradication, consider captive maintenance of South Georgia pintails and speckled teal until risk of poisoning has receded

- Eradication of reindeer prior to bait spreading, to reduce risk of operational failure through loss of bait and remove the risk of secondary poisoning due to scavengers feeding on poisoned reindeer carcasses
- Monitoring during first phase of eradication to gain more information on potential of primary poisoning on non-target species other than pintail
- To the extent possible, time bait application for when wildlife has departed from breeding colonies

5.6 Potential for secondary poisoning of non-target species

Secondary poisoning of non-target species may occur due to scavenging of carcasses of poisoned animals. Brodifacoum is not readily metabolised and is stored in the liver of sub-lethally exposed animals, where it can remain for many months. Dead or dying rodents found outside the nest are therefore dangerous for a relatively long period, although due to the slow-acting nature of the poison, poisoned rats are likely to retire to their nests and not remain exposed (Mason and Littin, 2003). The majority (88%) of rat carcasses recovered after brodifacoum application on islets in the Bay of Islands off Adak (Alaska) were found underground (U.S. Fish and Wildlife Service, 2007). A similar result was found after a recent rat eradication in the Aleutian Islands in October 2008 (S. Buckelew in DPIPWE, 2009). This will reduce the chance of secondary poisoning from consumption of rats as the majority of carcasses will not be accessible.

Most of the birds on South Georgia, including penguins, albatrosses, petrels (except giant petrels) and terns have a marine diet and are likely to show no interest in scavenging poisoned carcasses. The species most vulnerable to secondary poisoning on South Georgia are brown skuas, kelp gulls, northern and southern giant petrels and snowy sheathbills as these birds will likely scavenge accessible dead or dying rodents and birds. Pipits, pintails and teal may be at risk from feeding on poisoned invertebrates.

Scavengers generally have to eat several poisoned rodents before experiencing ill effects, and secondary poisoning is therefore considered unlikely in most cases (Mason and Littin, 2003). Fatal secondary anticoagulant poisoning has been implicated in the deaths of owls, buzzards, kites, corvids and many others (Mason and Littin, 2003).

Carcasses of poisoned birds may be available to carrion feeders, thereby perpetuating the cycle. Following aerial brodifacoum baiting on Rat Island, Alaska, 43 bald eagle carcasses were recovered (Woods et al., 2009). These were probably killed by feeding on poisoned rat or glaucous-winged gull carcasses.

During the baiting of Macquarie Island to remove rabbits and rodents in June 2010 a substantial number of giant petrels (285 birds discovered), and sub-Antarctic skuas (78 discovered) were thought to have succumbed to secondary brodifacoum poisoning. The number found dead represented one bird for every 7 nesting pairs on the island for Northern giant petrels, one bird for every 253 nesting pairs for Southern giant petrels and a bird for every 13 pairs of nesting skuas (DPIPWE, 2010), though it is very likely that others died and were not found. Only a small proportion of the island was baited, and it is probable that more petrels and skuas would have been killed if the operation had been completed.

Table 7 (section 5.7) shows an assessment of the risk to bird populations of significant secondary poisoning, defined as causing the death of >20% of all individuals in a given baiting area. Even this level of mortality is likely to be easily recoverable because no

more than 10% of the island's area will be baited in any season. The basis for those assessments is as follows:

5.6.1.1 Giant petrels

Giant petrels feed in coastal areas on dead seal and penguin carcasses and injured penguins; there should be an adequate supply of this food during the operational period. However, there is a risk that they may also feed on poisoned carcasses of rats or birds and become fatally poisoned. The results from Macquarie Island in 2010 indicate that secondary poisoning of giant petrels on South Georgia should be expected, although it is likely that a smaller proportion will be affected than on Macquarie, for two reasons. Firstly, the biomass of contaminated carcasses on South Georgia will be far smaller due to the lack of rabbits. Secondly, the density of brodifacoum dropped on South Georgia will be much lower than on Macquarie Island. The secondary poisoning of Northern and Southern giant petrels will be monitored during the initial phase of the South Georgia operation.

5.6.1.2 Brown skua

As skuas consume carrion, it is likely that there will be mortality due to the consumption of poisoned rats and/or birds on South Georgia. Skua chicks fledge during February and early March, and following this many skuas will be absent from the island. The timing of the baiting will therefore likely affect the number of skuas lost.

5.6.1.3 Kelp gulls

Kelp gulls are omnivores and there is a risk that they may scavenge poisoned carcasses resulting in mortality due to secondary poisoning. Kelp gull populations were estimated to have recovered quickly following mortalities during the Campbell Island rat eradication in 2001 (P. McClelland in DPIPWE, 2009). Kelp gull populations on South Georgia and regionally are healthy, so even substantial losses in baited areas should be recoverable on a scale of years or a decade at most.

5.6.1.4 The snowy (greater, American) sheathbill

Sheathbills may scavenge poisoned carcasses of rats or poisoned non-target species such as kelp gulls. Some mortality is considered likely, but the population would be expected to recover in a small number of years after the completion of the baiting programme.

5.6.1.5 South Georgia pintail

South Georgia pintail have been known to scavenge on seal carcasses. They may feed on rat carcasses if available, though as the rats generally die underground following poisoning, the availability of contaminated rat carcasses is likely to be very limited.

5.6.2 Potential risk of secondary poisoning of birds from feeding on poisoned invertebrates

Kelp gulls, shags, pipits and ducks may be at risk from feeding on poisoned invertebrates, but risk of lethal poisoning is not likely to be significant as concentrations of brodifacoum in affected invertebrates from other operations have been found to be low (Fisher and Fairweather, 2005; Morgan and Wright, 1996). As pipits are mainly present in rat-free areas, they should have minimal exposure to affected invertebrates.

Minimisation and mitigation – secondary poisoning of non-target species

- Collect mammal and bird carcasses for sampling and disposal as widely and frequently as possible, thereby reducing the biomass of contaminated carrion
- Monitoring during and after first phase of eradication to gain more information on potential of secondary poisoning on non-target species

5.7 Summary information on potential poisoning of non-target species

Table 7 presents the assessed risk of significant damage to bird populations on South Georgia from the rodent eradication campaign, where this is defined as more than 20% of the population being killed by primary or secondary poisoning. The fourth column is the potential medium-term consequence of the baiting campaign to the population, taking into account the abundance and status of the species concerned and the likelihood of population recovery in the event of significant losses.

Where few data of direct relevance are available for a species, risk assessment is then inferred on the basis of diet, behaviour and population status.

Table 7. Assessment of the probability of significant primary and secondary poisoning (defined as killing >20%) of South Georgia birds, and potential medium-term population consequences.

	Risk of primary poisoning	Risk of secondary poisoning	Potential medium-term population consequences	References
Penguins, albatrosses, smaller petrels	Negligible	Negligible	Negligible. Some birds on IUCN red list	Ormonde, 2007; DPIPWE, 2009
Northern / Southern giant petrels	Low-medium	medium	Low. Least concern on IUCN red list	Ormonde, 2007; DPIPWE, 2009; DPIPWE 2010
Brown skua	Low-Medium	Medium-high	Low. Population expected to recover losses	DPIPWE, 2009; DPIPWE 2010; Torr, 2002; Eason and Spurr 1995
Kelp gull	High	Medium	Low. Population expected to recover losses	Christie and Brown, 2007; Eason and Spurr, 1995; McClelland, 2001; Woods et al, 2009; DPIPWE, 2009; DPIPWE 2010
Blue-eyed / SG shag	Negligible	Negligible	Negligible.	DPIPWE, 2009
Snowy sheathbill	Low-Medium	Low-Medium	Low. Population expected to recover losses	Burger, 1981
Antarctic tern	Negligible	Negligible	Negligible.	DPIPWE, 2009
South Georgia pipit	Low	Negligible	Very low. Endemic species	Eason and Spurr, 1995
South Georgia pintail	Medium	Negligible	Medium. Endemic sub-species	Martin, 2008; DPIPWE, 2009; Fisher and Fairweather, 2005; Dowding et al., 1999. Appendix 4
Speckled teal	Medium	Negligible	Low-medium.	Martin, 2008
Note: Some assessments are based on limited data and are intended as a guide and reference point. IUCN red list birds for South Georgia are listed in section 4.6.3				

This assessment highlights the South Georgia pintail as facing the most significant medium-term risk, with the risk to giant petrels, skuas, sheathbills, pipits and speckled teal assessed as non-trivial. Kelp gulls, skuas, giant petrels and sheathbills are likely to suffer losses due to primary or secondary poisoning, but their populations will almost

certainly fully recover in the medium term. No bird population is expected to suffer negative effects of the baiting campaign in the long term.

5.8 Potential effects of bait on soil and water quality

The toxin brodifacoum has a very low solubility in water (less than 0.01g/litre at 20°C – even less in the cold conditions on South Georgia), but binds strongly to organic material in the soil rendering it relatively immobile. Once in soil, brodifacoum is slowly degraded over weeks to months (half-life of 157 days), breaking down into carbon dioxide and water (WHO, 1995). Degradation time is affected by soil type, temperature, and the presence of soil micro-organisms. Only the erosion of soil itself would result in brodifacoum reaching water. If soil containing brodifacoum reached a waterway, the brodifacoum is likely to remain bound to organic material and settle out in sediments (Fisher and Fairweather, 2005).

The potential for groundwater and surface water contamination from brodifacoum is low (Ogilvie et al., 1997). Cereal-based bait pellets which fall directly into lakes and ponds will break up rapidly and become dispersed. The brodifacoum will bind to organic material and settle out (Eason and Wickstrom, 2001). When baits have been sown directly into streams during pest eradication operations, brodifacoum residues have not been recorded in water (DOC, 2007). No brodifacoum was detected in stream or soil samples following eradications on Lady Alice and Red Mercury Islands (Ogilvie et al., 1997, Morgan and Wright, 1996). During the 2004 Hauturu rat eradication, eight water samples were taken directly downstream from baits lying in stream beds within 24 hours of the aerial drop and brodifacoum was not detected in any (Griffiths, 2004). Similarly, no traces of brodifacoum were found in water following trials on Adak Island, Alaska (U.S. Fish and Wildlife Service, 2007).

At Karori Sanctuary Pestoff 20R pellets were placed in cages and samples of the pellets and soil beneath them were taken at monthly intervals. After one month 70% of the toxin remained in the bait, after three months 34% remained, and after six months 9% was still present (Empson, 2002). At Kapiti Island, only 10-30% of the toxin remained in samples taken 3 months after the aerial spreading of brodifacoum.

The breakdown of brodifacoum is likely to be slower on South Georgia due to the lower temperatures compared to the studies outlined above. Breakdown will be slower at drier and higher altitude locations on the island. However, the high precipitation on the island means that the bait pellets are likely to disintegrate and the brodifacoum will be held in the soil or substrate, where it poses negligible risks, until it breaks down. Monitoring of the breakdown of bait under South Georgia conditions will be undertaken during the first phase of the eradication (see section 6.3).

Due to its low solubility, the toxin is unlikely to have any effect on wildlife drinking from affected water bodies. Animals may ingest a small amount of sediment containing the toxin when drinking, but this is unlikely to have any significant effect. Similarly, water for human consumption should not be affected, provided that it does not contain very large quantities of particulate matter.

Brodifacoum will be spread over all water catchment areas during the Grytviken zone eradication. However, it is extremely unlikely to leach through soil to concentrate in the station water supply, due to its low solubility in water and its characteristic for strong binding to soil particles (DPIWPE, 2009). Some bait will fall directly into the stream

supplying the station. These baits will disintegrate in the water and brodifacoum will bind to organic material.

The water supply for Grytviken and King Edward Point is taken from a pond formed by a dammed section of the stream in the Bore Valley around 0.5km from Grytviken. The water is piped from the pond to the settlements, where it is treated with UV and filtered using coarse and paper filters prior to consumption.

The measures included in the section below (minimisation and mitigation) will be taken to ensure that no brodifacoum bait or particulate matter contaminates station water supplies.

Minimisation and mitigation – soils and water

- Avoid spreading bait into freshwater lakes if possible
- Following aerial baiting, flush station water system and ensure that intake pipe is in open water to minimise sediment uptake
- Remove bait immediately following bait spreading from within 2m of main water systems feeding base water supply
- Animal carcasses to be removed from within 20m of waterways feeding base water supply

5.9 Potential effects of bait on the marine environment

Pellets may enter the marine environment during bait spreading as helicopters will drop bait along the beaches and coastline to ensure that all areas are effectively treated. Rats have been observed foraging in the inter-tidal zone and are able to swim short distances. Baiting will therefore include small off-shore islands and rock stacks.

Water or wave action will disintegrate the cereal baits relatively quickly and disperse the toxin, which will be rapidly diluted in the sea. However, it is possible that marine fish will consume whole baits before breakdown occurs.

In 2001, a semi-trailer truck rolled off the road on South Island, New Zealand and spilled 20 tonnes of bait containing 0.02g/kg brodifacoum into the near shore marine environment (Primus et al., 2005). Estimates indicated that a maximum of 360g of brodifacoum was spilled into the tidal environment. Bait spilled into the water began to soften and disintegrate quickly. Samples of seawater on the day of the crash indicated significant concentrations of brodifacoum, but concentrations had dropped off very quickly within 24 hours. Brodifacoum above the safe level for human consumption was detected in mussels, limpets and abalone collected from the intertidal zone near the crash site. No marine life was found dead as a result of poisoning, but some mortality was considered likely (Primus et al., 2005). A dispersal of this quantity of bait on South Georgia is extremely unlikely and a mass drop of bait into the marine environment would only occur if there was a shipping accident, loss of a bait bucket from a helicopter or loss of bait to the sea during unloading to FOB sites.

A study of marine fish undertaken during the Kapiti Island rat eradication found no evidence for a reduction in fish populations as a result of bait spreading (DOC, 2007).

The insolubility of brodifacoum and the relatively small amount of bait which will enter the sea means that there is unlikely to be a significant effect on the marine environment from the South Georgia operation.

Minimisation and mitigation – marine environment

- Use of GPS guidance for helicopter navigation and the use of experienced pilots to ensure that coastal areas are covered accurately with minimal bait drop into the sea
- Care during unloading and FOB operations to ensure that bait containers do not get damaged or fall into the sea

5.10 Potential effects of the operation on vegetation

Due to the low solubility of brodifacoum, plant uptake is unlikely to occur (Fisher and Fairweather, 2005) and therefore the use of the bait will not impact vegetation growth.

Native tussac is expected to significantly recover following rat eradication because it is a favourite food of this species on the island.

The establishment of FOBs and monitoring activities may cause limited local physical damage to vegetation during the period of the operation and there is also the potential for transfer of introduced plants around the treatment zones. Proposed FOBs have been chosen carefully to avoid vegetated areas (Poncet and Poncet, 2009).

Minimisation and mitigation – vegetation

- Care to be taken when establishing FOBs and conducting ground-based field work and monitoring to avoid vegetation damage
- Sensitive vegetation areas will be avoided where possible
- All staff briefed on island biosecurity and the need to ensure that they do not facilitate the spread of introduced flora

5.11 Negative ecosystem effects

Ecosystem effects which may result from the eradication of rats from South Georgia include increased success of non-native vegetation and non-native invertebrates. However, little is known about these potential effects.

The entire Nunez Peninsula is designated as mouse infested, as well as the coast from Shallop Cove to Cape Rosa up to a glacier on the south coast of King Haakon Bay (Christie and Brown, 2007). There are no rats in these areas. Ideally, the mouse population should be eradicated at the same time as the rats, while the infrastructure is in place. This would reduce the possible spread of mice to other areas via ice bridges or in the event of glacier recession. Mouse eradications in the past have been less successful (failure rate of 19%) than rat eradications (failure rate of 5%) (Howald et al, 2007). Mouse eradications are currently being planned for Gough Island and Macquarie Island. A different eradication methodology including a higher density of bait would be required to eliminate mice.

There is a possibility that mice may be more widespread on South Georgia than is currently recognised, as their numbers could be suppressed by the presence of rats. If this is the case, any such mouse population may increase once rats have been eradicated. Increased numbers of mice on South Georgia would have a negative ecological effect and diminish the benefits of the rat eradication. Mice on sub-Antarctic Gough Island have developed predatory behaviour toward nesting albatrosses and burrowing seabirds and are therefore as much of a threat as rats (Wanless et al., 2007),

though no such predation is suspected for the extant mouse population on the Nunez Peninsula.

The skua population on South Georgia may diminish in response to the absence of rats as a food source, but there may be a consequent increase in pressure on other skua prey such as burrowing petrels. However, as the rats will not be consuming tussac grass it may be more difficult for skuas to access the petrels due to increased vegetation cover.

Minimisation and Mitigation – negative ecosystem effects

- The known mouse population on South Georgia is planned to be removed concurrently with, and using the same techniques as, the rat eradication programme

5.12 Physical disturbance and noise

Helicopter operations will cause physical disturbance and noise during the proposed rodent eradication campaign on South Georgia. The level of impact will vary according to the intensity, duration and frequency of flights, type of aircraft, the species involved and the phase in their breeding season. Disturbance will also vary depending on the location.

The noise levels at ground level resulting from helicopter operations will be affected by flight height, flight profile, type of helicopter and engine, weather and topography. Two twin-engined Bolków 105 helicopters will be used (see sections 2.4.2 and section 3.7).

Noise levels are a concern for operations near to animals, but disturbance can be diminished by taking a gradual approach in line of sight of the animals rather than suddenly appearing overhead (P. Garden, pers. comm.).

Disturbance may be caused by cereal bait falling on, and in the vicinity of, wildlife. The establishment and operation of FOBs is likely to cause some disturbance to wildlife. Also, the landing of helicopters or helicopter operation close to the ground will result in the production of down draughts which may raise loose soil, sand or debris into the air, depending on the location. This may cause minor erosion and may also increase the disturbance of wildlife in the area.

Monitoring activities such as leg ringing of South Georgia pintail ducks and assessment of rat presence will cause physical disturbance to wildlife and some trampling of vegetation.

5.12.1 *Effects of physical disturbance and noise on marine mammals*

The breeding season for southern elephant seals will be complete, but seals will be moulting during the proposed operational period. Fur seals will still be suckling young at the onset of the project. Disturbance may result in a temporary increase in metabolic rate and consequent energy expenditure, but the impact is likely to be trivial.

A study of moulting male southern elephant seals on Macquarie Island during the operation of a Sikorsky S76 helicopter indicated that the flights had a minimal effect on the seals. The helicopter landing 20m away caused an increase in head-lifting, but no other observed changes (Burton and van der Hoff, 2002).

Research on Marion Island indicated that there were no differences in the success of southern elephant seals in areas of high and low human research activity (Wilkinson and Bester, 1988).

Minor disturbance may also be caused by FOB operations and any other operations when team members are working on the ground in the vicinity of seals, but again these will be minor and temporary.

5.12.2 *Effects of physical disturbance and noise on birds*

Noise or physical disturbance to breeding birds may result in loss of eggs or chicks through abandonment of nests or due to raiding by skuas, northern giant petrels and gulls. A small number of bird strikes are also known to have occurred due to aircraft operations (SCAR, 2008) and some bird strike may be anticipated during the proposed rat eradication on South Georgia. Proposed FOB sites are away from concentrations of birds to reduce the possibility of bird strike.

Minimum recommended separation distances for aircraft operations close to concentrations of birds have been agreed for operations in Antarctica (ATCM, 2004; Harris, 2005). These guidelines recommend a height separation when in the vicinity of penguin, albatross and other bird colonies of 2,000ft Above Ground Level (AGL) and avoidance of landings within around 1km of such colonies.

The recommended altitude for bait deployment from helicopters is around 300–500ft AGL (IEAG, 2009). All bird colonies in rat infested areas of South Georgia will require baiting. In order to minimize disturbance to birds, it is possible to spread bait at 1500-2000ft AGL if there are low or zero cross wind to ensure adequate coverage (P. Garden, pers. comm.).

5.12.2.1 King penguins

King penguins remain resident and breeding on South Georgia throughout the year and are known to be susceptible to disturbance from low flying aircraft, including helicopters. Research has been conducted on South Georgia, Marion Island and Macquarie Island to investigate the tolerance of king penguins to over-flights by helicopters (Giese and Riddle, 1999; Hughes et al., 2008; Cooper et al. 1994; Giese and Gales, 2009).

The trials on Macquarie Island in 2007 and 2008 used a single-engine AS350BA 'Squirrel' helicopter to conduct over-flights at altitudes of 500–1500ft AGL and the behavioral response of the birds was monitored. During over-flights adults and older chicks increased their flipper movements and became physically displaced, generally walking in response to the direction of the helicopter. Stronger responses were observed with lower altitudes, until, at 500ft AGL, the majority of adults and older chicks walked quickly in response to the helicopter. No birds were seen to run, panic or stampede. Flights in an east/west (seaward to inland) direction gave a stronger response among the birds than north/south flights. This research recommended a minimum flying altitude of 500ft within a 1km radius of king penguin colonies (Giese and Gales, 2009). These results were confirmed by further studies at three penguin colonies on Macquarie Island in 2008.

On South Georgia, a study of the short-term behavioural effects of king penguins at Antarctic Bay was undertaken during 17 over-flights at altitudes of 750–5,800ft AGL (Hughes et al., 2008). Noise levels were measured and were found to increase from a background level of 65-69dB(A) to a maximum mean peak level of 80dB(A) during over-flights. The helicopter in this study was a Westland Mk 3 Lynx helicopter from the Royal Navy ice-patrol vessel HMS *Endurance*. Penguin behaviour changed significantly during all over-flights, regardless of the altitude, and non-incubating birds showed an increased response. Pre-flight behaviour resumed after around 15 minutes and no predation of eggs or chicks was observed. The study also indicated that penguins may become

habituated to the noise as they showed a reduced response with increased exposure to aircraft noise. It should be noted that the helicopters to be used in the proposed eradication project would be smaller and quieter than the Lynx.

The responses of the penguins were not considered to cause death, injury or even long-term disruption to breeding adults or chicks in any of these studies. Disruption to king penguin colonies caused by bait-spreading helicopters is therefore likely to be minor and transitory under normal circumstances.

A number of measures have been identified at the end of this section to reduce impacts on bird and seals. These will include the prohibition of hovering and sharp turns over colonies, and a minimum altitude of 500ft when operating within a kilometre of the outer perimeter of king penguin colonies. Conducting familiarisation flights at higher altitude (1000-1500ft) over king penguin colonies prior to baiting may also reduce disturbance. A vertical separation of at least 800ft AGL will be maintained when flying directly above king penguin colonies where practicable.

Table 8. Summary of aircraft operation effects on king penguins

Location	Results	Reference
Antarctic/sub-Antarctic	Recommended operational height of aircraft of 2,000ft AGL when in the vicinity of bird colonies	ATCM, 2004
Bait deploying	Recommended operational height of helicopter 300-500ft AGL	IEAG, 2005
Macquarie Island	500–1500ft AGL single engine Squirrel helicopter: king penguins walking away from noise, followed by return to normal	Giese and Gales, 2009
South Georgia	750–5,800ft AGL Westland Mk 3 Lynx helicopter – penguin behaviour changed during all overflights; greater response from non-incubating birds. No deaths, injuries or predation of eggs or chicks. Reduced response with increased exposure. Return to normal after 15 minutes.	Hughes et al., 2008

5.12.2.2 Gentoo penguins

Gentoo penguins are also known to be at risk from helicopter disturbance. The main breeding season for gentoos is complete by mid-February, but there will be fledging chicks and moulting adults ashore during the operational period.

Gentoo penguins observed during overflights of a C-130 Hercules on Marion Island did not abandon their nests if they were guarding chicks, but lone penguins fled (Cooper et al., 2004). Studies of gentoo penguins disturbed by tourism and research indicated that there was no difference in the success of the undisturbed compared to the disturbed sites (Cobley and Shears, 1999).

Gentoo penguin colonies are smaller and less densely packed than those of king penguins and they are therefore considered less at risk than king penguins as a stampede of animals would have a less significant effect (DPIPWE, 2009).

During a fur seal survey helicopter trial in 2006, a series of overflights of the gentoo penguin colony at Maiviken, South Georgia was carried out by the HMS *Endurance* Lynx helicopter. Overflights were made at 2000ft, 1000ft and 800ft AGL at a speed of 60 knots. Observers reported no reaction of gentoo penguins, other than an awareness of the

aircraft (Martin and Lurcock, 2006). Significant disturbance of gentoo penguins due to the planned eradication operations is therefore not anticipated.

5.12.2.3 Albatrosses

Wandering albatrosses on Marion Island showed minor responses to C-130 aircraft flying at around 300-1000ft AGL and conducting airdrops at around 500ft (Cooper et al., 1994). The albatrosses were around 50m away from the aircraft activity.

In the sub-Antarctic Crozet Islands, birds in a seldom-visited area were approached to 1m and heart rates doubled as soon as human presence was detected. They were three times higher when the person was less than 20m from the nest and increased by 3-4 times if birds were handled (Weimerskirch et al., 2002). Nesting birds will be avoided wherever possible during any ground-based activities on South Georgia.

Light-mantled sooty albatrosses were observed during helicopter bait trails on Macquarie Island in 2005 and none showed any signs of alarm or distress (DPIPWE, 2009).

Disturbance due to bait falling onto nesting chicks is unlikely as no effects on albatrosses were reported following the successful eradication on Campbell Island. The Campbell Island eradication used the larger and heavier 16mm bait, compared to 12.5mm bait to be used on South Georgia.

Disturbance and noise is unlikely to result in more than a minor response from albatrosses, but a precautionary approach will be taken in that commuting flightlines will be routed around albatross colonies.

5.12.2.4 Northern and Southern giant petrels

Southern giant petrels can be very sensitive to some forms of human disturbance. An intense ringing programme for research took place in colonies at four island sites in East Antarctica. At three of the four monitoring sites there were rapid population decreases (94%, 75% and 80%). However, restrictions on human access to these sites allowed a significant recovery in petrel populations (Woehler et al, 2003).

Northern giant petrels are also sensitive to human disturbance, with increased heart rate of incubating birds measured when a person is detected 40m away, which continued to increase during approach to 5m (de Villiers et al., 2006).

Incubating and hatching in these birds is complete by mid-February. Although chicks will no longer be brooded, the last of the Southern Giant Petrel chicks do not fledge until late April / early May. No FOBs will be located in the vicinity of Northern and Southern giant petrel nests and care will be taken when conducting monitoring activities on the ground near to known breeding locations.

Giant petrels are also likely to be disturbed by helicopter overflights. Field supply operations on Macquarie Island use helicopters near to giant petrel congregations and petrels are seen to take flight, circle and resettle quite promptly (DPIPWE, 2009). The impact from South Georgia operations is likely to be less as the helicopters will be operating at altitude.

5.12.2.5 Other birds

The main risk of disturbance to smaller birds is that they may abandon their nests, allowing predators to take eggs and chicks. From mid-February the only bird on South Georgia still hatching eggs is the Wilson's storm petrel. As storm petrels nest in burrows they are unlikely to be significantly disturbed by helicopter overflights.

The monitoring of SG pintail and speckled teal will necessitate approaching and catching these birds. This will be supervised by the Project Director, who has substantial experience in handling these species.

Minimisation and Mitigation – physical disturbance and noise

- Use of experienced helicopter pilots; briefing of pilots to ensure awareness of specific issues of wildlife disturbance on South Georgia.
- Flights within 1km of king penguin colonies should be undertaken at 500ft or above and tight turns avoided.
- All transit flightlines will be routed around concentrations of breeding albatrosses, penguins and giant petrels unless unavoidable.
- FOBs should be located away from concentrations of wildlife, including Northern and Southern giant petrel nesting sites.
- Pilots should follow the South Georgia Low Flight Avoidance map and guidelines, except when operationally necessary (during bait spreading)
- Where practical, landings near to concentrations of birds should be downwind and/or behind a prominent physical barrier (e.g. hill) to minimise disturbance.
- Flying toward concentrations of birds immediately after take-off (increased noise) will be avoided
- Avoid steep banking turns in flight (increased noise). Maintain 1km distance from king penguin colonies when making turns during bait spreading.
- Never hover over wildlife concentrations.
- If potentially damaging wildlife disturbance is observed at any separation distance, a greater distance should be maintained wherever practical unless gaps in bait coverage may occur.
- Baiting to occur when the breeding cycle and moulting periods for much of the wildlife is complete.
- Aircraft operations should be delayed or cancelled if weather conditions (e.g. cloud base, winds) are such that the suggested minimum vertical and horizontal separation distances cannot be maintained.

5.13 Atmospheric emissions

Atmospheric emissions will predominantly be caused by the use of the ship to input materials and set up FOBs and the use of helicopters for bait spreading.

The MV *Pharos* will be used for the project for an estimated 80 days, burning around 4 tonnes of Marine Gas Oil each day (320 tonnes total for the whole project). Approximately 500 drums of Jet A1 fuel will be used for helicopter operations for the whole operation (100,000 litres). Ship and helicopter use during the project would produce an estimated 1264 tonnes of carbon dioxide. To put this in context, around 70 cruise ships visit South Georgia in a typical season would emit in excess of 13,000 tonnes of carbon dioxide, compared to 316 tonnes per season for the eradication project (based on 70 ships for 5 days with fuel burn of 12 tonnes per day).

Table 9. Carbon dioxide emissions from ship and helicopter during project

Source	Estimated fuel consumption (tonnes)	Conversion factor (UK National Atmospheric emissions inventory www.naei.org.uk)	Carbon dioxide emissions (tonnes CO₂)
Ship (MGO)	320	3.2	1022
Helicopter (AVTUR)	150	3.15	472
Total			1494

In addition, fuel oil will be used for the generators as well as lubricants and hydraulic oils for mechanical equipment and vehicles. However, the volume of fuel for these applications is negligible compared to ship and helicopter use.

Use of fossil fuels will generate carbon dioxide, carbon monoxide, hydrocarbons, nitrogen oxides, sulphur dioxides and particulates. Refuelling activities and fuel spills will cause some emissions to the atmosphere as much of the fuel may evaporate. The vapours will include hydrocarbons and carbon dioxide, which are greenhouse gases and contribute to climate change.

Emissions at sea will be rapidly dispersed and are unlikely to have any significant impact on wildlife, marine or air quality.

Atmospheric emissions are cumulative and certain gases emitted may contribute the local burden of pollutants caused by past and current activities in the area and to regional atmospheric pollution.

Minimisation and Mitigation

- Use of ship already operating in the area (no fuel burn for relocation) for transporting materials to South Georgia
- Helicopters to be flown in most fuel-efficient way (speed, altitude etc.), where consistent with flight plans
- Use of light refined fuel for ship (eg. Marine gas oil) with low sulphur content
- Maintain all mechanical equipment to high standards; use fuel filtration and fuel injection systems to reduce emissions if practicable.

5.14 Fuel and oil spills

Fuels and oils will be stored at Grytviken. Fuel will be input each season. FOBs will be input at the start of each season as required. Fuel will be stored in 200 litre drums.

Fuel spills are most likely to occur during refuelling operations, but may also occur during transportation or during use. Types of spill which may occur include:

- Leakage from damaged drums
- Oil or fuel leak from generator or vehicle
- Spills during refuelling operations

Most spills are likely to be of less than 5 litres. The maximum realistic risk is the loss of two drums of fuel (400 litres) during FOB supply by helicopter.

Fuel is relatively volatile and spills will evaporate to leave a waxy residue. Fuel spilt on land will seep into the ground, leading to contamination of that area until the substance

has biodegraded. At Grytviken, this will have a cumulative impact on the contamination of the area. Fuel spills at FOBs, which are likely to be pristine, may have a biological effect on the flora in the area of the spill.

An Oil Spill Contingency Plan has been prepared for Phase 1 of the project (SGHT, 2010c).

Minimisation and Mitigation

- Correct equipment will be used; handling and transfer of fuels will be minimised.
- All fuel transfer and storage equipment should be of highest standards and should be tested prior to use
- Fuel drums will be stored in a safe place to prevent accidental damage by operational activities
- Staff involved in refuelling operations will be trained appropriately
- All spills will be reported to the Project Director
- Fuel handling and spill response procedures will be regularly audited.
- Absorbents and oil spill clean up equipment will be provided

5.15 Waste

5.15.1 Solid waste

Waste is discussed in section 2.7. The project Waste Management Plan is shown as Appendix 3.

If not correctly managed, some waste may be scattered by winds. Wastes could be scavenged by the local avian population or contaminate the marine environment.

Minimisation and Mitigation

- A nominated team member will be assigned responsibility for implementing correct waste management procedures
- All project staff will be briefed on waste management procedures
- Minimisation by reduction of packaging where practicable
- Hazardous materials will be kept to an absolute minimum and all hazardous material will be removed from South Georgia
- No prohibited products will be brought to South Georgia (see Appendix 1)
- Waste items will be re-used and recycled as much as possible
- Poultry food waste will be incinerated and no poultry products will be used except at Grytviken/KEP
- All food wastes will be stored in secure containers to prevent scavenging by birds and rats
- All waste will be sorted, labelled and securely contained, to prevent wind

dispersal or scavenging

5.15.2 Sewage and waste water (grey water)

Government approved policy will be followed throughout. Domestic waste water (grey water) will result from washing, food preparation and ablution activities. Grey water and sewage will be discharged to the sea.

Human sewage has the potential to contain parasites, bacteria and viruses that are not native to South Georgia and which may prove pathogenic to wildlife (Smith and Riddle, 2009), as well as heavy metals and organic pollutants. In summer, human derived faecal coliform cells are likely to be killed off by the biologically damaging effects of solar radiation (Hughes, 2003). The impact of the effluent is likely to be localised.

The direct effect of sewage and grey water disposal will be a temporary increase in the contamination of the water in Cumberland East Bay. This will add to the cumulative impact of sewage and waste water produced by ships and stations in the area.

Minimisation and Mitigation

- Care will be taken that no sewage or grey water discharges are made directly in the vicinity of wildlife.

5.16 Light pollution

Prions and petrels are attracted to lights and can become disorientated, particularly in foggy weather during January-March, and may collide with buildings or vessels (Poncet and Crosbie, 2005). During the 2008/09 season a ship in Stromness Bay reported a serious bird strike in which over 280 birds (prions and diving petrels) struck the vessel, resulting in at least 17 mortalities. In this instance, the reasons for the bird strike were very clearly a combination of excessive lighting and poor visibility (McKee, 2009). Lighting on support ships and yachts and at the operational base on dark evenings may therefore cause disturbance to birds.

Minimisation and Mitigation

- External lighting will minimise stray light emission, particularly above the horizontal.
- Windows will be covered during dark periods to prevent disorientating birds.

5.17 Aesthetic and heritage values

The operation of helicopters will cause noise, temporarily affecting the wilderness value of South Georgia and this may affect visitor experience of South Georgia. For example helicopter operations in Grytviken may cause disturbance to tourists visiting the whaling station and museum. However, this will be temporary and only for the duration of operational periods. The input of and presence of FOBs will have an effect on the wilderness value of these areas, but this too will be short term.

There are a large number of heritage sites on South Georgia (see section 4.8). The chosen method of aerial bait application means that most sites will not be physically disturbed. Where members of the team do work in or around any of these sites, care will be taken to avoid damage. Permits from GSGSSI will be required for access to the whaling stations (with the exception of Grytviken).

Minimisation and Mitigation

- Special care should be taken during operations in or near to heritage sites.
- Ensure that any other visitors to South Georgia are fully briefed about the project and its conservation importance
- Eradication team members will be suitably briefed to not disturb or destroy any artefacts found at heritage sites. Artefacts must not be removed, unless there is immediate risk of damage or loss. If any items are moved, this should be reported to the South Georgia Museum. Smoking is prohibited in the locality of heritage sites

5.18 Introduction of alien species and translocation of diseases

Alien species are those introduced directly or indirectly by humans. For example, soil and seeds may be introduced by unclean footwear, vehicles or equipment.

The proposed eradication of rats from South Georgia will take several years to complete. A significant amount of equipment and supplies will be brought to the island including helicopters, bait, food and fuel. Personnel working on the eradication will also come to South Georgia for each phase of the eradication. These activities present an increased risk of introduction of alien species to South Georgia.

Scavenging of unsecured food wastes by birds is a simple pathway for alien species or diseases to enter the system. South Georgia's bird and seal populations are susceptible to infection by disease. Viral diseases (i.e. morbillivirus, Newcastle disease, infectious bursal disease) and agricultural and zoonotic diseases (i.e. brucellosis, tuberculosis) are considered to be the greatest potential risk to the health of wildlife. Avian cholera is known to cause mass mortalities in wild waterfowl as well as subacute and chronic infections, and can also be carried by rats (Kerry et al., 1998).

The GSGSSI have produced guidelines for preventing the introduction of alien species (see Appendix 1) and they ensure that all visitors are aware of these. In addition, biosecurity facilities have recently been built at KEP. A Biosecurity Plan has been prepared for Phase 1 of the eradication (SGHT, 2010b).

Minimisation and mitigation

- Measures described in the Biosecurity Plan for this operation (SGHT 2010b) will be followed as appropriate.
- Thorough biosecurity measures should be taken for pre-border cleaning
- Biosecurity facility at KEP will be used to process small amounts of equipment, loose items, field equipment, fresh stores etc.
- Helicopters will be scrupulously cleaned before departure from the Falkland Islands

5.19 Use of trained rodent detection dogs

Dogs would provide an invaluable tool for detecting any remaining rodents following the treatment of each zone. They are used on eradication programmes in New Zealand and Australia, where a system for training and assessment is in place. Dogs are trained to be absolutely obedient and to ignore the scents of any animals other than the target species.

The dogs will be specially trained in New Zealand and assessed for work on the South Georgia project.

The temporary introduction of dogs could result in the introduction of non-native parasites or diseases. However, dogs will be inoculated (especially for any disease transmissible to seals), treated for parasites and will have a veterinary treatment regime and record for the period they are under training prior to departing for the island. A permit will be required from GSGSSI for the use of dogs on South Georgia.

Dogs were used on Macquarie Island for two years during cat eradication operations and are not considered a significant biosecurity issue or threat to non-target species. No adverse disease events have been demonstrated to have occurred from this operation or from earlier use of dogs on Macquarie Island (DPIPWE, 2009).

The need for dogs and handlers to travel through or near penguin colonies and other sensitive wildlife may cause temporary disturbance. Also there may be some damage to vegetation or burrows through trampling.

Dog faeces will be disposed of by burying and will have a trivial impact on soil and water quality on South Georgia due to the small biomass involved.

Minimisation and mitigation

- The dogs and handlers will be fully trained and highly skilled so that they are not a risk to non-target species
- Dog handlers will be briefed on sensitive wildlife areas and how to work in these areas to minimise impacts and disturbance
- Dogs to be treated for parasites prior to arrival on South Georgia
- Dogs should be kept under strict control at all times
- Dogs will wear a collar and a radio tracking device
- Dog faeces should be buried locally if working away from base. At the base they should be placed in the sewage treatment system

5.20 Adjacent and Associated Ecosystems

The features of the proposed activities which are most likely to impact associated ecosystems are

- Atmospheric emissions (see section 5.13) as these contribute to regional air pollution burdens
- Removal of solid waste (see section 5.15) resulting in increased landfill, probably in the Falkland Islands and a limited amount of hazardous waste in UK. This has the indirect effect of contamination of soil and groundwater.

The contribution of this project to atmospheric emissions and waste disposal will be small compared to overall emissions on South Georgia (see section 5.13) and to the amount of waste going to landfill in the Falkland Islands.

5.21 Indirect and cumulative impacts

Indirect impacts may result from the purchasing of products to be used for the project, such as the use of a large quantity of chemical poison, which will be manufactured in New Zealand.

Cumulative impacts are those which are repeated and therefore, even though the individual impact may be small, the continuing effect may become more significant. The impacts of the project will add to those of the existing activities at South Georgia. This includes emissions to air, fuel spills and discharge of sewage and grey water in the marine environment.

Whilst noting such cumulative impacts, it is unlikely that they will significantly affect the biota in the region or reduce the scientific value of the area.

5.22 Impact matrix

The impact matrix in Table 11 summarises the predicted environmental impacts which may result from the proposed eradication of rats from South Georgia. Activities which will have an impact are identified and the output and predicted impacts of each activity is stated. The probability, extent, persistence, intensity and significance of the impacts are then assessed according to the criteria described in Table 10 below. The final column of Table 11 gives proposed mitigation measures which should be put into place to reduce or eliminate the impacts described.

Table 10. Parameters used in impact matrix

Activity	Type of activity
Output	Description of potential results of activity that may cause impact
Predicted Impact	Description of what is directly, indirectly and cumulatively impacted by the activity/output
Probability	Likelihood of impact occurring: Unlikely (<5%), Low (<25%), medium (25–75%), high (>75%), certain (100%)
Extent	Geographical area affected: Local (directly in area of impact), regional (whole of South Georgia and immediate offshore area), global
Persistence	Period of time during which changes in the environment are likely to occur: Short (minutes–hours), medium (days–weeks), long (months–years), very long (decades to centuries), unknown
Intensity	Severity of impact: Low, medium, high
Significance	Severity and importance of the impacts on the environment: Very low (negligible impacts), Low (less than minor or transitory impacts), medium (minor or transitory), high (greater than minor or transitory), very high (major or irreversible changes)
Mitigation	Suggested measures that will be put in place to mitigate or prevent the impacts from occurring, such as operational procedures, timing of activity, training of personnel.

Matrix – Eradication of rodents from South Georgia

it	Predicted Impact	Proba bility	Extent	Persis tence	Intensity	Signifi cance	Key mitigation measures
spheric ions	Minor, cumulative contribution to atmospheric pollution inc. GHGs, and local fallout of particulates and heavy metals.	Certain	Local to global	Long	Low	Very Low	<ul style="list-style-type: none"> No requirement for repositioning of ship Use of light refined fuel (e.g. MGO) with low-S content Ships engines maintained to highest standards and fuel injection systems if practicable
and liquid , including je, grey food.	Introduction of faecal bacteria; nutrient enrichment, sea water and contamination of by heavy metals and organic pollutants.	Certain	Area-specific (ship route)	Short	Low	Low	<ul style="list-style-type: none"> All wastes managed in accordance with project V Management Plan (Appendix 3) Sewage treated and effluent discharged according requirements
uction of species	Displacement of native species; ecosystem effects	Low	Local-regional	Short - long	Low - high	Low - high	<ul style="list-style-type: none"> All vehicles and equipment to be cleaned before SG Biosecurity measures (Appendix 1) to be followed Helicopters will be scrupulously cleaned before departure the Falkland Islands
e pance	Decrease in colony size decrease in reproductive success	Low - Medium	Local	Short	Low	Low	<ul style="list-style-type: none"> Choice of FOBs to avoid wildlife (especially giant king penguins) Maintain minimum distances from wildlife
	Disorientation/disturbance of birds; decrease in colony size	Low	Local	Short	Low	Low	<ul style="list-style-type: none"> Use blinds; minimise use of outside lighting Lights angled below horizontal

OPERATIONAL BASE

spheric ions	Minor, cumulative contribution to atmospheric pollution and local fallout of particulates	Certain	Local	Long	Low	Low	<ul style="list-style-type: none"> Generators and engines maintained to highest standards
je, grey and food	Introduction of bacteria, nutrients, heavy metals and organic pollutants. Cumulative contribution to pollution	Certain	Local	Short	Low	Low	<ul style="list-style-type: none"> Do not discharge directly in area where wildlife are present Discharge where rapid mixing can occur
solid and waste	Contamination of area around Grytviken, FOBs and other operational areas if not stored securely. Reduction in scientific value. Effects on wildlife and vegetation. Indirect effect of disposal outside South Georgia	Low	Local-regional	Short-Long	High	Medium	<ul style="list-style-type: none"> All wastes managed in accordance with project V Management Plan (Appendix 3). A nominated team member will be assigned responsibility for implementing waste procedures All project staff will be briefed on waste management Bring minimal packaging to site Regular litter checks All wastes to be removed from South Georgia for recycling or safe disposal Hazardous materials kept to an absolute minimum from South Georgia after project No prohibited products will be brought to South Georgia

Impact	Predicted Impact	Probability	Extent	Persistence	Intensity	Significance	Key mitigation measures
							<ul style="list-style-type: none"> Waste to be sorted, labelled and securely contained to prevent wind dispersal or scavenging
RIVINITIES							
Primary eradication of species	Total eradication of mice and rats	High	Regional	Very long	High	Very high	<ul style="list-style-type: none"> None
Primary eradication of target species	Decrease in colony size; potential eradication of endemic species or subspecies	Low	Local	Short	Low-High (depending on species)	Medium	<ul style="list-style-type: none"> Design bait pellets to be unattractive to non-target species Monitoring during first phase of eradication to gain information on potential of primary poisoning (esp. pintail) Eradication of reindeer prior to bait spreading Timing of bait application for when wildlife have left colonies where possible Capture of SG pintail and holding until the risk of receding (if first phase of operation indicates that)
Secondary eradication of target spp.	Decrease in colony size	Low	Local	Short	Low-Medium	Medium	<ul style="list-style-type: none"> Collect contaminated carcasses. Monitoring during first phase of eradication to gain information on potential of secondary poisoning
Spillage on soil/water	Contamination of water and sediments with poison: illness or poisoning due to ingestion; decrease in colony size	Unlikely	Local	Short	Low	Very Low	<ul style="list-style-type: none"> Following aerial baiting, flush station water systems that intake pipe is in open water Remove bait immediately following bait spreading of main water systems feeding base supply Animal carcasses to be removed from within 24 hours of feeding base water supply Measures to be taken to ensure that bait does not enter water supplies (micro filtration of sediment) Avoid spreading bait into freshwater lakes if possible
Spillage of bait on environment	Mortality of marine species; contamination of fish with brodifacoum	Unlikely	Local	Short	Low	Very Low	<ul style="list-style-type: none"> Use of differential GPS guidance and experience to ensure coastal areas are covered accurately with bait; use of skirts or deflectors to all spread in one direction. Care during unloading and FOB operations that bait does not get damaged or fall into the sea
Disturbance of vegetation	Damage to plants; loss of scientific value	Low	Local	Short-Med		Low	<ul style="list-style-type: none"> Care taken at FOBs and during ground-based field monitoring to avoid vegetation damage Sensitive vegetation areas will be avoided where possible
Dispersal of introduced species	Possible spread of other non-native species following removal of rats	Low	Local	Short-Long			<ul style="list-style-type: none"> Removal of introduced flora and fauna (ie. mice) and particularly if rat removal results in spreading introduced species.
Special care values	Damage or disturbance to	Unlikely	Local	Short	Low	Low	<ul style="list-style-type: none"> Special care taken during ops in or near heritage sites

Impact	Predicted Impact	Probability	Extent	Persistence	Intensity	Significance	Key mitigation measures
	heritage sites or artefacts. Loss in historic value of area	likely					<ul style="list-style-type: none"> Eradication team members will be briefed not to destroy any artefacts or heritage sites
of dogs	<ol style="list-style-type: none"> Introduction of non-native parasites or diseases Wildlife disturbance and damage to vegetation and burrows 	Unlikely Med	Local Local	Med-Long Short	Med Med	Low Low-Med	<ul style="list-style-type: none"> The dogs and handlers will be fully trained and that they are not a risk to non-target species Dog handlers will be briefed on sensitive wildlife areas to work in these areas Dogs to be treated for parasites prior to arrival on site Dogs should be kept under strict control at all times Dogs will wear a collar and GPS tracking device Dog faeces should be properly disposed of
atmospheric emissions	Contribution to atmospheric pollution inc. GHGs, particulates and heavy metals.	Certain	Local to global	Long	Low	Low	<ul style="list-style-type: none"> Engines maintained to highest standards Fly at fuel efficient speeds
fuel and oil	Contamination of soil or water	Med	Local	Med	High	Low	<ul style="list-style-type: none"> Correct fuel transfer and storage equipment will be tested prior to use Handling and transfer of fuels minimised Fuel drums stored in a safe place to prevent damage Staff involved in refuelling ops trained appropriately Fuel handling and spill response procedures in place Absorbents and oil spill clean up equipment available
visual nuisance and disturbance	<p>Disturbance of wildlife, leading to increased predation of vulnerable chicks or eggs and possible colony size decrease</p> <p>Disturbance of local human population at Grytviken and King Edward Point</p> <p>Effects on scientific activities</p>	Certain	Local	Short	High	Medium	<ul style="list-style-type: none"> Use of experienced helicopter pilots; briefing on wildlife disturbance on South Georgia Flights near king penguin colonies at 500ft or above Locate FOBs away from wildlife, especially king penguins & albatrosses Flight plans to avoid unnecessary flights over wildlife concentrations South Georgia wildlife avoidance map and procedures followed, except when operationally necessary Landings near concentrations of birds downwind of a physical barrier (e.g. hill) if possible Avoid flying toward concentrations of birds in the vicinity of take-off (increased noise) Avoid steep banking turns in flight (increased noise) Never hover over wildlife concentrations. If wildlife disturbance is observed, a greater separation should be maintained wherever practical Ops to occur after wildlife breeding complete if possible

6 MONITORING AND VERIFICATION

6.1 Current and on-going monitoring

An annual census of wandering albatrosses is undertaken on Albatross and Prion Islands. Other wildlife and habitat surveys are conducted during the austral summers on South Georgia recording the abundance and distribution of seabirds, non-native species and assessments of historic sites and artifacts. This includes monitoring undertaken as part of the South Atlantic Invasive Species Project including the survey for baseline information on introduced vascular plants and invertebrates (Osborne et al., 2009).

Information is added to the South Georgia Geographical Information System (GIS; <http://www.sggis.gov.gs>), based at the British Antarctic Survey.

6.2 Baseline monitoring in preparation for rodent eradication

Little work is *needed* in advance of the eradication programme, other than what is necessary to evaluate possible impacts on vulnerable non-target birds. Such information is required to ensure that any damaging effects are detected at an early stage and subsequently prevented during the rest of the work. That said, it would be very *desirable* to be able to measure the recovery of native wildlife after rats and mice have been eliminated. The possible scale and cost of such monitoring is almost unlimited. For birds, the timeframe involved is on the scale of a few years for species such as the pipit, to decades for long-lived species with high natal fidelity like petrels.

6.3 Monitoring during and after the eradication programme

A Monitoring Plan has been developed for Phase 1 of the operation (SGHT 2010d), and another will be produced for Phase 2. The step-wise approach to this eradication program allows for monitoring and assessment to be undertaken throughout the project to determine the effectiveness and impact of the campaign. Monitoring in the early phases of the operation will provide important information to improve successive steps towards complete eradication. During the first phase of the eradication, monitoring will focus on the effectiveness of the baiting technique and spreading density, and impacts on non-target species, particularly the endemic South Georgia pintail (see Appendix 4).

Visits to each baited area will be made one week and two weeks after treatment to search for, and collect, carcasses of birds that may have succumbed to Brodifacoum poisoning.

A rolling programme of monitoring to establish whether rats have been eradicated from each baiting zone will be undertaken. At minimum, visits to each treated zone will occur one year and two years after baiting to:

- search for signs of recent rat and/or mouse activity (using gnawsticks and a wide variety of other detection devices, including a trained sniffer dog)
- assess the recovery (abundance and distribution) of bird populations
- assess native vegetation recovery
- search for non-native plant expansion or new invasions

7 GAPS IN KNOWLEDGE AND UNCERTAINTIES

The main uncertainties associated with this project are:

- Likelihood of primary poisoning of significant numbers of non-target species, particularly the South Georgia pintail duck
- Likelihood of secondary poisoning of scavenging non-target species such as giant petrels, skuas and sheathbills
- Precise and up-to-date information on the location of some breeding bird species in the operational area
- Precise information on extent of rat range in marginal areas near to glaciers and on mountain slopes
- Information on location and extent of mouse presence
- Operational – South Georgia is a more extreme operational environment compared to other rodent eradication projects hitherto. Timing of operation and proposed bait spreading densities will be different to those used elsewhere.

Further research and data collection will be undertaken during the first phase of the eradication and will inform the subsequent phases. Changes may be made to the project plans following the first phase and any changes will be assessed for their potential environmental impacts.

8 ENVIRONMENTAL MANAGEMENT

8.1 Policies and procedures

All GSGSSI policies and procedures will be followed, unless specific permission has been obtained to the contrary. Environmental policies and procedures are set out in *South Georgia: Plan for Progress* (Pasteur and Walton, 2006), which includes policies on conservation of flora and fauna, visitor management and scientific research. Updated information is available on the South Georgia website (<http://www.sgisland.gs>).

Information on biosecurity and waste management is given in Appendices 1 and 3 of this document, respectively. Biosecurity and Oil Spill Response also have their own Plans for Phase 1 of this operation (SGHT 2010b, c).

8.2 Roles and responsibilities

Effective environmental management of the rodent eradication project is dependent on the awareness, cooperation and common sense of all involved.

The Project Director will be responsible for overall environmental performance during the eradication operation and for compliance with environmental regulations, permitting conditions and the implementation of mitigation measures. This will include close cooperation and coordination with the Government Officer on South Georgia during operations.

8.3 Implementation of mitigation measures

The Project Director will ensure that the minimisation and mitigation measures described in section 5 are implemented and that a team member is tasked with the coordination and oversight of waste handling.

The Project Director and project team will review and update mitigation measures during the timeframe of the project as further information becomes available or conditions change.

8.4 Environmental reporting

A report will be produced at the end of each phase season's work, to include details of accidents and incidents, including any environmental incidents. The report will also include information from monitoring activities and recommendations for improvements or modifications to better protect the environment in subsequent seasons of work where possible.

9 CONCLUSIONS

The removal of rodents from South Georgia will have a profound, positive impact on the terrestrial environment of the island. Over two centuries the Norway rat, a non-native predator and scavenger, has brought about a fundamental change in the ecosystem of South Georgia by eating the eggs and chicks of small birds attempting to nest within its range. Experience elsewhere in the world demonstrates that recovery of native wildlife populations and vegetation will commence almost immediately following the successful conclusion of each season's work on this project.

The possible negative environmental impacts which may result from a rodent eradication project on South Georgia have been described and assessed. Birds such as skuas, giant petrels, sheathbills, kelp gulls and the endemic South Georgia pintail may be affected by brodifacoum poisoning. However, short-term losses are likely to be more than replaced once rats have been removed as there will be more rat-free habitat. All non-target populations are likely to make a full recovery on a scale of years. As the South Georgia pintail is an endemic subspecies, extreme care must be taken to avoid population-level damage from bait-spreading. Monitoring of pintails before and after the first phase of the operation will be carried out, with the objective of identifying the level of risk to individual birds. Subsequent evaluation of the results obtained will inform planning for subsequent phases of the operation.

If the recommended mitigation measures outlined in section 5 are taken, the physical disturbance to wildlife and non-target species losses will be minimised and sustainable. Disturbance caused by helicopter flying is likely to be minor and transitory and should not result in any significant loss of life.

As the project will be undertaken in stages, monitoring of environmental impacts will be an ongoing part of the operation. Should significant and unpredicted impacts be observed, project plans will be modified accordingly.

Despite diverse mitigation measures, it is possible that hundreds or even low thousands of birds (all non-target) may die during this operation. The death of any animal is regrettable, especially if it involves suffering, and it is therefore very important that the

context in which this baiting campaign will be carried out is understood. The negative effects of this operation are measurable in hundreds or thousands of birds and on a scale of years or, at worst, a decade or two. In the event of success, which is highly likely, the benefits would be measured on a scale of many millions of birds and thousands of years. With adequate follow-up biosecurity, the benefits to wildlife populations of this one-off operation should exceed the costs by many orders of magnitude.

10 PREPARERS AND ADVISORS

This EIA was prepared by Dr Liz Pasteur, with assistance from Prof. Tony Martin. Assistance and advice were provided by Derek Brown (Private eradication consultant, New Zealand), Darren Christie (GSGSSI), Sally Poncet (South Georgia Surveys), Peter Garden (Eradication pilot, New Zealand) and Les Whittamore, Alison Cook and David Herbert (British Antarctic Survey).

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12 ABBREVIATIONS AND ACRONYMS

Acronym	Meaning
AGL	Above Ground Level
BAS	British Antarctic Survey
CEE	Comprehensive Environmental Evaluation, as defined by the Protocol to the Antarctic Treaty (1992)
CRE	Centre for Remote Environments, Dundee University
DGPS	Differential Global Positioning Systems
DOC	Department of Conservation (New Zealand)
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
FOB	Forward Operating Base
GHG	Green House Gas
GIS	Global Information System
GPS	Global Positioning System
GSGSSI	Government of South Georgia and the South Sandwich Islands
SGHT	South Georgia Heritage Trust
IEAG	Island Eradication Advisory Group (New Zealand)
IEE	Initial Environmental Evaluation
IUCN	International Union for Conservation of Nature
KEP	King Edward Point
LD ₅₀	Lethal Dose 50%. The estimated dose that kills 50% of the test animals
OP	Operational Plan
RSPB	Royal Society for the Protection of Birds
SAISP	South Atlantic Invasive Species Project
SPA	Specially Protected Area

13 APPENDICES

APPENDIX 1: BIOSECURITY MEASURES FOR ALL VESSELS LANDING PASSENGERS, CREW, EXPEDITION STAFF OR STORES ON SOUTH GEORGIA

- **Absolutely no plants, animals or soil may be brought ashore.**
- Bootwashing with Biocide (eg *Virkon*) is obligatory for all passengers, staff and crew prior to **all** landings and again when returning to the ship. Bootwashing must be overseen by a designated competent member of staff / crew.
SG Government Officers will randomly inspect bootwashing facilities on visiting vessels (including yachts).
- **Bootwash to be cleaned and refilled for each new landing.** For this to remain effective, passengers and staff returning from the shore should wash off soil and organic material with seawater before embarking on the zodiac to return to the ship.
- Inspect all clothing prior to arrival at South Georgia and again between landing sites. Wash off and or remove all soil, seeds and any other organic material. **Pay particular attention to all Velcro, footwear, gaiters, pockets, turn-ups in trousers and hoods of jackets. (Pockets to be turned inside out).**
SG Government Officers will randomly inspect visitors as they come ashore.
- Prior to arrival at South Georgia all luggage and equipment to be brought ashore (such as daypacks), must be thoroughly inspected. Special attention must be given to seams and pockets. **Daypacks must be brushed out and vacuumed to remove all soil, seeds and organic material before disembarking at South Georgia.** Thereafter, visitors must inspect luggage and equipment between landings.
- Self – audit checks must be completed prior to arrival by anyone intending to go ashore (crew, passengers or expedition staff).
The Expedition leader (EL) on cruise ships should ensure that all passengers complete this process. Passengers and staff will be required to sign a declaration before landing. The Government Officer (GO) will inspect these. In the event that a vessel is permitted to undertake landings prior to arriving at King Edward Point, the EL must contact the GO to confirm that all persons going ashore have signed the declaration.
(On Merchant vessels and Warships, the Chief Officer or Executive Officer should oversee this procedure).
- No fresh meat, vegetables, fruit or dairy products, especially poultry products and eggs to be brought ashore.
- Vessels securing to the jetty at KEP must use serviceable rat guards at all times and gangways must be raised off the jetty at night.

All food on yachts must be stored in rodent proof containers. If berthed alongside the jetties at KEP or Grytviken then bait stations must be in use. Rat guards must used. (Bait stations will be provided at KEP).

- All staff and ships officers must ensure that biosecurity measures are fully implemented for every landing in order to minimise the risk of intra-island transfer.
- All visiting vessels must have South Georgia Biosecurity information on display in a public area. (Information sheets will be provided to vessels at the start of the season. Leaflets will also be included in each passenger's South Georgia visitor pack).

BIOSECURITY MEASURES FOR LANDING OPERATIONS

- Only open boats such as RIBs may be used to land passengers on the shoreline and beaches (any landing other than at the jetties at KEP, Grytviken and Bird Island). All boats must be thoroughly inspected for rodents and any organic material before embarking passengers and again when departing from the island to return to the ship. The Government Officer may randomly inspect these.
- All visitors must inspect bags and daypacks again for rodents before disembarking to go ashore. Bags should not be left open and unattended ashore and these should be inspected again before returning to the ship
- All boats with cabins or hold space (including tenders and Government boats), must have bait stations on board and the cargo area must be inspected and cleaned (including use of pesticide). Bait stations will be provided by GSGSSI.
- Rodent proof boxes to be used for all stores. (Boxes must be robust, fully sealed with no openings. Either plastic, metal or wood).
- No 'loose cargo' to be landed (such as loose items in open bags). All cargo should be inspected, boxed and sealed before landing.

Government of South Georgia and the South Sandwich Islands. 04.06.07

Biosecurity checks for all passengers embarking on journeys to visit South Georgia and the South Sandwich Islands

Invasive animal and plant species pose a very real threat to South Georgia's fragile environment. Prior to arriving in South Georgia the staff on your ship will supervise a number of biosecurity checks with you. However, before you leave home to embark on your journey, South Georgia Government requests that you assist us in protecting this very special island by undertaking some simple checks. By complying with the measures below you will personally be making a real and valuable contribution to the conservation of the island.

The following biosecurity measures are intended to protect the South Georgia and the South Sandwich Islands by preventing the introduction or transfer between landing sites of any organic material including animals, plants, seeds, soil and diseases.

Please undertake the following checks before you leave home.

- Ensure that the footwear you intend to take has been scrubbed clean and all soil and seeds removed.
- Check all of your clothing for soil, seeds and insects, especially cuffs, pockets, seams, hoods and all Velcro.

- Check that any equipment and luggage you plan to bring is clean and free of soil and seeds. This includes walking sticks, ski poles and tripods for cameras.
- Before packing, please vacuum and inspect inside any bags, particularly those that you plan to take ashore, to ensure absence of soil, seeds and insects.

Your assistance is greatly appreciated and the Government of South Georgia and the South Sandwich Islands hopes that you have very enjoyable and memorable visit.

Further information about the management of South Georgia may be found on the Government's website: www.sgisland.gs

GSGSSI April 2009

APPENDIX 2: DATASHEET FOR BAIT TO BE USED IN PHASE 1 (BELL LABS' 25W CONSERVATION)

<i>BRODIFACOUM 25W CONSERVATION MSDS</i>				
SAFETY DATA SHEET	ACCORDING TO EEC DIRECTIVE: 93/112/EEC	DATE OF ISSUE: 13 August 2010	PREPARED BY: CAR	
1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND COMPANY				
PRODUCT NAME: <i>BRODIFACOUM 25W CONSERVATION</i>				
USE: Anticoagulant Rodenticide	MANUFACTURER/IMPORTER: Bell Laboratories, Inc. 3699 Kinsman Blvd. Madison, WI 53704 USA	EMERGENCY PHONE NO.: 1-877-854-2494 (United States/Canada) +1-651-917-6125 (Outside United States/Canada) or Local or Regional Poison Control Center		
FORM: Formulated Dry Bait				
2. COMPOSITION/INFORMATION ON INGREDIENTS				
COMPOSITION: Brodifacoum [3-[3-(4'-Bromo-[1,1'-biphenyl]-4-yl)-1,2,3,4-tetrahydro-1-naphthalenyl]-4-hydroxy-2H-1-benzopyran-2-one]	% BY WEIGHT: 0.0025 %	CAS NO.: 56073-10-0	ECC NO.: Not Established	
3. HAZARD IDENTIFICATION				
PRIMARY ROUTES OF ENTRY: Ingestion.				
4. FIRST AID MEASURES				
EYE CONTACT: Flush with cool water for at least 15 minutes. If irritation develops, obtain medical assistance.				
SKIN CONTACT: Wash with soap and water. If irritation develops, obtain medical assistance.				
INHALATION: None				
INGESTION: Call physician or emergency number immediately. Do not give anything by mouth or induce vomiting unless instructed by physician.				
SYMPTOMS: Ingestion of excessive quantities may cause nausea, vomiting, loss of appetite, extreme thirst, lethargy, diarrhea, bleeding.				
ADVICE TO PHYSICIAN: If ingested, administer Vitamin K ₁ intramuscularly or orally as indicated by bishydroxycoumarin overdoses. Repeat as necessary as based upon monitoring of prothrombin times.				
5. FIRE-FIGHTING MEASURES				
EXTINGUISHING MEDIA: Extinguish with water, foam or inert gas.				
MEASURES UNSUITABLE FOR SAFETY REASONS: None				
PROTECTIVE EQUIPMENT: Firefighters should be equipped with protective clothing and self-contained breathing apparatus.				
6. ACCIDENTAL RELEASE MEASURES				
PERSONAL PROTECTION: Gloves should be worn during clean up.				
ENVIRONMENTAL PROTECTION: Avoid entry to watercourses.				
CLEAN UP AND DISPOSAL: Sweep up spilled material, place in properly labeled container for disposal or re-use. Dispose of all wastes in accordance with all local, regional and national regulations.				
7. HANDLING AND STORAGE				
HANDLING: Keep product in the original container. Do not handle the product near food, animal foodstuffs or drinking water. Keep out of reach of children. Do not use near heat sources, open flame, or hot surfaces. Wash thoroughly with soap and water after handling.				
STORAGE: Store in a cool, dry place inaccessible to children, pets and wildlife. Keep container tightly closed when not in use. Avoid contamination of lakes, streams and ponds by use, storage and disposal.				

Trade Name: Brodifacoum 25W Conservation
Supplier: Bell Laboratories, Inc.

Date Created: 13 August 2010
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8. EXPOSURE CONTROL/PERSONAL PROTECTION			
SPECIAL PROTECTIVE EQUIPMENT: Not Required	VENTILATION: Not required	RESPIRATOR TYPE: Not required	
SKIN PROTECTION: Rubber gloves (recommended)	EYE PROTECTION: Not required	HYGIENE RECOMMENDATIONS: Wash thoroughly with soap and water after handling.	
9. PHYSICAL AND CHEMICAL PROPERTIES			
APPEARANCE: Blue pellets with sweet grain-like odor.	BOILING POINT: N/A	MELTING POINT: N/A	FREEZING POINT: N/A
FLASH POINT: N/A	DENSITY: N/A	VAPOR PRESSURE: N/A	SOLUBILITY: N/A
10. STABILITY AND REACTIVITY			
STABILITY: Stable if stored in original container in a cool, dry location			
INCOMPATIBILITY/CONDITIONS TO AVOID: Strongly alkaline materials.			
HAZARDOUS DECOMPOSITION PRODUCTS: Oxides of carbon.			
11. TOXICOLOGICAL INFORMATION			
LD50, ORAL (INGESTION): >5000 mg/kg (rats)	LD50, DERMAL (SKIN CONTACT): > 5001 mg/kg (rats)	LC50, INHALATION: N/A	
EYE IRRITATION: None (rabbits)	SKIN IRRITATION: None (rabbits)	DERMAL SENSITIZATION: Not Considered a Sensitizer	
12. ECOLOGICAL INFORMATION			
ENVIRONMENTAL BEHAVIOR: Solid, non-volatile. Material is essentially insoluble in water.			
ENVIRONMENTAL TOXICOLOGY: Prevent access to non-target mammals and birds.			
EFFECTS ON WASTEWATER TREATMENT: Unlikely to have any effect on wastewater treatment.			
13. DISPOSAL			
WASTE DISPOSAL METHOD: Wastes resulting from use may be disposed of on-site or at an approved waste disposal facility. Dispose of all wastes in accordance with all local, state and national regulations.			
14. TRANSPORT INFORMATION			
CLASSIFICATION: Not regulated or not classified as dangerous by DOT (USA), IATA (Air), or IMDG (Vessel).		SHIPPING NAME: Rodenticide containing Brodifacoum.	
15. REGULATORY INFORMATION			
CLASSIFICATION: Not classified as Dangerous for supply/use.			
16. OTHER INFORMATIONS			
The information provided in this Safety Data Sheet has been obtained from sources believed to be reliable. Bell Laboratories, Inc. provides no warranties, either expressed or implied, and assumes no responsibility for the accuracy or completeness of the data contained herein. This information is offered for your consideration and investigation. The user is responsible to ensure that they have all current data relevant to their particular use.			

Trade Name: Brodifacoum 25W Conservation
Supplier: Bell Laboratories, Inc.

Date Created: 13 August 2010
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APPENDIX 3: WASTE MANAGEMENT PLAN FOR RODENT ERADICATION ON SOUTH GEORGIA

1. Introduction

It is GSGSSI policy that all waste from South Georgia, other than sewage or wet domestic waste, should be removed from the islands (Pasteur and Walton, 2006). The amount of waste produced (particularly packaging) should be minimized in the first instance, and items re-used or recycled where possible.

The Project Director has responsibility for waste management, but may nominate a member of the eradication team to supervise waste management operations.

2. Waste Disposal Procedures

Procedures developed to dispose of waste at King Edward Point are based on the separation of wastes at source, followed by compaction. Waste will be removed from South Georgia by ship for disposal in the Falkland Islands (general waste) or the UK (recycling and hazardous waste).

Waste at FOBs will be returned to KEP where possible. Some empty fuel drums and bait containers may be left securely tied down at FOBs for later collected by ship. Bait containers will be reused where possible.

Wastes categories (based on the *Environmental Protocol to the Antarctic Treaty*) are classed as:

Group 1. Sewage and domestic liquid wastes:

Sewage, grey water and wet domestic waste will be discharged directly to the sea below the low water mark in an area where the current/tide will involve rapid dispersal and dilution.

Group 2. Other liquid wastes and chemicals, including fuel and lubricants:

Waste fuels and lubricants will be packed and clearly labelled as per the BAS Waste Management Handbook and stored at KEP to await shipping.

Group 3: Solids to be combusted

A small incinerator may be taken to KEP by GSGSSI which would allow for combustion of waste poultry products, waste bones and other materials. Special care will be taken with waste poultry products (including egg shells) since they can carry avian viruses which may be a danger to Antarctic birds, particularly penguins and skuas. Waste poultry products will be boiled for at least ten minutes and the remains burned in the incinerator. No poultry products should be taken to areas other than Grytviken and KEP.

Group 4: Other solid wastes

Compactable material such as plastics, card and paper and fabrics should be returned to KEP for compacting. Bait bags will be compacted.

Glass and aluminium cans should be placed in the appropriate containers at KEP for recycling.

Scrap metal and wood should be packed for recycling where appropriate.

Empty fuel drums will be returned to KEP. The dregs should be decanted (using absorbent mats in case of spillage) and, where practical, used in station boilers or heaters. Empty

drums may be used at KEP for waste storage. Other drums will be sent out by ship for reuse in the Falklands or landfill.

Group 4: Other solid wastes (hazardous)

Clinical/medical and sanitary wastes will be packed and labelled as per BAS Waste Management Handbook at KEP.

Used batteries, waste chemicals and other hazardous substances (e.g. paints, glue) will be packed and labelled as per BAS Waste Management Handbook and stored at KEP for onward shipping to UK.

<p>APPENDIX 4: MANAGING THE RISK TO PINTAILS OF RAT ERADICATION ON SOUTH GEORGIA: AN UPDATE</p>
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Report to SGHT by A.R. Martin, September 2009

Introduction

One of the greatest potential drawbacks of a pest eradication programme on any island is that of unintended negative impacts on non-target species. Such concern is of course amplified when the potential victim is endemic.

The proposed spreading of brodifacoum bait to remove brown rats on South Georgia has the potential to negatively affect several species of birds to some extent, but only one taxon at risk is endemic to the island – the South Georgia pintail (*Anas g. georgica*). In a previous paper (submitted to the April 2009 trustees meeting) I outlined the possible consequences of the eradication campaign to this duck, and proposed a number of lines of research that could provide guidance on how to minimise the risk of fatally poisoning enough birds to significantly impact the population as a whole.

The purpose of the current paper is to assess the results of some initial applied research on this pintail and, in light of this, (a) re-assess the risks of the baiting campaign, and (b) propose what research might offer answers to the most pressing remaining questions in a cost-effective way.

Results of research undertaken hitherto

Within the period January-March 2009, in conditions quite similar to those pertaining on South Georgia during the proposed baiting window, I exposed two groups of captive-bred South Georgia pintails to PestOff 20R bait pellets. These were identical in every regard to the bait proposed for use on South Georgia, except that they contained no toxin. Like the toxic bait, these pellets were dyed green, and this dye would be apparent in the faeces of any animal consuming it. Trials were carried out in the Fens north of Cambridge, UK. Temperatures were between -6 and +10 degrees Celsius, and there was precipitation most days – rain and occasionally snow.

PestOff pellets remained intact for periods of weeks on the saturated ground, but then slowly degraded into a pulp. Fresh pellets were added every few days, to ensure that birds always had access to them.

PestOff pellets were provided on the ground *ad lib*, sometimes in piles but usually distributed randomly. Initially the birds' usual food (wheat and dry pellets) was provided in parallel, but over a period of 10 days this material was gradually reduced. In group 2 it was stopped

altogether for 2 weeks, then recommenced at a low level to prevent starvation. Birds in both groups became hungry, and in group 2 they lost weight substantially, some becoming emaciated.

Throughout the period, which involved >600 bird days of exposure to the PestOff, no bait was seen to be consumed and only one faecal sample was seen to be coloured by the dye in the bait. This had more the characteristics of moorhen faeces than pintail (moorhens occasionally got into the pen) and is not proof that any pintail ate any PestOff bait.

Implications of the Trial results

The reluctance of captive pintails to eat the PestOff pellets does not prove that no wild pintails would eat the same pellets, but the Trial does indicate that:

1. Toxic bait delivered in this form is not intrinsically attractive as food to pintails.
2. Even when in poor body condition and hungry, pintails are reluctant to eat the pellets.

Consequently, it would seem reasonable to infer that the probability of mass mortality of ducks due to ingestion of PestOff pellets on South Georgia is low. As such, there would appear to be little justification in using resources on either large-scale pintail research or the setting up of facilities to maintain ducks in captivity, away from baiting zones, before the 2011 baiting on Greene peninsula is carried out. Such activity should not be ruled out at a later stage, but the unambiguous feeding trial results have arguably changed expectations to the extent that proof of significant mortality would be required to justify these activities.

Next steps

The question as to whether *wild* ducks are vulnerable to PestOff bait could be answered by monitoring the fate of birds exposed to it during the Greene, Mercer and Thatcher Peninsula trial in March 2011. To do this effectively, it is insufficient merely to look for corpses after the bait has been spread. Even if none were found, this would not be evidence that none were killed. The likelihood of discovering a duck corpse in such a large area of dense vegetation would be very small, even if poisoned ducks died *in situ* and were not taken by predators or scavengers.

A far more robust result could be gained by tagging some birds with small VHF transmitters prior to the bait drop and following their fate subsequent to it. The transmitters could be relocated over ranges of hundreds of metres from a boat or land, and at distances of many km from a helicopter. Whether dead or alive, the ducks (or their remains) should be rediscovered.

The monitoring of pintails (and speckled teal if they are encountered) before and after aerial bait spreading on a relatively small area of South Georgia would seem to be a precautionary and pragmatic next step. Even if the captive trials were entirely misleading, and all wild birds exposed to the toxic bait ate it and died, the total number involved would very likely represent a small proportion of the South Georgia population. Especially at a time of year when many ducks will be flightless due to Primary moult, the probability of endangering the island-wide population by spreading bait on Green Peninsula must be remote in the extreme.

Methodology of the proposed monitoring

A sample of 10 birds captured on Greene Peninsula and remaining there after the baiting campaign should suffice to answer the question. To allow for birds moving away after capture, it may be necessary to mark more than this. Anecdotal reports indicate that

capturing 10-20 pintails should not pose too much of a problem over a period of a few days of adequately good weather.

Capture techniques would be those used safely and successfully on Bird Island with >500 pintails. Ducks would be captured individually after dark, using a net and a powerful torch. Transmitters would be leg-mounted, using a ring. Each bird would be uniquely identifiable by virtue of the frequency of its transmitter and a numbered colour-ring on the opposing leg. Feather-mounted devices would not be appropriate because adult ducks will be in full body moult around the time of the Trial. The leg-mounted transmitter design would be tested on captive pintails before field deployment.

A rigid Yagi antenna and a standard hand-held receiver would be used to relocate the birds both before and after the aerial baiting had taken place. If necessary, the baiting helicopter can be used as a high-level receiving platform to roughly locate each transmitter, but in each case an observer on the ground will be required to check whether the bird is alive or dead.

The research team (two people will be adequate) would need to be resident on Greene Peninsula for the duration of the capture work and for a few days afterwards to establish the normal movement patterns of the marked birds. Accommodation would be in the field hut on the Peninsula. Transportation from KEP and return would be by boat or helicopter.

APPENDIX 5: SOUTH GEORGIA RODENT ERADICATION PLANNING DOCUMENT: REVISED RODENT DISTRIBUTION AREAS AND BOUNDARIES

Prepared by Dion Poncet and Sally Poncet

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Attached as separate file.