Timing aerial baiting for rodent eradications on cool temperate islands: mice on Marion Island

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Abstract Aerial baiting from helicopters with a bait-sowing bucket and GPS to ensure coverage with anticoagulant toxins in cereal-based baits can reliably eradicate rodents on islands. Current best practice for temperate islands is to bait in winter when the rodents are not breeding, rodent numbers are lowest so competition for toxic baits is lowest, natural food is likely to be scarce, and many non-target species are absent from the island. However, short winter day lengths at high latitudes restrict the time helicopters can fly and poor weather in winter may increase risks of failure. This paper notes precedents from cool temperate islands where baiting was not conducted in winter and then uses the extensive data on mice on Marion Island to explore whether current recommendations for winter baiting based on breeding and natural food availability are important risk factors in determining time of year to bait. Marion Island mice do not breed between early May and late September, mouse densities reach a maximum in May and minimum in November, but the biomass of main natural food (invertebrates) does not fluctuate greatly over the year. This means the per capita food availability is least in autumn and increases through winter to most in spring and summer. The weight of the stomach contents of mice is also highest in winter. Based on this per capita food parameter, mice are likely to be most hungry between about March and May suggesting baiting would be more effective in this period (perhaps towards the end of it when breeding stops) than in the more traditional winter season.

Keywords: food availability, rodent abundance, seasonality

INTRODUCTION

Successful attempts to eradicate one or more (up to four) species of rodent by sowing toxic baits from an aircraft have been made on at least 166 islands in 13 countries (DIISE, 2018; J. Parkes, unpubl. data) since the first use of this method in 1985 against Norway rats (*Rattus norvegicus*) on Whale Island (143 ha) in New Zealand (Imber, et al., 2000). Most of these islands are at latitudes with temperate climates (n = 96) biased by the large sample from New Zealand, or in tropical latitudes (n = 64) biased by those in the Montebello Group of islands in Western Australia. Few islands are at latitudes with cold climates similar to Marion Island (n = 6). Aerial baiting is currently the only practical option to eradicate rodents on large or topographically difficult islands and has a high success rate when modern best practice is followed (Parkes, et al., 2011; Parkes, 2016). The cost of operational failure is high, especially for large, remote islands, both in the money invested (Holmes, et al., 2016) and if failures discourage risk-averse funders from attempting further projects. Therefore, careful planning and application of best practice based on precedence and analysis of the particular constraints and risks for each project is essential.

Pest eradications achieved by reduction of the target population to zero by a sequence of removal events (e.g. by shooting, trapping or by deployment and re-baiting of bait stations) provide information (e.g. catch per unit effort, kill locations, trends in rates of bait-take across seasons and years) as the population is reduced (e.g. Thomas & Taylor, 2002). Under this strategy, the ‘start rules’ are not critical as managers can (and should) adapt actions as information accrues during the project, e.g. to allow a change in tactics to account for animals that might avoid one control method (Parkes, et al., 2010). In these projects knowing when to stop and declare success is the more critical issue – at least in terms of efficiency and risk management (Ramsey, et al., 2011).

In contrast, the use of aerial baiting provides little information on likely success or failure from the control itself, other than bait coverage if GPS technology is used. Under this strategy everything has to ‘go right on the day’ and ‘start rules’ with meticulous planning are critical (Cromarty, et al., 2002; Springer, 2016). One key ‘start rule’ is to identify the optimal time of year (or at least avoid sub-optimal times) to conduct the baiting. Broome, et al. (2014) suggest that winter to early spring is the preferred time of year to aerially bait rodents on New Zealand’s temperate islands because it is supposed that (a) rodents are often not breeding and so young individuals that might not be exposed to bait because of possible lack of dependence or subordinate behaviours are at lowest levels of abundance, (b) rodent densities are likely to be lowest and so competition for baits least, (c) natural foods are likely to be least abundant, the rodents most hungry and so 100% are likely to eat the baits, and (d) some potential non-target animals such as seabirds are not present in this season. Most rodent eradication projects have followed this advice by baiting in winter for temperate islands. However, these factors are not always mutually independent (least food and fewest rodents), and other factors (weather or logistics) may constrain decisions. The parameter around food availability we are really seeking is the time of year when there is least per capita food, which may or may not be when there is least food or fewest rodents and may or may not be what drives any breeding season. Managers are probably wise to stick with precedence and bait in winter or early spring (or during dry seasons in the tropics) in the absence of any data on the seasonality of food, rodent dynamics or breeding seasonality.

However, for a variety of reasons a few rodent eradications on cool temperate islands using aerial baiting have been conducted in the summer. Mice (*Mus musculus*) were eradicated on Enderby Island (710 ha at 50ºS) in January 1993 because that was when the primary target species, the rabbits (*Oryctolagus cuniculus*), were not breeding (Torr, 2002). Norway rats and house mice were eradicated on the subantarctic island of South Georgia (103,000 ha and 4,900 ha, respectively, at 54ºS) between late February and late May (mostly in March–April) in phases between 2011, 2013 and 2015 because weather conditions and persistent snow cover made a winter operation impossible (Anon., 2016; Martin & Richardson, 2017). Timing and other operational details of aerial baiting on several islands in the French Southern Territories appear to have been determined by the timing of the supply ship, the *Marion Dufrense*. Rabbits and ship rats (*Rattus rattus*), but not mice were eradicated from Saint Paul Island (900 ha at 38ºS) in January–February (Micol & Jouventin, 2002). Attempts to eradicate rodents from some of the islands in the Golfe du Morbihan in the Kerguelen group (49ºS) have

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been made during summer months when the supply ship visits the region. Ship rats and mice were eradicated from Île Château (220 ha) (Anon., 2006) and ship rats but not mice from Île Australia (2337 ha). Attempts to eradicate mice on Île Stoll (60 ha) and ship rats and mice on Île Moules (500 ha) failed (Anon., 2006; DIISE, 2018).

So, maybe we are unnecessarily constraining ourselves to times of year with the worst weather and shortest days on islands at high latitudes by baiting in winter. This paper explores this seasonality question by describing the process used to inform decision-makers of a proposed eradication of mice on Marion Island, a place where the long history of research by South African scientists has provided most of the information to answer the question.

RESULTS AND DISCUSSION

Marion Island

Marion Island (29,000 ha) and the adjacent Prince Edward Island are South Africa's only offshore islands. They lie on the sub-Antarctic convergence at 46º54′S in the south Indian Ocean. Apart from a meteorological station on Marion Island, the islands are uninhabited. Marion is an active volcano rising to 1,230 m a.s.l. (Fig. 1). The climate is cool, wet and temperate with only a few degrees seasonal variation between coldest and warmest months (mean annual temperature is 6.4ºC and mean annual precipitation is about 200 cm). The physical and biotic characters of Marion Island are described in detail in Chown & Froneman (2008) and the impacts and history of the introduced flora and fauna by Angel & Cooper (2011) and Greve*,* et al. (2017).

Mice were introduced accidentally some 200 years ago, probably with sealers, and are having a significant impact on the native biota (Angel & Cooper, 2011; Dilley, et al., 2016) such that the South African government is considering whether they might be eradicated (Parkes, 2016). Cats (*Felis catus*) were introduced in 1948 in an attempt to control mice at the meteorological station but soon spread as feral animals over the island, killing mice as primary prey and an estimated 450,000 seabirds per year (Dilley, et al., 2017). The cats were eradicated between 1977 and 1991 (Bester, et al., 2002).

Breeding season

Mice can breed all year if high quality food is available, e.g. during beech (*Nothofagus* spp.) mast events in New Zealand winters (Ruscoe, et al., 2005). However, mice have a distinct breeding season on Marion Island with no pregnant animals present between early May and late September (Fig. 2). However, this is not a universal rule on all cool temperate islands as 16% of mice sampled during August/September 2012 on Steeple Jason Island (51ºS in the Falkland Islands) were pregnant (Rexer-Huber, et al., 2013).

Fig. 1 Vegetated lava (foreground) and swamp habitat (middle background), Marion Island (Photo by John Parkes, April 2016).

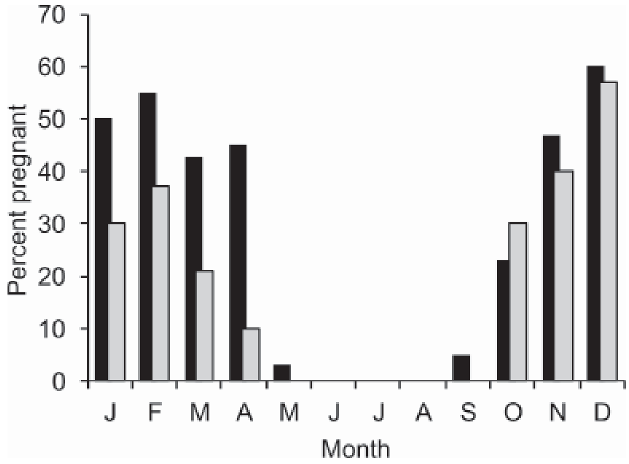

Fig. 2 Monthly pregnancy rates of adult mice, Marion Island in 1991/92 (after Matthewson, et al. (1994) black bars) and 1992/93 (after Avenant & Smith (2004) grey bars).

Density of mice and competition for bait

This breeding season is reflected in the monthly abundance of mice on Marion Island with increasing numbers from the start of breeding in late spring and declining numbers once breeding ends in late autumn (Fig. 3), resulting in lowest densities (at the favoured habitats) at the start of the breeding season (43/ha) in spring and highest (242/ha) in early winter before the decline (Avenant & Smith, 2004).

Baiting during low rodent densities is recommended by Broome, et al. (2014) in part to ensure there are plenty of baits such that all mice, irrespective of their social status, have access to baits. Bait sowing rates in high-density rodent populations of 8 kg/ha in an initial sowing followed by a second sowing of 6 kg/ha about eight days later would result in 7,000 baits/ha – or even in the highest density mouse habitats of Marion Island of 23 baits per mouse. This seems more than adequate to overcome any potential between-mouse competition given each bait contains a lethal dose.

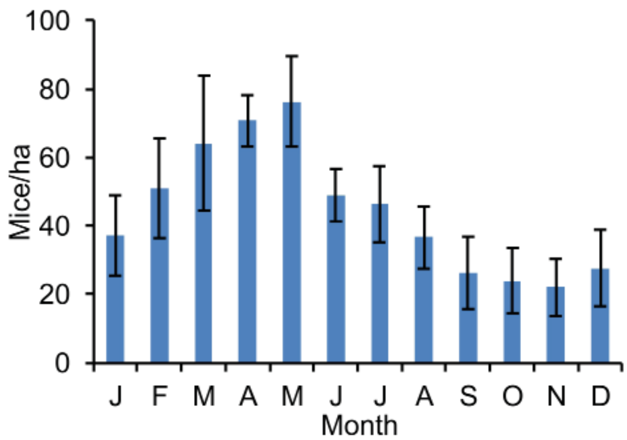

Fig. 3 Seasonal abundance of mice (minimum number known to be alive/ha) averaged across three main habitat types, Marion Island (after Ferreira, et al., 2006).

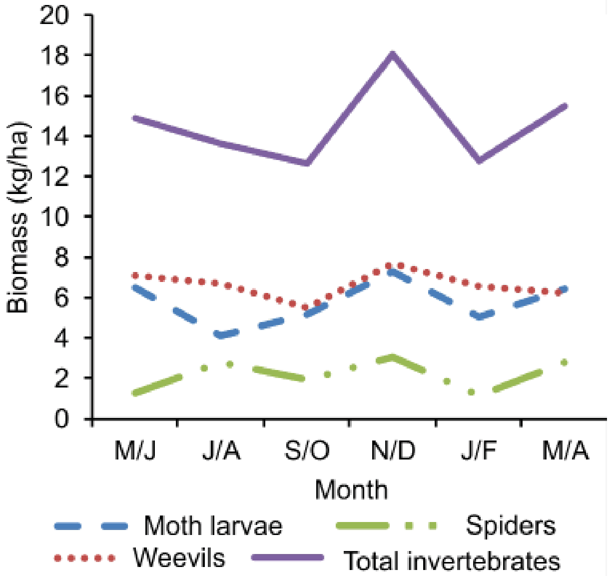

Fig. 4 Seasonal biomass of main invertebrate prey of mice (after Gleeson & van Rensburg (1982)). Total invertebrate biomass (top solid line), weevils (dotted line), moth larvae (dashed line), spiders (lower broken line).

Seasonal variation in per capita natural food

The decades of detailed research conducted on Marion Island (Chown & Froneman (2008) have included studies on the seasonal diet of mice and on the seasonal biomass of their prey. Invertebrates form the bulk of mice diet (depending on habitat) with the larvae and adults of the flightless keystone moth (*Pringleophaga marioni*) (between 13 and 64% by volume) and weevils (*Ectemnorhinus* spp.) (between 11 and 32% by volume) being the most important, followed by earthworms (*Microscolex kerguelarum*) (between 1 and 9% by volume). Plant material, mostly grass and sedge seeds was important, between 16 and 48% by volume (Smith, et al., 2002).

There appears to be only small seasonal variation in the abundance of the main invertebrate fauna favoured by mice (Fig. 4) and Avenant & Smith (2004) found no significant summer–winter differences in invertebrate biomass in the habitat most favoured by mice – apart from spiders which were actually more abundant in winter. The preferred prey for mice, larvae, pupae and adults of *Pringleophaga marioni*, has a long-life cycle of between two and five years (Haupt, et al., 2014) so the absence of seasonal fluctuations is not unexpected given also the small seasonal differences in climate on Marion Island (le Roux & McGeoch, 2008).

The absence of strong seasonal changes in invertebrate prey abundance mean that there is least food per mouse when mouse density is at a maximum, i.e. between March and May, and most food per mouse over winter and spring. For example, the per capita food availability is an order of magnitude lower in early winter when mice are at maximum densities than in early summer when they are at lowest densities. The weight of stomach contents of mice also increases during winter to reflect this (Fig. 5), and mice begin to scavenge or prey upon other mice in autumn and winter (Smith, et al., 2002).

Seasonal absence of non-target species

Most cool temperate islands have a mix of permanent resident bird and seasonally present nesting or moulting seabirds. Unacceptable risks to the former from toxic baiting and secondary poisoning have to be mitigated, e.g.

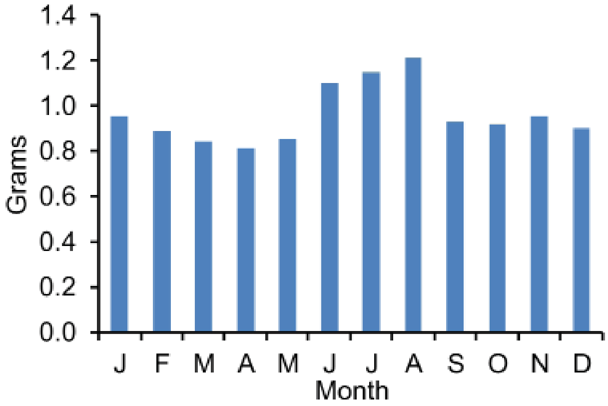

Fig. 5 Monthly changes in the weight of stomach contents adjusted for body weights of Marion Island mice (after Matthewson, et al. (1994) reported in Smith, et al. (2002)).

by holding individuals in safe captivity (Rexer-Huber & Parker, 2011), but risks to the latter have to be accepted (e.g. as on Macquarie Island; Parkes, 2016; Springer, 2016) or avoided by baiting when the birds are least common on the island. Marion Island has only two terrestrial birds at risk – the kelp gull (*Larus dominicanus*) and lesser sheathbill (*Chionis minor*) while among the 26 nesting seabird species only three (sub-Antarctic skua (*Catharacta antarctica*), southern giant petrel (*Macronectes giganteus*) and northern giant petrel (*M. hallii*) are at low to modest risk if the baiting was conducted in mid-winter (Parkes, 2016; Springer, 2016).

CONCLUSIONS

Optimal timing of aerial baiting on Marion Island depends on whether the non-breeding season is more or less important than the period with minimum per capita food availability for the mice. Neither hypothesis has been tested. If the latter is most important then a March–May baiting is indicated, but if the former then a May–September baiting is indicated – May at least being a month of overlap. Of course, an earlier timing in late summer is better than a later one in winter, when short days, snow and gales limit flying time.

It is not clear whether the lack of large changes in seasonal abundance and biomass of invertebrates seen on Marion Island is normal for all cool temperate islands. Most studies on other islands lack the year-round data on changes in invertebrate biomass available for Marion Island. However, mice on other cool temperate islands also show a lack of strong seasonality in the occurrence of invertebrates (the bulk of their diet) in their diet, e.g. on Macquarie Island (Copson, 1986) and Île Guillou (Le Roux et al., 2002). This suggests the multi-year life cycles of the invertebrate species on Marion Island may also apply on similar islands and the per capita food supply depends on seasonal changes in mouse density rather than on food abundance. Therefore, mice are likely to be hungriest when they are at maximum densities and not during the winter when they are likely to be least hungry and perhaps less likely to eat artificial food such as baits. An aerial baiting project between March and May is indicated on this condition. Of course, the other considerations mooted by Broome, et al. (2014) might constrain such a choice, as might weather, day length, logistics of ship and helicopter availability as with other projects noted in the introduction.

However, there are several caveats. First, the comparisons between mouse and food abundance are derived across several studies over several decades. This may not be a problem except that the whole ecosystem around mice on Marion Island is highly dynamic. Second, the biomass of invertebrates has collapsed by about 90% since the mid-1970s (Table 1 in Parkes, 2016 and references therein), despite which mouse densities have increased (between 1990 and 2002; Ferreira, et al. (2006) and well after cats were eradicated; the climate is warming (le Roux & McGeoch, 2008); and mice are switching their primary prey from moths to weevils and earthworms (Chown & Smith, 1993) and learning to eat albatross chicks (Dilley, et al., 2016).

Finally, if natural food availability is a problem limiting bait acceptance by rodents (i.e. the proportion of a population that eat the bait) as suspected for some recent failures on tropical islands (Parkes, et al., 2011; Keitt, et al., 2014), and such food competition cannot be predicted or avoided, then one solution is to increase the palatability of the bait relative to natural foods by adding lures or attractants.

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