

Improving capture rate for an invasive species in Mauritius: determining Asian musk shrew *Suncus murinus* bait preference

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SUMMARY

The Asian musk shrew *Suncus murinus* is an invasive insectivore that first colonised Mauritius in the eighteenth century. It is a significant predator and poses a threat to terrestrial endemic reptiles in Mauritius. On the islet nature reserve Ile Aux Aigrettes, Mauritius, shrews predate juvenile Telfair's skink *Leiolopisma telfairii*, limiting the recruitment of this threatened species. It is therefore important to reduce numbers of Asian musk shrews, and live and fatal trapping are potential methods that can be used to control or eradicate invasive vertebrates. This study tested whether Asian musk shrews preferred the bait currently used for trapping shrews on Ile Aux Aigrettes compared to a novel bait, crushed cockroach. We also tested whether shrews preferred bait in the presence or absence of musk, a chemical attractant. Shrews were observed in a specially designed choice box where a behavioural tally recorded their activity. Their strongest preference was for compartments containing no bait, although they also displayed a significant preference for crushed cockroach in the presence of musk, and a lack of interest in the existing bait. These results suggest that the use of this novel bait plus musk could improve the success of trapping shrews on Ile aux Aigrettes and elsewhere.

BACKGROUND

Invasive alien vertebrates are considered the second most important factor affecting the loss of biodiversity after habitat destruction (Branco *et al.* 2015). They pose a major threat to ecosystems, competing with or preying on native species, and potentially spreading disease (Cerri *et al.* 2016). Eradication of invasive alien species is desirable but often unfeasible, and in most cases control methods are implemented (Olszańska *et al.* 2016). A variety of methods can be used to control or eradicate invasive vertebrates, including live and lethal trapping (Torre *et al.* 2011), with baits and lures often used as attractants in order to entice animals into traps (Kok *et al.* 2013).

The Asian musk shrew *Suncus murinus* is one of the largest species of shrew, and is native to southern Asia (Solow *et al.* 2008). They have a high metabolic rate, store little fat, and lose body water through sweat, and thus spend most of their time foraging (Temple 2004). They are highly invasive and are believed to have been transported via boat across Asia, western Africa, and throughout the Indian Ocean (Solow *et al.* 2008).

Since being introduced in the eighteenth century Asian musk shrews have become abundant across mainland Mauritius, and have recently invaded some of the surrounding islets, including the offshore nature reserve Ile Aux Aigrettes on the east coast of the island. Here they prey on and compete with Telfair's skink and many other native and endemic Mauritian wildlife species (Brown *et al.* 2014). Being efficient breeders, with females becoming fertile by induced ovulation (Temple 2004), and having a varied diet, thus having no 'ideal' bait, Asian musk shrews are difficult to eradicate. Many factors have been found to influence trap capture rate of small mammals, including weather, scent, and bait used (Eulinger & Burt 2011, Roy *et al.* 2006). A previous eradication attempt on Ile Aux Aigrettes in 1999 failed due to potential trap shyness (Seymour *et al.* 2005). Therefore improving the efficacy of

trapping shrews could potentially aid in reducing numbers or eradicating shrews.

In this study we tested whether Asian musk shrews exhibit preferences over the bait used in traps, and whether the presence of musk affects their behaviour. Bait is often used when trapping small mammals, as it both acts as an attractant and provides sustenance for any trapped individuals (Kok *et al.* 2013). By testing the bait that is currently used in control protocols against newly developed crushed cockroach bait, with and without musk scent, we aimed to determine whether shrews have a preference for specific baits.

ACTION

The study took place in La Preneuse, Black River in Western Mauritius between July and September 2016. Shrews were caught using 12 live mammal traps; eight Sherman live traps and four small mouse traps (Figure 1). Traps were baited with a 1:3 ratio of peanut butter and rolled oats and were placed along flat, linear surfaces such as walls and shrubs (Hayes *et al.* 1996). Traps were set at 22.00 h and collected at 06.00 h each day to minimise the time animals potentially spent in traps.

Upon catching a shrew, a 24 x 14 x 13 cm mammal enclosure was prepared using wooden shavings, ample bedding (a cardboard toilet roll tube and shredded newspaper), water and dog biscuits. Ensuring water and food were always available was essential as shrews are prone to dehydration. After being caught, shrews were placed in the enclosures and left in a quiet location for a minimum of nine hours, allowing them to adjust to captivity before being tested. They were not tested more than once in the same day to prevent unnecessary stress, and were marked (a small patch of fur shaved on the shrew's rump) and released after two tests. Determining the sex of Asian musk shrews is difficult, therefore sex was not considered when observing shrews.

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Figure 1. Mouse trap (above) and Sherman live trap (below).

A choice box was created to test the shrews' preference for bait, using six 29 x 24 x 33 cm cardboard boxes attached to a 54.5 x 33 x 35 cm central box using 17.5 x 8 x 7 cm plastic tubes (Figure 2). Each of the experimental compartments contained one tablespoon of one of the following attractants in a dish: peanut butter and oat mix, peanut butter and oat mix with a musk-infused cigarette filter, crushed cockroach, and crushed cockroach with a musk-infused cigarette filter. A musk-infused cigarette filter compartment, and an empty compartment were used as controls. Current control programmes use a variety of baits that do not replicate the shrews' natural diet, such as peanut butter and oats, or birdseed and banana (Kok *et al.* 2013). By creating crushed cockroach bait we aimed to test whether Asian musk shrews preferred the existing baits or this novel alternative. Cockroaches were purpose-bred by Durrell Wildlife Conservation Trust and the Mauritian Wildlife Foundation.

Musk-infused cigarette filters were created by dissecting eight shrews caught and dispatched as part of the eradication programme on Ile Aux Aigrettes. An incision was made along the lower abdomen, allowing the two musk glands either side of the anus to be pierced and the musk fluid absorbed using cigarette filters (Greenhalgh 2015). Musk produced by male shrews is more potent than that of females, and thus only males were used (Temple 2004). The crushed cockroach and musk filters were preserved in a freezer for the duration of the study. During each preference experiment musk filters were removed, thawed and re-frozen; musk filters were replaced every three weeks as the musk scent may become weaker over time.

Shrews are crepuscular in nature and were therefore observed during the three hours before dusk and after dawn. Twenty-seven shrews were each tested on two occasions. This involved placing the shrew in the central compartment of the choice box under a 24 x 14 x 13 cm enclosure for 10 minutes to allow them to familiarise themselves with their surroundings. The enclosure was then removed and all behaviour recorded for 30 minutes by the lead author. Water and a cardboard toilet roll tube for cover were left in the central compartment for the duration of the experiments. Shrews are excellent mammals to observe as they are not disturbed or



Figure 2. The choice box, with centre box and attached compartments.

distracted by human presence, and thus their behaviour could be easily recorded (Matsuzaki 2002).

Each shrew was tested twice over two days, to reduce potential bias caused by stress in individual shrews, and average behaviour was calculated. In order to see which compartments the shrews entered most frequently, and which baits were most often fed on, a tally was recorded for each behaviour: entering a tube but not entering the compartment, entering a compartment fully (excluding the tail), and feeding on the bait. In some cases shrews entered a compartment, fed, and without leaving the compartment returned to feed on the bait; whenever this occurred, each return was tallied as a new feed. The choice box was rotated daily to prevent individuals becoming familiar with specific compartments. All equipment was disinfected after use. This practice was especially important after testing shrews, in order to prevent 'non-musk' compartments smelling of musk. Compartments without musk were lined with plastic tape to ensure they could be disinfected without risk of damaging the boxes. The compartments containing musk were not cleaned unless a shrew had defecated inside them, in which case only the droppings were removed.

As the data were continuous and normally distributed, a one-way ANOVA was used to test for significant differences in the data set. Where significant differences were detected, a post-hoc unpaired t-test was used to identify which pairs of variables were significantly different from each other.

CONSEQUENCES

Shrews were often observed to enter all the compartments, and frequently returned to those they had already entered. Shrews did not significantly avoid any specific compartments ($F_{5, 156} = 0.4$, $p = 0.85$), and shrews were rarely observed just entering a tube without fully entering a compartment.

Unexpectedly, shrews were found to enter the empty box most frequently (Figure 3). With the exception of the empty box, shrews entered compartments containing musk-infused filters more often than compartments without musk (Figure 3). There was a significant difference between the average number of occasions that shrews entered each compartment ($F_{5, 156} = 2.35$, $p = 0.043$). Post hoc t-tests highlighted significant differences in the number of times shrews entered compartments containing peanut butter and oats, and musk ($t =$

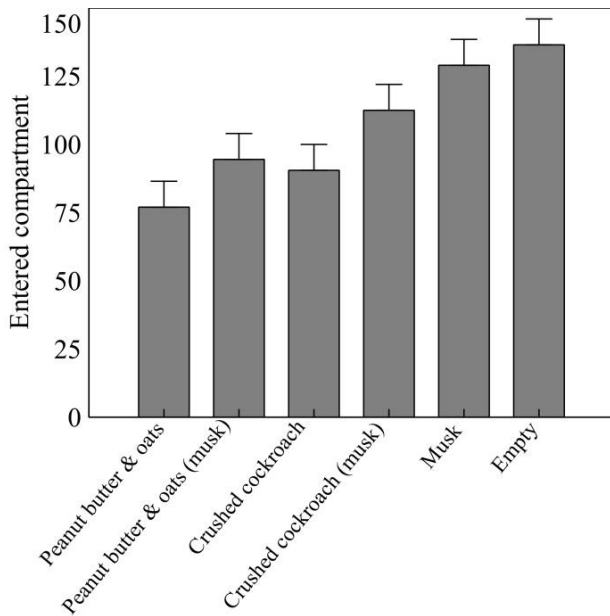


Figure 3. The average number of recorded occasions that shrews entered each compartment (with positive S.E. bars)

-2.16, d.f. = 52, $p = 0.018$); peanut butter and oats, and the empty compartment ($t = -2.99$, d.f. = 52, $p = 0.0021$); crushed cockroach, and the empty compartment ($t = -2.28$, d.f. = 52, $p = 0.013$); and peanut butter and oats (musk), and the empty compartment ($t = -2.05$, d.f. = 52, $p = 0.023$).

Shrews were observed feeding at different frequencies on the four different baits available ($F_{3,104} = 14.5$, $p < 0.001$) (Figure 4). Shrews would remain in the same compartment, and repeatedly return to the baited dish to feed.

The novel bait, crushed cockroach with or without musk, was fed on more frequently than the currently used bait, peanut butter and oats (Figure 4, post-hoc t-test: $t = -3.59$ d.f. = 52, $p < 0.001$ (with musk), and $t = -4.89$, d.f. = 52, $p < 0.001$ (without musk)). A further post hoc t-test showed a significant difference in the frequency with which shrews fed on crushed cockroach with and without musk ($t = -1.90$, d.f. = 52, $p = 0.031$), suggesting that the presence of musk acts as an additional attractant to the shrew (Figure 4).

DISCUSSION

Our results support the premise that shrews exhibit preferences for specific baits (Parker *et al.* 2002), with crushed cockroach being fed on significantly more frequently than peanut butter and oats. This suggests that the current bait used on Ile Aux Aigrettes might not be as effective as crushed cockroach. Bait preference also appears to be influenced by the presence of musk, with crushed cockroach being fed on significantly more in the presence of musk. This supports previous work carried out by Greenhalgh (2015) who also observed musk to be a more effective attractant than bait alone. However, in this study it appeared that shrews preferred entering empty compartments or those containing musk only, rather than baited compartments. This supports the findings of Seymour *et al.* (2005), that small mammals will often enter unbaited traps equally, if not more frequently, than baited ones.

Our finding that shrews preferred a novel bait over the currently used bait could change the current shrew control protocol in Mauritius. Currently the Durrell Wildlife

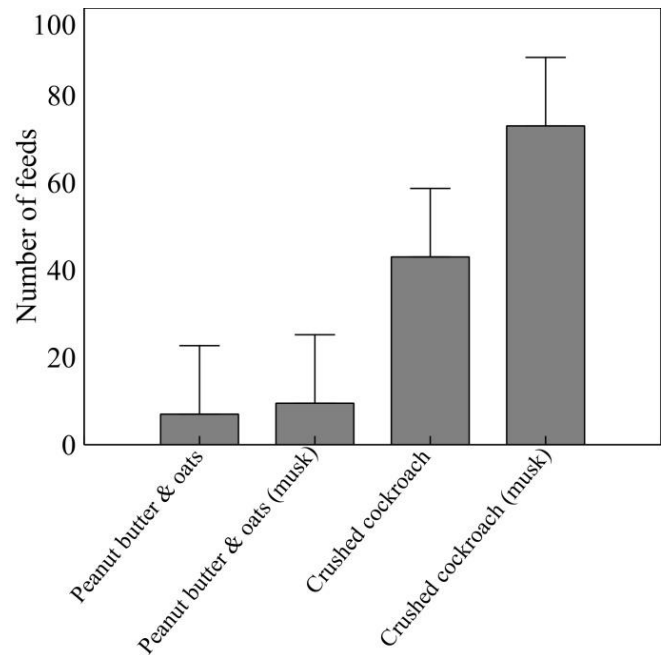


Figure 4. The average number of recorded occasions that shrews fed on the specific baits within each compartment (with positive S.E. bars).

Conservation Trust and the Mauritian Wildlife Foundation set eight Sherman live traps around juvenile Telfair's skink head-starting facilities twice a week to control shrew abundance and reduce the likelihood of shrews finding their way inside the enclosures and predated the juvenile Telfair's skink. The long-term aim for Ile Aux Aigrettes is to support a population of Telfair's skinks in an environment free of invasive mammals. These findings provide useful information on bait preference in shrews, which could be used in a future eradication programme in Mauritius or elsewhere.

However, the effectiveness of crushed cockroach, musk, and empty traps must be tested in the field, where conditions are different. This will help inform management decisions concerning the bio-security work undertaken on Ile Aux Aigrettes and the other islands. The tailless tenrec *Tenrec ecaudatu*, an omnivorous mammal, has also been introduced to the nature reserve and predated native and endemic fauna. The crushed cockroach bait may also prove effective in trapping tenrecs, and could be used to assist in their future eradication as well. If this is achievable, biodiversity on Ile Aux Aigrettes can be expected to improve, potentially allowing the reintroduction of extirpated endemic species.

Unlike peanut butter and oats, which can be moulded into a solid ball, crushed cockroach is less compact and risks being fed on by ants (Mitchell *et al.* 1996) or washed away by rain. A possible solution would be to fill a bottle cap with the crushed cockroach and coat the edges with lithium grease to deter ants. Field tests could also be used to investigate whether non-target species like the Telfair's skink are attracted by the crushed cockroach bait. If the number of non-target captures increased, the effectiveness of trapping would decrease and it could prove detrimental to the individuals caught (Phillips & Winchell 2011).

Shrews displayed a variety of active and inactive behaviours. Previous studies have discussed how an animal's behaviour changes when stressed, and shrews that remained inactive may have been displaying behaviours associated with such stress (Zaidan & Gaisler-Salomon 2015). Apart from two

individuals, all shrews showed interest in every compartment, and there was a significant difference in the extent to which particular compartments were entered, with the compartments containing no bait being entered most frequently. This suggests that although shrews may have entered compartments containing musk and crushed cockroach more often than the compartments containing peanut butter and oats, the presence of bait did not seem to be a primary cause of their frequent use.

The results from this study contribute to our understanding of how to improve shrew control on Ile Aux Aigrettes. By using crushed cockroach and not cleaning traps after use, leaving them smelling of musk, one could expect more shrews to be attracted to them. If this does improve trap success rate it could contribute towards future eradication attempts, leading towards a more biodiverse Mauritius, free from invasive mammals.

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