REPORT ON MORTALITY OF NON-TARGET SPECIES FOLLOWING YEAR 1 OF PHASE 2 OF THE SOUTH GEORGIA RODENT ERADICATION

Jennifer Lee, Andy Black, Graham Parker and Kalinka Rexer-Huber

November 2013

Table of contents

1. SUMMARY

With funding support from the South Georgia Heritage Trust (SGHT), the Government of South Georgia and the South Sandwich Islands (GSGSSI) is conducting a programme monitoring into the non-target mortality following rat eradication. This report covers the findings of non-target monitoring within the Stromness and Salisbury baiting zones, from early March to mid May 2013. In summary:

- Brown skuas suffered a high degree of non-target mortality in the areas monitored during Phase 2. Birds were vulnerable to primary, secondary and tertiary poisoning. Direct consumption of bait pellets, was not observed in Phase 1 but was observed frequently during phase 2, indicating that this species is vulnerable to primary poisoning.
- South Georgia pintail were highly vulnerable to primary poisoning. In the absence of rats, this species has the potential to rapidly recover from the decline in the population caused by non-target mortality.
- Snowy sheathbills were subjected to a moderate to high risk of mortality during Phase 2 of the rat eradication. Where a large number of birds congregated around king penguin colonies, the risk was apparently lower (moderate) than in areas with fewer scattered birds (Stromness and Phase 1). However, sheathbill mortality was on going at the end of the study and is therefore likely to have been higher than reported here.
- Although kelp gulls were present throughout the areas monitored, very few carcasses were recovered. These observations are in line with those from the Phase 1 area but contrary to observations on other sub-Antarctic Islands where kelp gull mortality was high.
- Foraging giant petrels were far more numerous in the Salisbury zone than the Stromness zone and Phase 1 area. However, only a single carcass of a bird poisoned by brodifacoum was found, suggesting a negligible impact on the local population.
- Although no carcasses were found, the apparent disappearance of the South Georgia pipits from Grass Island is of concern as passerines elsewhere are known to be at risk from primary and secondary poisoning.
- Over-flying king penguin colonies at between 500 and 1,000ft caused some disturbance to loafing birds but had no detectable effect on adults brooding eggs or chicks.
- Overall, non-target mortality was at an acceptable level and the benefits of rodent removal to the island as a whole far outweighs the short-term impacts on a small number of species.

2. INTRODUCTION

2.1 Background

The Norway rat (*Rattus norvegicus*) is one of the most widely spread invasive mammals in the world. Rats can cause extensive damage to native ecosystems and are known to restrict the regeneration of many plant species by eating seeds and seedlings (Moles and Drake, 1999). They also prey upon many animal species including small birds and birds' eggs (Major et al., 2006).

It is likely that rats were accidentally introduced to South Georgia on numerous occasions over the past 200 years. Rats and house mice (*Mus musculus*), are the only mammalian land predators on the archipelago and, prior to commencement of the eradication programme, rats had successfully expanded their range to cover most of the mainland (Pye and Bonner, 1980) and mice covered a discrete area along the south-western coastline. As elsewhere, rats have a detrimental effect on the native bird fauna including the endemic South Georgia pipit (*Anthus antarcticus*) and most of the small ground-nesting and burrowing petrels and prions, which are unable to survive in the presence of rats (Pye et al., 1999).

Following successful eradications of rodents on other, smaller, sub-Antarctic islands (McClelland, 2001; Torr, 2002), the SGHT embarked upon a project to eradicate rodents from South Georgia. Following a successful trial of the aerial baiting methodology in March 2011, in February 2013 this operation entered Phase 2 with the aim of eradicating rodents from all remaining infested areas of the island (see http://www.sght.org/sght-habitat-restoration-project). This second phase of the project is scheduled to take at least two summer seasons to complete.

The toxin selected for the eradication was the second-generation anti-coagulant brodifacoum, which was delivered within cereal pellets. Brodifacoum was chosen as it is effective after one dose, is persistent in the environment (with a half life of 12-25 weeks) and the active ingredient is not soluble in water (therefore the toxin does not leach into the soil or contaminate water courses). However, some of these properties also increase the risk of non-target mortality. The concentration of the active ingredient in each pellet (25 parts per million) is enough to kill most rats after consumption of a single pellet. Although designed to be palatable to rodents, pellets can also be attractive to other species (Dowding et al., 1999; Eason et al., 1999; Eason et al., 2002), resulting in primary poisoning. Vertebrate predators and scavengers that feed on poisoned rats or poisoned non-target species will succumb to secondary/tertiary poisoning if sufficient toxin is ingested.

Although the overall long-term benefits of removing invasive species far outweigh the short-term impact on individual populations, monitoring mortality of non-target species is essential.

2.2 Non-target mortality during Phase 1 of the rat eradication

Following Phase 1 of the South Georgia rodent eradication, systematic searches of key habitat resulted in the collection of 174 bird carcasses, the majority of which were South Georgia pintail (*Anas georgica georgica*) (Black, 2011). Other species affected were brown skua (*Stercorarius antarcticus),* snowy sheathbill *(Chionis albus)* and kelp gull *(Larus dominicanus).* Although the results from Phase 1 informed monitoring priorities for Phase 2, the relative abundance of species present in the areas covered during Phase 2 differed from that found in the Phase 1 area, making further monitoring necessary. In particular, the presence of far higher numbers of penguins and Antarctic fur seals (*Arctocephalus gazella*) appears to influence the distribution and feeding habits of scavenging birds. For instance, the number of giant petrels, brown skuas and sheathbills feeding terrestrially in association with large king penguin (*Aptenodytes patagonicus*) colonies or beaches with high fur seal density was markedly different to anything encountered within the area baited during Phase 1.

On South Georgia, king penguins are known to react to the presence of overflying helicopters (Hughes et al, 2008). No large aggregations of king penguins were present in the Phase 1 area and so the impact of over flights would have been minimal. However, the presence of several large king penguin colonies within the Phase 2 area necessitated the monitoring of bird behaviour when helicopters were flying overhead.

This report provides the results of the monitoring in the Phase 2 area following the baiting operation in March and April 2013.

3. MATERIALS AND METHODS

3.1 Study sites

Only species of bird that forage on land are at risk from non-target mortality as a result of consuming brodifacoum. Of the thirty-five species of seabird that nest on South Georgia, this places seven at risk namely: South Georgia pintail, snowy sheathbill, brown skua, northern and southern giant petrel, kelp gull and South Georgia pipit. It was not logistically, or financially feasible to monitor non-target mortality in all areas. Instead, two baiting zones were selected to allow monitoring of non-target mortality for the maximum length of time possible and in areas that contained the full suite of species that were likely to be at risk.

3.1.1 Stromness zone

The Stromness zone was the second largest to be baited in the 2013 season, after the Northwest zone, and consisted of a treatment area of 16,267 ha, of which 4,400 ha is vegetated. Baiting operations took place between the 3rd of March and the 17th of March and dedicated monitoring teams were in place between the 3rd of March and the 8th of May (although field teams had been present in the are throughout January and February)

The Stromness zone was selected as it was the first area to be baited and therefore allowed field teams to intensely monitor non-target mortality for at least a two full months post-baiting prior to the onset of winter. This was thought to be important as the results from Phase 1 indicate that fresh carcasses were still found eight weeks after the bait had been dropped. The timing of the monitoring in the Stromness zone was also significant, as many of the species at risk from non-target mortality were still breeding/provisioning dependent chicks in March when the bait was broadcast. Although the area is relatively large, it was mostly accessible on foot from a field hut approximately 1 km west of Tønsberg Point, and so allowed a single field team to monitor a large area.

Figure 1. Field hut near Tønsberg Point

Although the king penguin colony in Fortuna Bay is relatively small (ca. 7,000 pairs; Poncet and Crosbie, 2005), it was selected for over-flight monitoring since it was one of the first to be baited during Phase 2 of the project. As such, it provided valuable information about penguin behaviour during baiting before the over-flights of larger colonies later in the baiting programme.

3.1.2 Salisbury zone

The Salisbury zone consisted of a treatment area of 3,581 ha, of which 342 ha is vegetated. Baiting operations took place between the 29th of March and the 8th of April (although there was a gap between the 30th of March and the 6th of April) and monitoring teams were in place between the 29th of March and the 13th of May.

The zone is home to large wildlife aggregations, including the king penguin colony at Salisbury Plain, the largest to be baited during the first season of Phase 2. This was therefore a critical site for over-flight monitoring. There are also large populations of species susceptible to non-target poisoning in the area, such as skuas, which along with numerous kelp gulls and giant petrels feed and/or occur in association with the king penguin rookeries. Much of the area could be accessed on foot allowing a single field team to monitor the entire zone.

Personnel were based at a tented camp in Sea Leopard Fjord (Figure 2).

Figure 2. The campsite at Sea Leopard Fjord was situated in an area of flat ground surrounded by tussac grass (*Poa flabellata*)

Initially it had been hoped to deploy a monitoring team in the Northwest zone, but by early April it became apparent that there was a chance that this area might not be baited, or would only be baited at the very end of the fieldwork season. To ensure that the field team was able to monitor for a reasonable period (i.e. at least one month post-baiting), it was decided to switch to the fall-back position of monitoring the Salisbury zone.

3.2 Systematic searches

Field teams of two people systematically searched relevant habitat types (skua breeding sites and clubs, beaches, freshwater margins, knolls and wetlands with dense tussac grass) for bird carcasses. Initially it was thought that distance searched and/or time spent searching would provide a good indication of search effort but it quickly became apparent that both these measures were imperfect as searching a long distance in unfavourable habitats would lead to a misleading representation of search effort. Additionally, weather related factors, such as snow and ice cover, influenced the detectability of carcasses, which is not reflected in search effort alone. Instead, field teams defined fixed search areas (see section 4.1 and 5.1 for maps), which were systematically searched at 2–4 day intervals to quantify the timing and extent of non-target species impacts over time. The time spent in each search area varied depending on the weather conditions and number of carcases found but would typically be between four and six hours.

Since mitigation (through removal of carcasses) was also a key focus of this work, every carcass found was removed and subsequently buried, and efforts were made to extend the search range, covering as large an area as possible. Removal of carcasses will have reduced the rate of secondary and tertiary poisoning leading to a slight under-representation of true mortality.

With the exception of giant petrels, field teams made counts of the number of live birds present in each search area to provide some indication of how non-target mortality affected local populations.

3.3 Determining the presence of toxin

The bait pellets used for the eradication incorporated a marker (pyranine) that glows bright green under ultra-violet light. Although the poison (brodifacoum) accumulates in the liver, the marker is typically seen in the intestines and the lining of the gizzard. When an unscavenged bird was found, the abdominal cavity was opened to determine whether pyranine was present (Figure 3). In most cases internal haemorrhaging was also clearly visible and the location of this (for instance sub-cutaneous, abdominal, pericardial) was also noted. This was a useful indicator of brodifacoum poisoning in individuals where heavy abdominal bleeding made dissection and exposure of the gizzard problematic (Hosea, 2000). A liver sample from each bird was taken as a means of retrospectively testing/confirming the presence of brodifacoum.

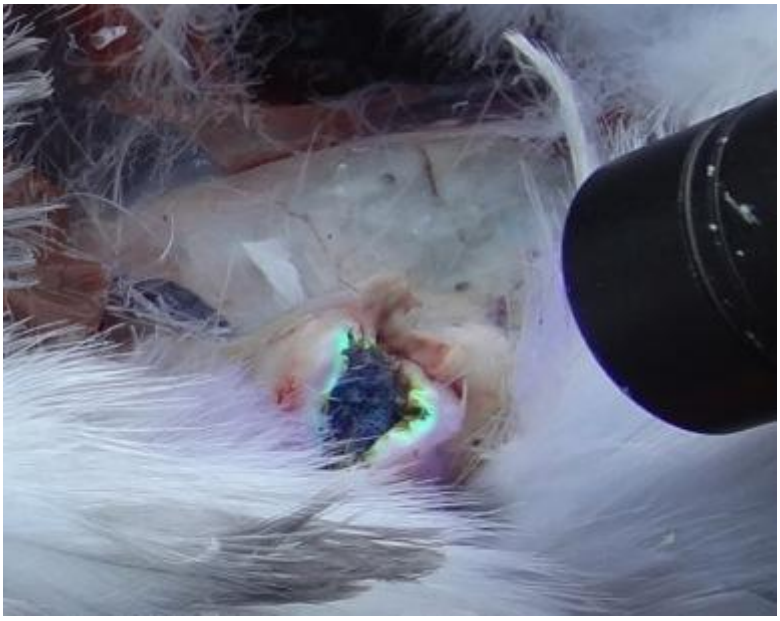

Figure 3. Gizzard of a northern giant petrel (*Macronectes halli*) showing the fluorescing marker

3.4 Post-mortem measurements

For each carcass, the bird was identified and, where appropriate, weighed, sexed and measured (culmen, total head, primary and tarsus length). For South Georgia pintail, moult stage was also noted. Carcasses were scored to indicate freshness and the degree to which they had been scavenged.

All carcasses were subsequently buried at sufficient depth to prevent the risk of further scavenging.

3.5 Over-flight monitoring

Baiting of king penguin colonies was monitored at Fortuna Bay and Salisbury Plain. Observers positioned themselves at vantage points that provided a good view of the colony and used a video camera to film the reaction of the birds as the aircraft flew over. Pilots relayed information about the height of the aircraft to observers via VHF radio, and if necessary, observers could feed back information on penguin behaviour to pilots, allowing them to adjust their height. During over-flights, a note was made of any changes in colony behaviour, particularly movement of birds that were incubating eggs or attending to young chicks. After the over-flight, a search was made of the margins of the colony and a note was made of any newly dead chicks or abandoned eggs. The interior of the colony was not searched, as this would have likely caused an unacceptable level of disturbance.

4. RESULTS

4.1 Stromness zone

The main search areas in the Stromness zone are identified in Figure 4. The primary search areas were the vegetated areas within Stromness and Husvik Harbours (areas 3, 5 and 6), which were searched every 2–4 days. Searches extended to Fortuna Bay, Leith Harbour, Kelp Point, Jason Harbour and Carlita whenever possible, generally towards the end of the study period. Grass Island was visited once, on the 12th of April, 32 days after the island was baited. Overall, 272 bird carcasses were found in the 65 days after bait was first dropped in the zone (Table 1).

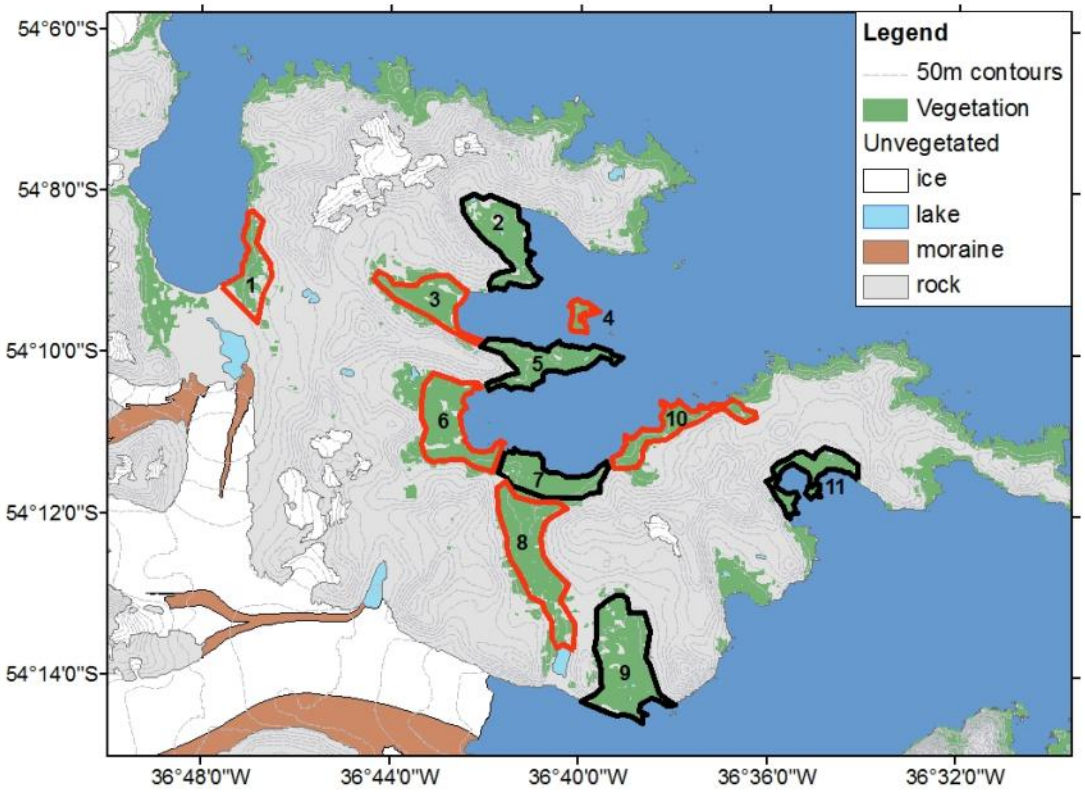

Figure 4. Search areas within the Stromness zone

1 = Fortuna Bay, 2 = Leith, 3 = Stromness, 4 = Grass Island, 5 = Tønsberg, 6 = Husvik, 7 = Olsen Beach, 8 = Olsen Valley, 9 = Carlita, 10 = Kelp Point and 11 = Jason.

Table 1. The number of carcasses collected in each search area

Search area	Pintail	Skua	Sheathbill	Giant petrel	Kelp gull	Total
1. Fortuna Bay		1				1
2. Leith	4	14	9			27
3. Stromness	1	6	1			8
4. Grass Island	6	2		3		11
5. Tønsberg	48	32		1	1	82
6. Husvik	27	26	1		4	58
7. Olsen Beach	3	13	1		1	18
8. Olsen Valley		4				4
9. Carlita	3	11				14
10. Kelp Point	1	9				10
11. Jason	22	16			1	39
Total	115	134	12	4	7	272

4.1.1 Brown skua

In total, 134 skua carcasses were found in the Stromness zone, of which 15% had been scavenged before they were located. All 123 skuas that were sufficiently intact to allow dissection of the gut, tested positive for pyranine. Counts of live birds suggested that the pre-baiting local population was between 200 and 250.

Many of skuas were found near SGHT's main camp at Husvik and near Tønsberg Point (Figure 5). Adult birds may have been drawn to the human activity in those regions in January and February during the reindeer eradication project and remained during March because of the large Forward Operating Base at Husvik Villa.

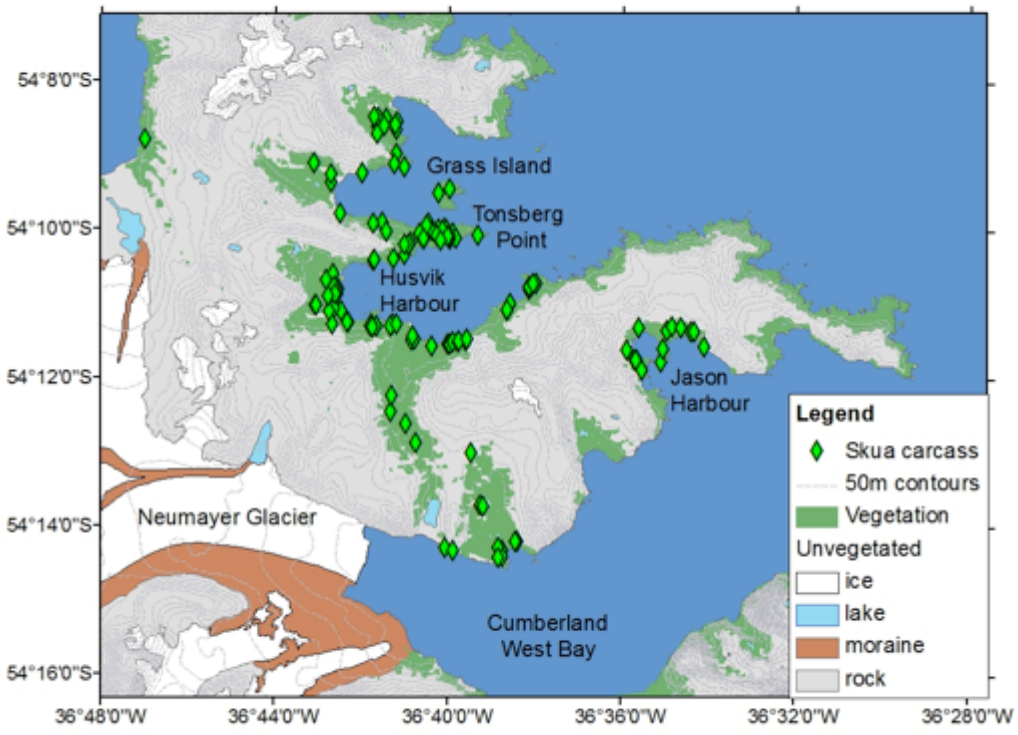

Figure 5. Location of skua carcasses in the Stromness baiting zone

The adult sex ratio was approximately equal (26 female: 28 male). There were equal numbers of adult and immature skuas (mostly this season's chicks found close to a nest cup, plumage still with traces of down). A high proportion of the immature skuas were found with another immature within c.5 m, apparently from the same brood. In almost all cases green faeces were clearly visible around the nesting area, sometimes with clumps of pasted-together bait pellets (4–8 per clump). Clumps appeared to have been regurgitated, as they would have been too large to have passed through the spreading hopper (P. Garden pers. comm.). This is indicative of primary poisoning and was supported by observations of skuas eating pellets throughout the zone.

The first skua carcass was found eight days after bait was a dropped and fresh carcasses (i.e. those which showed no sign of decay and likely died 24-48 h before discovery) were still being found 51 days later (Figure 6). Some birds had obviously been dead for a number of days/weeks before discovery, especially if they were found in an area that was visited infrequently e.g. Jason Harbour.

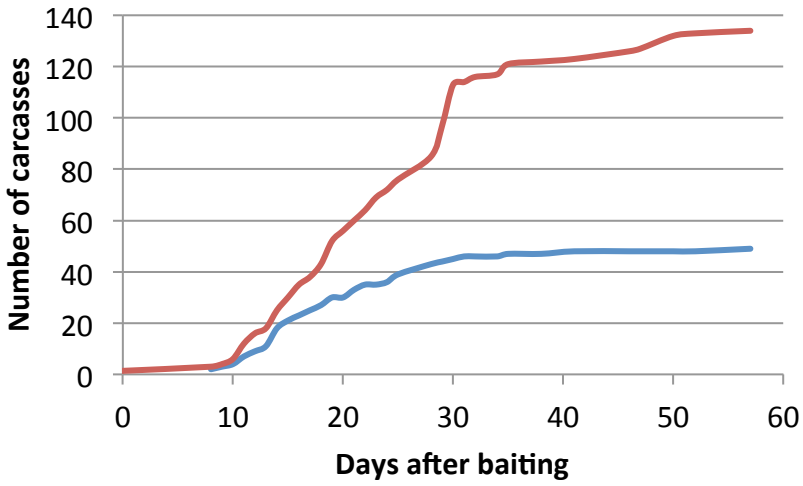

Figure 6. Discovery curves for the number of fresh skua carcasses (blue line) and all skua carcasses (red line) found in the Stromness zone.

By the end of the monitoring period, very few live skuas were present in the Stromness Zone. The small number of live skuas that remained had still not left South Georgia in early May, and were observed targeting white-chinned petrel (*Procellaria aequinoctialis*) fledglings.

4.1.2 South Georgia pintail

In total, 115 South Georgia pintails were found, of which 20% were scavenged before they could be located. Most carcasses were of adult ducks (97%) but two were immature and one was a duckling (although no pyranine was detected in the duckling). Carcasses were mostly found in pools and marshy areas with dense overhanging tussac, but occasionally also in the open areas that ducks frequent/graze at night. Pintail carcasses were concentrated in tussac pools at Kanin Point, Tønsberg Point, the area opposite Brain Island, and were also numerous on Grass Island (Figure 7).

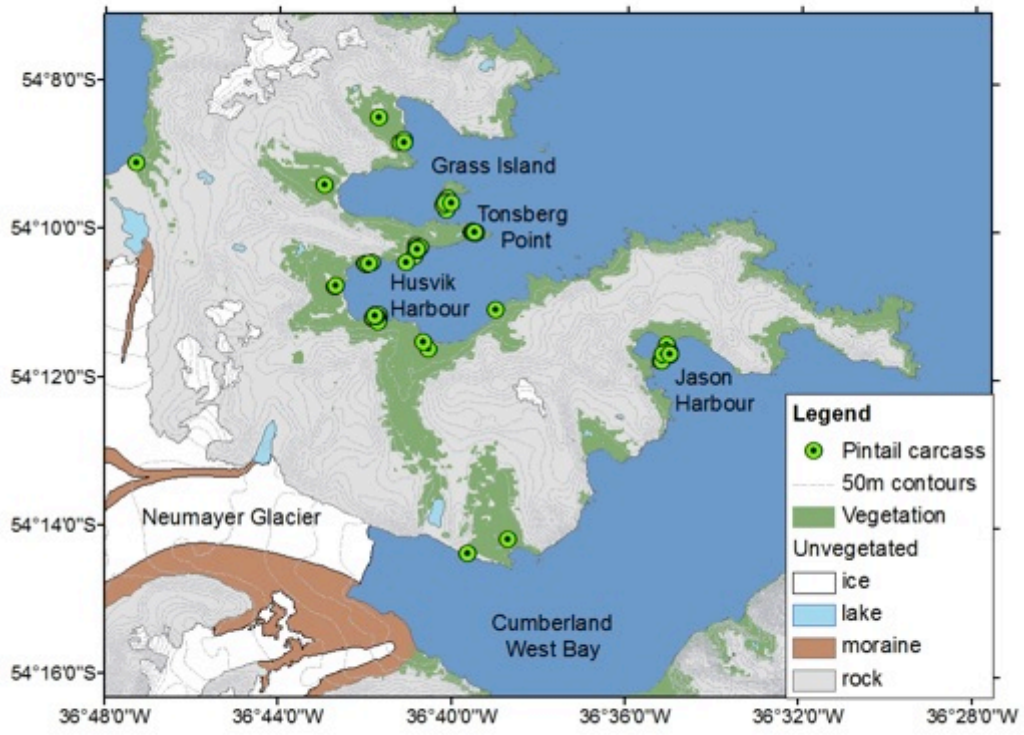

Figure 7. Location of South Georgia pintail carcasses in the Stromness zone. NOTE: location of pintail carcasses is highly aggregated around areas with suitable pools and so points are overlapping.

The sex ratio of carcasses collected was 1:1.3 (F:M), which is consistent with the male-biased sex ratio observed elsewhere on South Georgia (T. Martin pers. comm.). Frequent, thorough searches, combined with a declining skua population, meant that 92 pintails (80%) were found before they were scavenged. Detection of birds in primary moult was challenging as these birds typically sought refuge in deep tussac. However, moulting birds were regularly encountered throughout the search period and 24 (21%) of the carcasses were in active moult at the time of death.

The first pintail carcass was found seven days after bait was dropped and fresh carcasses were still being found 59 days post-baiting (Figure 8). Like skuas, some carcasses were found which had obviously been dead for a number of days/weeks, especially if they were found in an area that was visited infrequently. All of the 91 carcasses that were sufficiently un-scavenged to allow dissection of the gut, tested positive for pyranine.

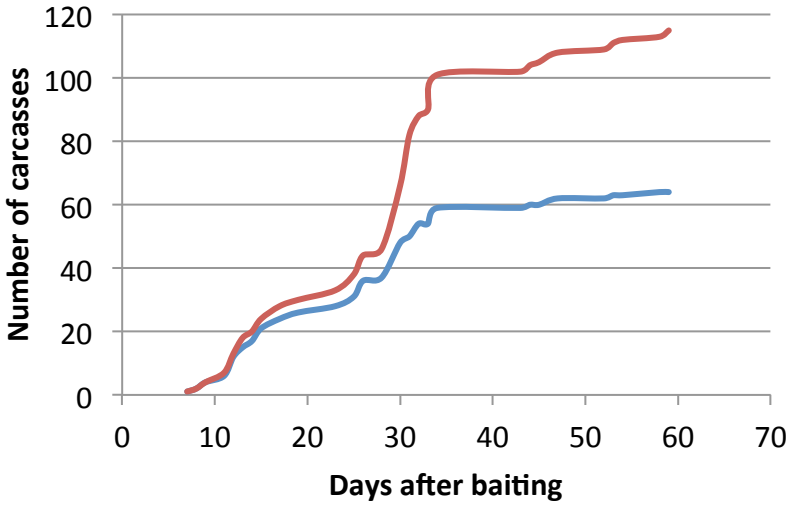

Figure 8. Discovery curves for the number of fresh South Georgia pintail carcasses (blue line) and all South Georgia pintail carcasses (red line) found in the Stromness zone.

Despite pintail mortalities, point counts of live ducks remained fairly constant over time, suggesting replacement via duck movement into the Stromness zone. Counts of live birds suggested that the local population was between 200 and 250.

4.1.3 Snowy sheathbill

Generally sheathbills appeared to be present in low numbers within the Stromness zone, probably because of a lack of a penguin or seal colonies in the area. Counts of live birds suggested that the pre-baiting local population was approximately 20.

Twelve sheathbill carcasses were found, of which seven were intact and five were scavenged. Nine of the sheathbills tested positive for pyranine, the other carcasses were either too degraded or unreachable to test. A low number of live sheathbills were still present in early May. Many of the sheathbills observed were in and around the old whaling stations at Husvik, Leith and Stromness, where they often associated with groups of southern elephant seals (*Mirounga leonina*).

4.1.4 Kelp gull

Seven kelp gull carcasses were collected, of which five were adults and two were immature birds. Four of the five kelp gulls, where an examination for pyranine was possible, were positive. One intact kelp gull did not have obvious pyranine but did have signs of internal bleeding, suggesting that toxin had been consumed. Kelp gulls were seen throughout the baiting period foraging close to the shore and roosting on coastal scree slopes suggesting

that the species was not heavily affected by either primary or secondary poisoning. Counts of live birds suggested that the local population was between 200 and 300.

4.1.5 Giant petrel species

Four southern giant petrel chicks were found dead. Three of these were on Grass Island, the other at Tønsberg Point. None of the chicks showed signs of internal bleeding suggesting that the mortality was natural, rather than as a result of the baiting operation and therefore the carcases were not included in final counts. The bird found at Tønsberg Point did show patchy fluorescence around the bill but the other birds tested negative for pyranine. However, the liver samples will be tested in case of false negatives; for instance brodifacoum ingested via parental provisioning, leaving chick without pyranine marker. The pre-baiting population was not surveyed here but counts in 2008 (Poncet, unpublished) indicated there are 175 breeding northern giant petrels and 126 breeding southern giant petrels in the Stromness area.

4.1.6 South Georgia pipit

Although pipits rarely breed in areas where rats are present, some individuals that nest on rat free offshore islands are known to disperse to the mainland. Pipits are known to be present on Grass Island and had been observed daily in the Tønsberg area throughout January and February (J. Lee & A. Black pers. obs.). Pipits were still conspicuous on the coast between the field huts and Tønsberg Point at the start of the baiting period and two adult pipits with recently fledged juveniles were observed daily for approximately one week. Counts of live birds suggested that the local population was approximately 25 birds. After the 19th of March pipits disappeared from the Tønsberg area and were not observed again until mid-April when one individual was seen at Tønsberg Point on three occasions.

Because of concerns that the pipits may have succumbed to either primary poisoning, secondary poisoning, from eating invertebrates (Bowie and Ross, 2006) that had eaten bait, or even tertiary poisoning from eating invertebrates that are feeding on carcasses of poisoned rats or non-target species, a survey of Grass Island was undertaken. Grass Island was searched thoroughly (10 man hrs; Figure 9) on the 12th of April, 32 days post-baiting, and no live pipits were detected.

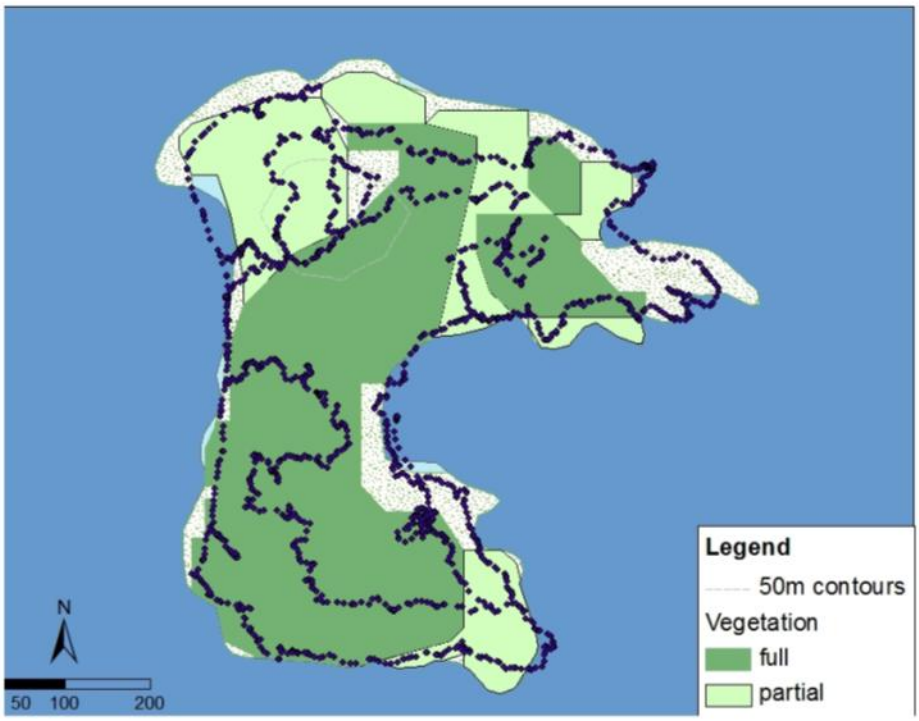

Figure 9. Search lines on Grass Island. NOTE: tracks followed coastline.

4.2 Salisbury zone

The Salisbury zone was divided into seven main search areas (Figure 10). Systematic searches of the Salisbury zone found 233 bird carcasses in the 45 days after bait was first dropped in the area (Table 2). Each area was typically visited every 3-4 days except Ample Bay, which was only visited once because the distance from the campsite made more regular searches of the area impractical.

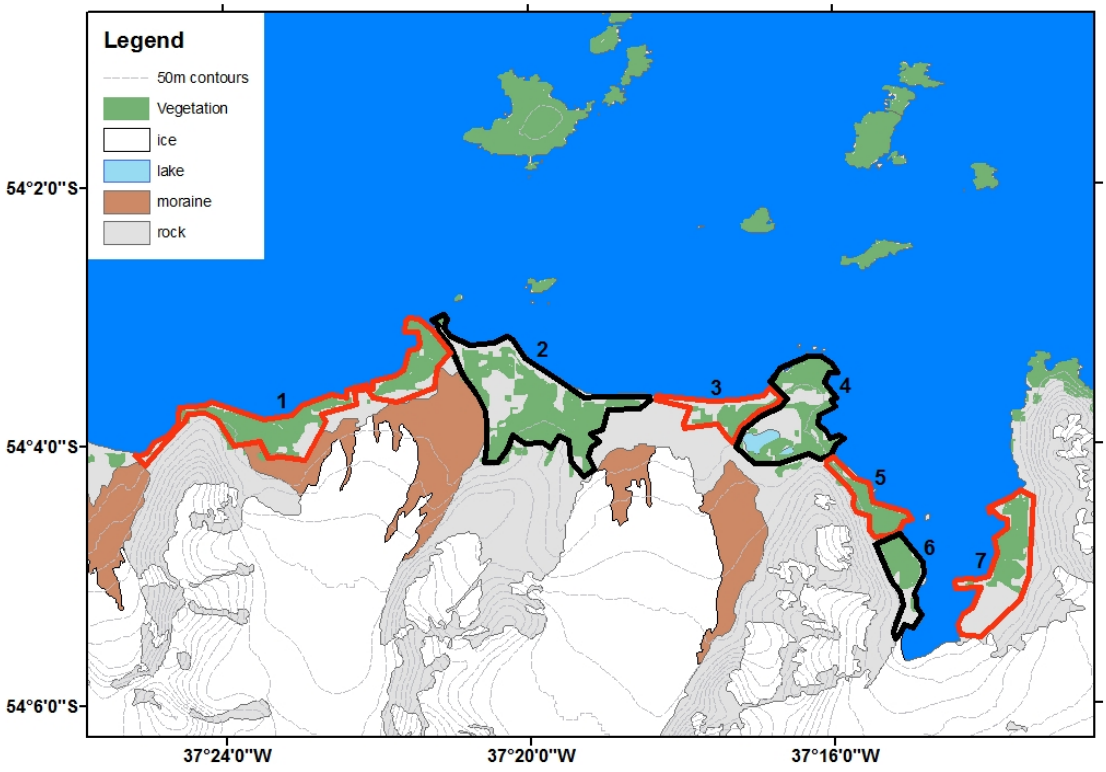

Figure 10. The Salisbury zone was divided into seven search areas. 1 = Ample Bay, 2 = Salisbury Plain, 3 = Echo Beach, 4 = Luck Point, 5 = Camp Tussac, 6 = Sea Leopard West and 7 = Sea Leopard East.

Table 2. The number of bird carcasses found in each search area.

Area	Pintail	Skua	Sheathbill	Giant Petrel	Kelp Gull	Total
1. Ample Bay	0	2	2	0	0	**4**
2. Salisbury Plain	9	15	18	0	1	**43**
3. Echo Beach	41	6	0	0	0	**47**
4. Luck Point	39	9	1	0	0	**49**
5. Camp Tussac	20	6	15	0	0	**41**
6. Sea Leopard West	5	3	0	1	0	**9**
7. Sea Leopard East	34	7	0	0	0	**41**
Total	**148**	**48**	**36**	**1**	**1**	**234**

4.2.1 Brown skua

In total, 48 skua carcasses were found, of which one was from a fledgling bird. Birds were typically found out in the open, often in close proximity to freshwater pools and known skua clubs (Figure 11).

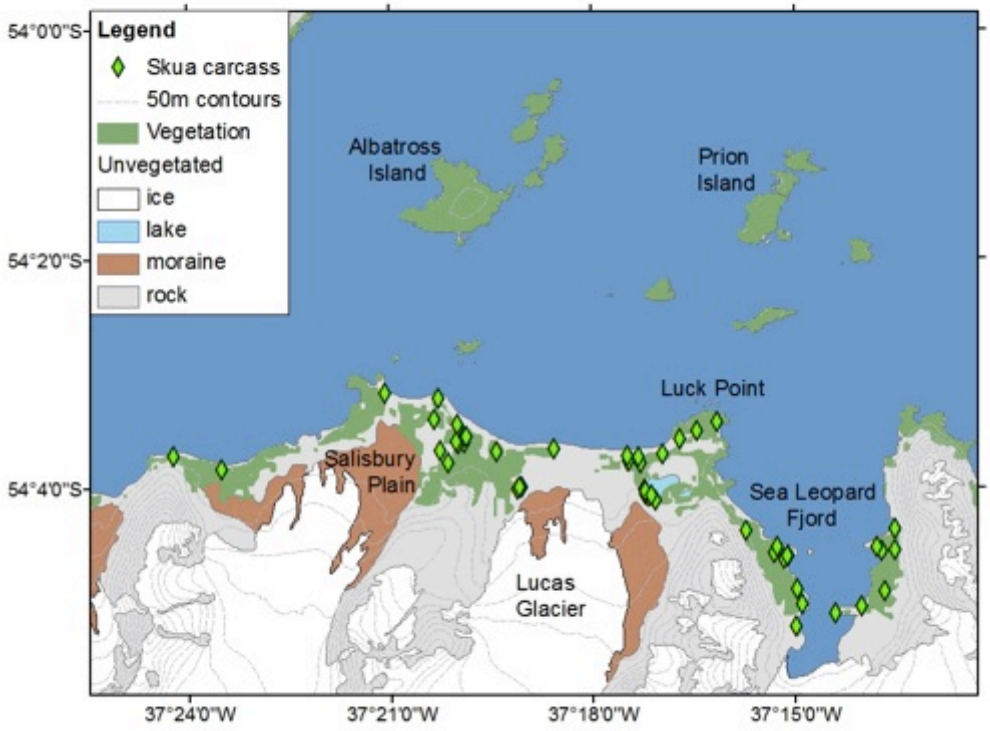

Figure 11. Location of skua carcasses in the Salisbury baiting zone

Of the 48 skua carcasses recovered, 34 birds (71%) were found intact and 14 (29%) had been scavenged either by other skuas or by giant petrels.

Twenty-three birds were either too scavenged or had too much internal bleeding to allow them to be sexed (skuas typically suffered heavy abdominal bleeding, which could make sexing birds problematic). Of the 25 birds that were sexed by internal examination of gonads, four were female and 21 were male. The sex bias is unexpected, and differs from the ratio recorded in the Stromness zone.

The first skua carcass was found six days after bait was dropped and fresh carcasses were still being collected 40 days post-baiting (observations ceased shortly after). The majority of skua carcasses found were fresh, although some of these had been scavenged. Towards the end of the sampling period some slightly older, more decayed, birds were found (Figure 12). Nevertheless, of the 39 birds that were examined for pyranine, all were positive.

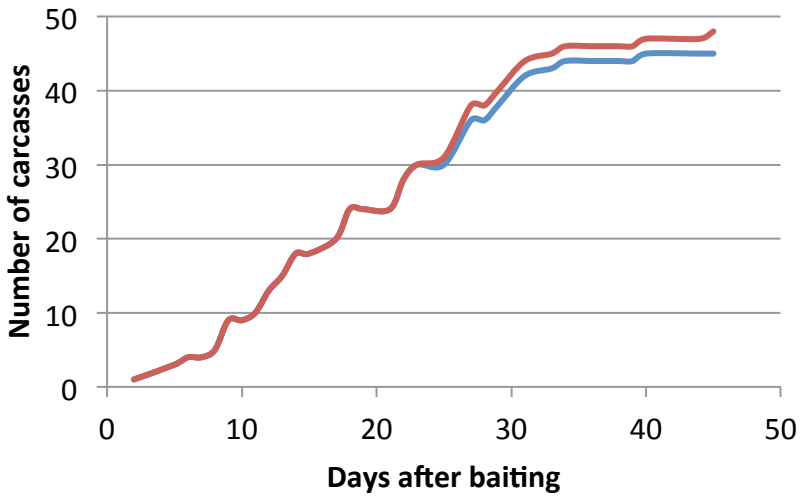

Figure 12. Discovery curves for the number of fresh skua carcasses (blue line) and all skua carcasses (red line) found in the Salisbury zone.

Counts of live skuas, especially around large king penguin colonies, remained high throughout the observation period. It was estimated that approximately 150-200 skuas occupied the core study area (excluding Ample Bay) at the time bait was dropped. Many more skuas are known to breed in the wider Bay of Isles area, with approximately 120 pairs breeding on Albatross and Prion islands alone (Poncet, 2012). Forty six carcasses were recovered, which gives an approximate mortality rate of 25-30% on the mainland population i.e. excluding birds on the off shore islands in the wider Bay of Isles area.

4.2.2 South Georgia pintail

In total, 148 adult pintail carcasses were found in the Salisbury zone. Carcasses were almost exclusively found in areas of freshwater pools with overhanging tussac. A high proportion of pintail carcasses were found in large ponds at Luck Point, Echo Beach and Sea Leopard Fjord (Table 2; Figure 13).

Ninety-one pintails (61%) were un-scavenged, whereas 57 (39%) showed some level of scavenging. From a sample of 77 adult birds that were sexed by internal examination, a sex ratio of 1:1.26 (F:M) was found. This is comparable with the sex ratio of birds found within the Stromness zone. Only 13 carcasses (approximately 9%) were found that exhibited active primary moult.

Pintail mortalities were on going at the time surveys ceased, 45 days post-baiting (Figure 14). Typically the field team found ducks within a few days of death; however, following heavy snow ducks became more difficult to locate and some slightly more decayed (but still pyranine-positive) carcasses were found later in the study period.

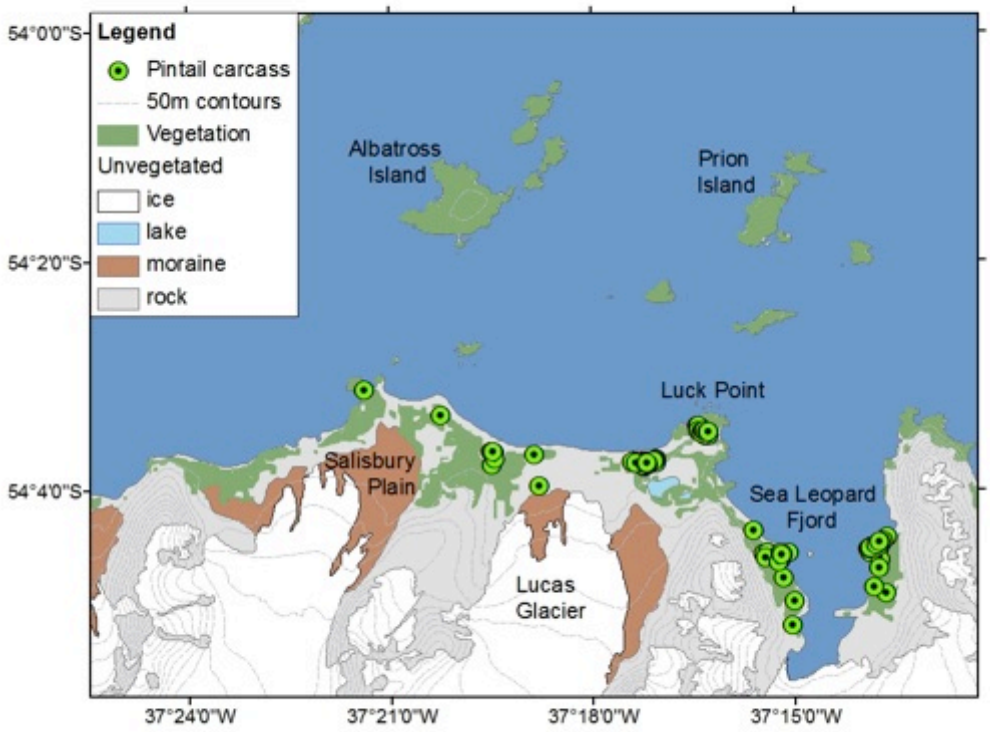

Figure 13. Location of South Georgia pintail carcasses in the Salisbury baiting zone. NOTE: location of pintail carcasses is highly aggregated around areas with suitable pools and so points are overlapping.

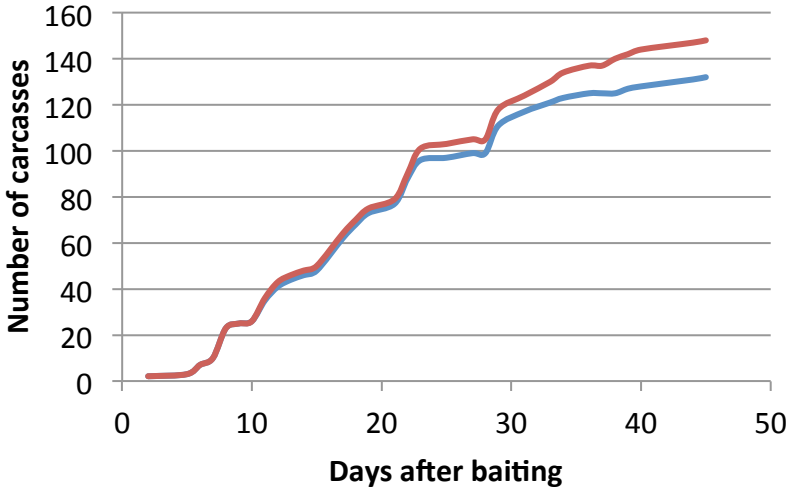

Figure 14. Discovery curves for the number of fresh South Georgia pintail carcasses (blue line) and all South Georgia pintail carcasses (red line) found in the Salisbury zone

Counts of live ducks remained high, until a period of cold weather (starting on the 23rd of April) when all of the freshwater pools froze and very few pintails were observed. It is unknown where the pintails went during the cold weather but it is clear that they left the search area. The distribution of pintails becomes more coastal during the winter months but in the Salisbury zone there was no evidence to indicate that the birds simply moved from freshwater pools to the adjacent coast.

At the time bait pellets were broadcast, there was an estimated 350-400 pintails in the area. At the end of the observation period, 148 dead pintails had been recovered and approximately 150 live pintail remained. This equates to a conservative estimate of approximately 40% mortality.

4.2.3 Snowy sheathbill

In total, 35 sheathbill carcasses were found; all but one of these were scavenged. Sheathbills were found almost exclusively in the immediate vicinity of king penguin colonies (Figure 15), often near to freshwater.

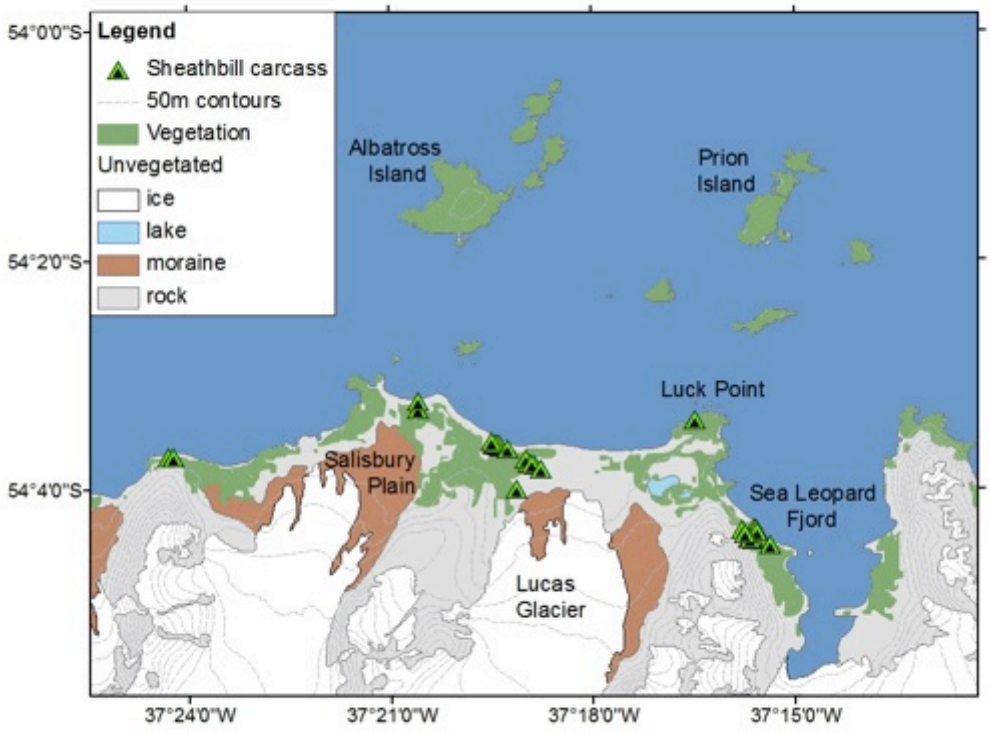

Figure 15. Location of snowy sheathbill carcasses in the Salisbury baiting zone

Although virtually all of the sheathbill carcasses recovered had been scavenged, the areas where carcasses were found were searched regularly and we are confident that the birds died during the study period. The abundance of scavenging birds and the conspicuous nature of sheathbill plumage made finding intact carcasses extremely difficult. The only intact carcass found was hidden under a rock.

Several hundred live sheathbills were observed in the study area and this number did not appear to change throughout the period of observations. Birds appeared to be primarily foraging in the immediate vicinity of penguin colonies and roosted on nearby scree or cliffs. Sheathbill carcasses were found in low numbers more or less continuously throughout the study period (Figure 16). Observations on the ground, and the slope of the discovery curve (Figure 16) indicate that sheathbill mortality would have continued for some time following the cessation of fieldwork. The overall impact on the species is therefore hard to quantify; however, the number of carcasses collected represented a small proportion (about 12%) of the overall number of live birds that were present at the time of baiting.

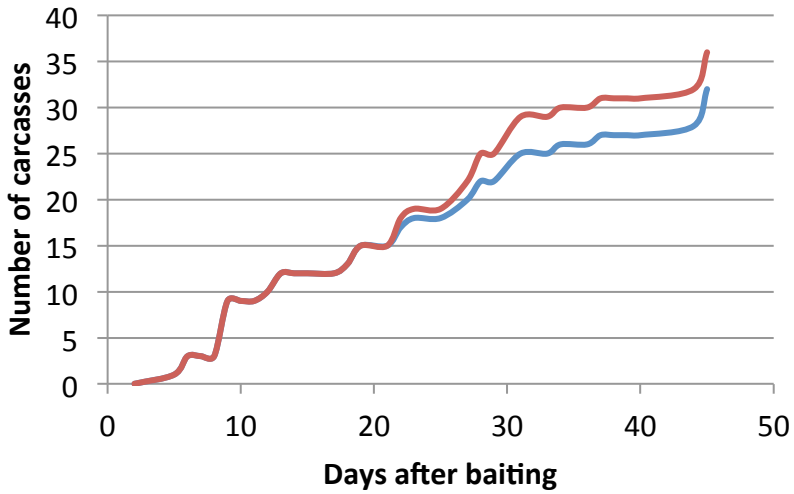

Figure 16. Discovery curves for the number of fresh (blue line) and all snowy sheathbill (red line) found in the Salisbury zone

4.2.4 Kelp gull

A single kelp gull carcass was found on the strand line at Salisbury Plain 31 days after baiting. It had been completely scavenged (only wings left) and therefore it was not possible to determine sex or if it had died as a result of brodifacoum poisoning. Kelp gulls were seen throughout the baiting period foraging over inshore waters and in the intertidal zone, suggesting that the species was not heavily affected by either primary or secondary poisoning. However flocks of several hundred kelp gulls were also regularly observed roosting ashore and therefore would have been exposed to bait pellets.

4.2.5. Giant petrel species

At the start of the observation period, southern giant petrel chicks were close to fledging: northern giant petrel chicks had already fledged. The pre-baiting population was not surveyed here but counts in 2008 (Poncet, unpublished) indicated there are 292 breeding northern giant petrels and 236 breeding southern giant petrels in the Salisbury area.

A single female northern giant petrel was found on the west side of Sea Leopard Fjord, 21 days post-baiting, an area where giant petrels were infrequently observed feeding. The bird tested positive for pyranine and showed signs of internal bleeding. However, on several occasions giant petrels were observed scavenging skua and pintail carcasses that subsequently tested pyranine-positive carcasses so even though only a single carcass was found more birds were exposed to the poison.

4.3 Incidence and location of internal bleeding

As bird carcasses were sampled, in addition to testing for pyranine, the location of internal bleeding was noted as this provided a further indication if the bird had died of ingesting brodifacoum (an anti-coagulant which causes internal bleeding) or of natural causes. Ninety-one per cent of birds had evidence of internal bleeding on autopsy. Approximately four present of birds showed no visible signs of obvious bleeding but proved positive for pyranine and two per cent of birds showed signs of obvious bleeding but did not test positive for pyranine. Many birds had bled in more than one location, 35% of skuas and 37% of pintails. The location of bleeding within skua and pintail carcasses was broadly similar (Figure 17). The abdominal cavity was the most common location to find bleeding in both species, with approximately 55-60% of birds examined showing abdominal bleeding (Figure 17). Thoracic and pericardial bleeds were more frequently observed in pintail whereas sub-cutaneous and pectoral bleeds were more frequently recorded in skua carcasses.

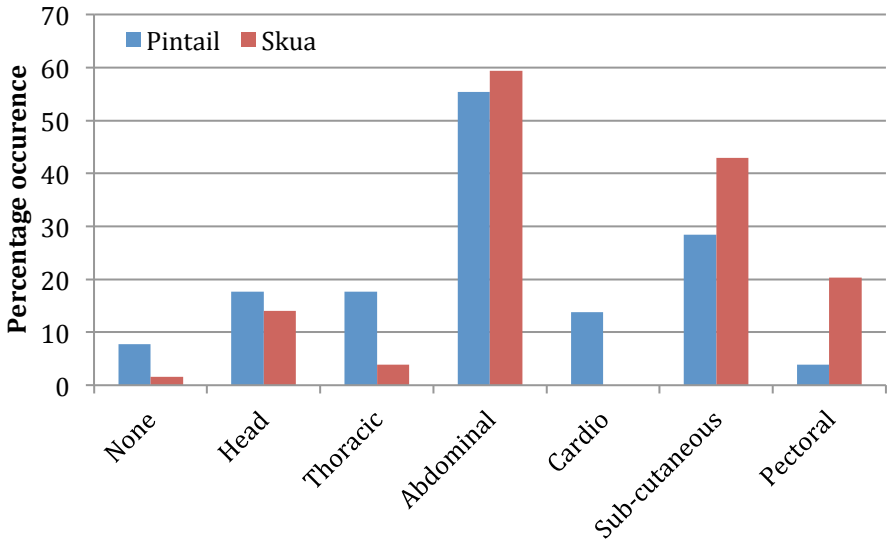

Figure 17. The location of internal bleeding in skua and pintail carcasses

4.4 Over flight monitoring

The Fortuna Bay penguin colony was baited on the 13th of March. The aircraft made passes over the colony at heights between 800 ft and 500 ft. In all instances, the birds on the periphery of the colony moved away from the area, typically in the direction of the sea. These birds were not associated with chick brooding or egg incubation and so this displacement is of no significance to the breeding success of the colony. No freshly dead chicks or abandoned eggs were found on the periphery of the colony immediately post-baiting.

Prior to the bait drop over the king penguin colony at Salisbury Plain, observations of a routine resupply flight to Rosita Harbour were made to gauge the level of disturbance to the colony. Two passes were made one at 700 ft and the other at 1000 ft. Flying at 1000 ft appeared to cause less disturbance than at 700 ft. Following discussion with the pilot (via VHF radio) it was deemed that at 1000 ft there was an acceptably low level of disturbance in the colony. Under reasonably calm conditions, broadcasting bait from this altitude should result in an even spread of bait pellets (P. Gardener pers. comm.).

At Salisbury Plain, the colony was baited on the 8th of April and over-flights were at 1000 ft. As at Fortuna, when the colony was over-flown, unattached birds vacated the area. The colony at Salisbury is a far larger than that in Fortuna Bay, and therefore many thousands of loafing birds moved out of the colony onto the open plain and birds that were aggregated on the beach moved into the water. However, birds that were attending eggs or young chicks generally did not move and there was no evidence of mortality of chicks or abandoned eggs.

For illustrative purposes, Figure 18 shows the same section of the colony before and during the bait was drop. The areas of bare ground in the lower image indicate areas that were occupied by loafing adult birds, which departed following helicopter disturbance. Incubating adults and older chicks remained in situ. Although there was considerable short-term disturbance, there is unlikely to have been any long-term impact on the colony. Loafing adult birds returned to the colony within 24 hours.

Figure 18. (a) King penguin distribution pre baiting and (b) king penguin distribution during baiting.

Prior to baiting the colony at Salisbury Plain, a cruise ship reported disturbance to the colony when an aircraft was transiting the area. As an official GSGSSI or SGHT observer did not witness this event, it is difficult to know what form this disturbance took. However, based on experience from other over-flights, it seems likely the cruise ship passengers observed a large-scale movement of unattached birds; while dramatic, this has no apparent negative impact on the colony.

5. DISCUSSION

The chronology of the non-target mortality showed that birds started to die 4-5 days after the initial bait drop and that the majority of mortality occurred within the first 30 days. However, in both study areas fresh carcasses were still being found at the time observations ceased, all be it at low levels, and so the numbers reported here are likely to under represent mortality to some extent. Mortality is further under-represented in both areas as some locations were visited infrequently, or not at all (in the case of west Fortuna Bay and Allen Bay in the Stromness zone). The removal of carcasses also acted as a mitigating

measure against further secondary or tertiary poisoning so the estimates presented here should be regarded as conservative.

5.1 Estimation of impact on non-target species in study areas

Throughout the observation period, the number of dead birds and the number of live, apparently healthy, birds were recorded at each location searched. The proportion of live and dead birds recorded during the observation period helped to estimate the impact on the local population, although there are many uncertainties with this approach, including rates of migration/dispersal during the study period.

Although the difficulties estimating live number of birds in each area before and during the observation period make it hard to estimate the risk of non-target mortality, broad categories of risk (High, Medium, Low and Negligible) can be assigned to each species (Table 3) in respect of the areas covered in this study. For the purposes of this report, a species is regarded to be at high risk of mortality where it was estimated that more than 25% of the local population died following consumption of brodifacoum. Medium risk is regarded as estimated mortality of between 10-25% of the local population. Where between 1% and 10% of the local population of a species was estimated to have died, the risk was deemed to be Low; mortality of less than 1% of the local population was regarded as Negligible risk.

Table 3. Assessment of species-specific potential risk of brodifacoum poisoning, based on data from the Stromness and Salisbury zones study areas

Species	IUCN Status	South Georgia population (breeding pairs)	Percentage of world population	Stromness		Salisbury		Risk of non-target mortality
				Local pop.	Carcasses	Local pop.	Carcasses	
Northern giant petrel *Macronectes halli*	LC	17,200[a]	45%[a]	175[b]	0	126[b]	1	Negligible
Southern giant petrel *Macronectes giganteus*	LC	8,700[a]	15%[a]	292[b]	0	236[b]	0	Negligible
South Georgia pintail *Anas georgica georgica*	LC	6,000[a]	Endemic sub-species	200-250	115	350-400	148	High
Brown skua *Stercorarius antarcticus*	LC	2,000[a]	10-20%[a]	200-250	134	150-200	48	High
Kelp gull *Larus dominicanus*	LC	2,000[a]	<1%[a]	200-300	7	200-250	1	Low
Snowy sheathbill *Chionis albus*	LC	2,000[a]	20%[a]	20	12	250-300	36	Moderate/ High†
South Georgia pipit *Anthus antarcticus*	NT	3,000[a]	100%[a]	25	0*	10	0*	Unknown

† In areas with no large king penguin colony the risk of non-target is high, in areas with large aggregations of king penguins, the risk of non-target mortality is moderate

* Although no carcasses were found there are residual concerns about the susceptibility of pipits to baiting (see text)

References: [a] Clarke et al 2012, [b] Poncet 2008 (unpublished)

5.2 Brown skua

Overall, skua mortality was at a similar level to that observed during Phase 1 of the rat eradication. Half of the birds found dead in the Stromness zone were juvenile. Although this represents the loss of almost the entire breeding output of one season, it is not catastrophic for long-lived species such as skuas. The loss of a large number of adult birds is a cause for some concern as under natural conditions adult skua mortality rates are low.

Skuas were far more vulnerable to primary poisoning than was appreciated following Phase 1 of the eradication. The relatively high density of skuas near field camps increased the likelihood of observing this behaviour, although the consumption of pellets by skuas had been noted following a bait palatability trial on house mice (Cuthbert et al., 2012). Many skuas were observed eating bait pellets that had been broadcast or spilt around loading sites. Although remedial action was taken to remove excess bait from loading sites, in some cases thousands of pellets were present in the few square metres around the loading site. While this may only represent a tiny area on which bait was distributed, loading sites were typically in areas of high skua density (coastal) and so a large number of birds were exposed to the poison. A simple but effective mitigation measure would be to ensure that spilt pellets are picked up at the end of each day's operations.

There is some evidence to suggest that successful breeders depart to sea soon after chicks fledge (average date 11th of March at Bird Island) and failed breeders depart soon after failing (Phillips et al., 2007). Egg oiling was carried out on Bird Island (under permit) in the hope that after breeding failure, adult skuas would migrate out to sea thus reducing the number of birds exposed to the bait at the north-west end of the South Georgia mainland. Initial observations suggested this mitigation measure was effective (BAS to provide full report) but it will only be possible to fully evaluate success once birds return to Bird Island to breed next season. Observations within the areas monitored indicate that breeding skuas were still provisioning dependent chicks into early April and many adults were present until observations ceased in mid-May.

5.3 South Georgia pintail

South Georgia pintail mortality was high in both baiting zones which was consistent with observations within the Phase 1 area (Black, 2011). Given the fecundity of the species, and the improved survival of eggs and chicks in the absence of rats, it is likely that this species will recover quickly.

Although pintail mortality was high, live pintails were seen throughout the observation period in both areas. Towards the end of the observation period, coastal pools frequently froze and large flocks of pintails seemed to disappear. Re-distribution of pintails to coastal

areas is expected at the onset of winter and significant reduction in the number of live birds seen should not be attributed to a rapid increase in non-target mortality.

5.4 Snowy sheathbill

A high proportion of the sheathbills observed in the Stromness zone succumbed to poisoning, which is similar to the results obtained following Phase 1. However, in the Salisbury zone, where sheathbill numbers were considerably higher, the proportion of mortalities was lower than in the Stromness zone (approximately 12 %). it is likely that sheathbills in the Salisbury zone avoided exposure to brodifacoum by feeding within king penguin colonies as bait pellets that fell within or near king penguin colonies would be consumed by rats or become trampled and buried relatively quickly. Although the impact may have been underestimated as mortality was on going at the time observations stopped and some birds in the Phase 1 area took several weeks to die.

5.5 Kelp gull

It appears that very few kelp gulls died as a result of consuming brodifacoum. This is in line with observations during Phase 1 of the South Georgia eradication but contrary to observations following eradications on other sub-Antarctic islands, for example Campbell (McClelland, 2001) and Macquarie (DPIPWE, 2010), where kelp gull mortality rates have been high. The reason for this difference is not clear but may be because it seems that most kelp gulls around South Georgia display maritime foraging habits, chiefly within kelp beds, where brodifacoum is unlikely to be found. However, kelp gulls do roost ashore, where they potentially have exposure to brodifacoum.

5.6 Giant petrel species

Only a single giant petrel was confirmed as having died as a result of brodifacoum poisoning with another suspected mortality that awaits the results of toxin testing of the liver sample. In the Salisbury zone, giant petrels foraged ashore in large numbers and were observed feeding on carcasses of birds that subsequently tested positive for pyrinine. Some birds showed signs that they may have ingested brodifacoum (wing droop, pronounced limp, reluctance to stand when approached) and so it is possible that more giant petrels may have died during Phase 2 than the one bird found. However, given the large population of giant petrels on South Georgia, it is likely that the overall impact would still be negligible.

5.7 South Georgia pipit

The correlation between baiting and the cessation of pipit observations is striking, particularly given that passerines are a known risk-species in rodent eradications (Eason et al., 2002). Pipits are known to disperse at the end of the breeding season and this may partly explain their disappearance from the area. However, immediately prior to baiting, several juvenile pipits which still had incomplete plumage (observed with down and short tail feathers foraging with parents) were observed in the area and are unlikely to have dispersed long distances i.e. outside of the wider Stromness area and beyond detection of observers. That said, fledging can be relatively rapid, and it is possible that it coincided with the start of baiting.

Without the ability to track individual birds there is a degree of uncertainty about the impacts of baiting on South Georgia pipits. However, since the pipit is an endemic species known to exist at low numbers in highly fragmented populations, primarily on off-shore islands, consideration of species-specific mitigation measures would be beneficial prior to the next season of baiting. Simple measures could avoid potential mortality of pipits. For example, small near-shore islands that support pipits and small burrowing petrels (i.e. Right Whale Rocks, East and West Skerries, island in Iris Bay, island in Wirik Bay, Cooper Island) could be checked for the presence of rats and if non are found, a risk assessment could be carried out and the requirement to bait them re-assessed by experts in the Island Eradication Advisory Group.

5.8 Conclusion

Non-target mortality varied greatly between species with South Georgia pintail and, brown skua being at High risk and snowy sheathbill at Moderate risk; kelp gulls at Low risk and giant petrels at Negligible risk. It is likely that affected populations will recover relatively quickly in the absence of rats. Overall, non-target mortality was at an acceptable level and the benefits of rodent removal to the island as a whole far outweighs the short-term impacts on a small number of species. However, where simple measures can be used to reduce non-target effects i.e. as clearing spilt bait pellets from loading sites and checking off shore islands for presence of rats before aerial baiting, they should be pursued as feasible and appropriate.

6. ACKNOWLEDGMENTS

Thanks to all members of the SGHT rat eradication team for their help on the ground, to the staff at KEP and the officers and crew of the *Pharos SG* for their hospitality. The GSGSSI Government Officers provided an invaluable lifeline through the daily contacts with both field teams.

7. REFERENCES

Black, A.D. (2011) *Mortality of non-target species following the trial Phase 1, eradication of rats on South Georgia.* Government of South Georgia and the South Sandwich Islands.

Bowie, M.H., Ross, J.G. (2006) Identification of weta foraging on brodifacoum bait and the risk of secondary poisoning for birds on Quail Island, Canterbury, New Zealand. *New Zealand Journal of Ecology* **30**, 219-228

Clarke, A., Croxall, J.P., Poncet, S., Martin, A.R.,Burton, R. (2012) Important Bird Areas: South Georgia. *British Birds*, **105**, 118-140

Cuthbert, R.J., Black, A., Rexer-Huber, K., Parker, G., Sommer, E. (2012). *Field trials for the eradication of House Mice from South Georgia. RSPB Research Report No. 48*. Royal Society for the Protection of Birds, Sandy, Bedfordshire, UK. ISBN 978-1-905601-35-6

Dowding, J.E., Murphy, E.C., Veitch, C.R. (1999) Brodifacoum residues in target and non-target species following an aerial poisoning operation on Motuihe Island, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology* **23**, 207-214.

DPIPWE (2010) *Macquarie Island non-target bird mortality specifically in relation to giant petrels – Interim report*. Biodiversity Monitoring Section, Resource management and Conservation Division.

Eason, C.T., Milne, L., Potts, M., Morriss, G., Wright, G.R.G., Sutherland, O.R.W. (1999) Secondary and tertiary poisoning risks associated with brodifacoum. *New Zealand Journal of Ecology* **23**, 219-224.

Eason, C.T., Murphy, E.C., Wright, G.R.G., Spurr, E.B. (2002) Assessment of risks of brodifacoum to non-target birds and mammals in New Zealand. *Ecotoxicology* **11**, 35-48.

Hosea, R.C. (2000) *Exposure of non-target wildlife to anticoagulant rodenticides in California.* Proc. 19th Vertebr. Pest Conf. (T.P. Salmon & A.C. Crabb, Eds.) Univ. of Calif., Davis pp 236-244

Hughes, K A; Waluda, C M; Stone, R E; Ridout, M S; Shears, J R. (2008) Short-term responses of king penguins *Aptenodytes patagonicus* to helicopter disturbance at South Georgia. *Polar Biology* **31**. 1521-1530

Major, H.L., Jones, I.L., Byrd, G.V., Williams, C.J. (2006) Assessing the effects of introduced Norway rats (*Rattus norvegicus*) on survival and productivity of least auklets (*Aethia pusilla*). *The Auk* **123**, 681-694

McClelland, P. (2001) *Operational report for rat (Rattus norvegicus) eradication on the Campbell Island Nature Reserve*. DOC Internal Report. Department of Conservation. Invercargill, New Zealand.

Moles, A.T., Drake, D.R. (1999) Post-dispersal seed predation on eleven large-seeded species from the New Zealand flora: A preliminary study in secondary forest. *New Zealand Journal of Botany* **37**, 679-685

Phillips, R.A., Catry, P., Silk, J.R.D., Bearhop, S., McGill, R. Afanasyev, V., Strange, I.J. (2007) Movements, winter distribution and activity patterns of Falkland and brown skuas: insights from loggers and isotopes. *Marine Ecology Progress Series*, **345**, 281-291

Poncet, S. (2012) *South Georgia Surveys Albatross and Prion Islands Monitoring Programme Fieldwork Report for January 2012*. SGS, Stanley.

Poncet, S., Crosbie, K. (2005) *A visitor's guide to South Georgia*. WildGuides Ltd. UK.

Pye, T., Bonner, W.N. (1980) Feral brown rats, *Rattus norvegicus,* in South Georgia (South Atlantic Ocean). *Journal of Zoology* **192**, 237-255

Pye, T., Swain, R., Seppelt, R.D. (1999) Distribution and habitat use of the feral black rat (*Rattus rattus*) on subantarctic Macquarie Island. *Journal of Zoology* **247**, 429-438.

Torr, N. (2002) Eradication of rabbits and mice from sub-Antarctic Enderby and Rose Islands. In: Turning the tide: the eradication of invasive species. (Eds. Veitch, C.R. & Clout, M.N.) IUCN SCC Invasive Species Specialist Group, IUCN Gland, Switzerland and Cambridge, UK pp 319-328