Possible control of introduced giant African land snails (*Achatina spp.*) by the reintroduced endemic skink *Leiolopisma telfairii,* Ile aux Aigrettes, Mauritius

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Abstract

The giant African land snail (*Achatina fulica*) is one of the world's worst invasive species, out-competing endemic snails, consuming native vegetation and potentially altering nutrient cycles. Attempts to eradicate the snail from islands have only been successful with incipient populations. We present correlative evidence that native island predators may act as an effective control agent for the snail. In 2000 a population of between 37,300 and 45,100 African land snails was estimated on the 26ha nature reserve island of Ile aux Aigrette, Mauritius. Between 2006 and 2007, 260 endemic Telfair's skink *Leiolopisma telfairii* were reintroduced to the reserve. Snail population surveys in 2008 and 2009 showed that the introduced snail population had declined to 5,569 (± 3,630) and 6,871 (±5,379), respectively. Previous studies showed that the introduced snails were selective over other invertebrate prey items. We suggest that predation by the endemic skink has been an important causal factor behind the snail population decline.

Keywords

Achatina fulica, Leiolopisma telfairii, introduced species, reintroduction

Introduction, Hypotheses and Problems for Management

The giant African land snail *Achatina fulica* has now become naturalised on islands throughout the Pacific, Caribbean and Indian Oceans (Meyer & Picot 2001). Once established it has had serious biological impacts consuming native vegetation, modifying habitats and out-competing endemic snails (Moore 2005). It has been implicated in the spread of exotic plant pathogens and may also alter nutrient cycles (Raut & Barker 2002).

Attempts to eradicate *Achatina* spp. by physical removal have only proved successful with incipient populations (Raut & Barker 2002). Although molluscicides have been developed (Raut & Barker 2002) the financial cost of control can be prohibitive (Muniappan 1987; Smith & Fowler 2003). The use of biological controls (e.g. the predatory snail *Euglandina rosea* and parasitic worm *Platydemus manokwari*) has proved disastrous for native gastropods (Civeyrel & Simberloff 1996; Griffiths et al. 1993). Although *Achatina* spp. are consumed by native predators, there is little evidence they can control established populations (Raut & Barker 2002). The main objective of the study was to analyse the status of an invasive *Achatina fulica* population in Mauritius following the reintroduction of the omnivorous endemic Telfair's skink *Leiolopisma telfairii*. Supportive evidence for the impact of the skinks on reducing the snail population is provided through analysis of skink diet and the representation of snails in relation to the availability of other invertebrate prey items.

Study Area

The study was performed on the Open Nature Reserve, Ile aux Aigrettes, a 26 ha coralline island with a maximum elevation of 13m and positioned 600 m off the south-eastern coast of Mauritius (Parnell et al. 1989). Average monthly rainfall varies from a high of 240 mm in January to a low of 60 mm in September. The island has been the recipient of an intensive restoration programme by the Mauritian Wildlife Foundation and now supports an almost complete

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coverage of native dry coastal forest and has been a focal site for the reintroduction of endangered vertebrate species (Anon 2006; Cristinnace et al. 2009; Jones & Hartley 1995; Dulloo et al. 1997; Newfield et al. 2003). Where the ebony forest has been restored the soil is rich (40%) in organic matter although it is still relatively shallow (10cm depth) (Parnell et al. 1989).

African land snails are thought to have been introduced to Ile aux Aigrettes as a source of food for pigs that were once kept on the island. Despite the occasional predation of snails by the Indian musk shrew *Suncus murinus*, no other animal on the island is known to consume the introduced snail, which are known to occur at a high density on the island (Craze & Mauremootoo 2002).

Between December 2006 and February 2007, 260 endemic Telfair's skinks *Leiolopisma telfairii*

Figure 1. Telfair's slink *Leiolopisma telfairii* and *Achatina fulica* shell.

Resumen

El caracol gigante africano (*Achatina fulica*) es una de las peores invasoras a nivel mundial debido a que desplaza por competencia a caracoles nativos, consume especies vegetales autóctonas y tiene potencialidad para alterar los ciclos de nutrientes.

Los intentos para erradicarlo en islas solo han tenido éxito en el caso de poblaciones incipientes. En este trabajo presentamos evidencias correlativas de que los predadores nativos de una isla han podido actuar como agentes de control efectivos frente al caracol. En el año 2000, dentro de la reserva natural Ile aux Aigrette, en la Costa de Mauricio, la población de *Achatina fulica* se estimaba entre 37.300 y 45100 ejemplares. Entre 2006 y 2007 se introdujeron 260 ejemplares de *Leiolopisma telfairii* (un reptil endémico) en la reserva. Los censos de *Achatina fulica* realizados en 2008 y 2009 mostraron un descenso hasta los 5.569 (± 3,630) y 6,871 (±5,379) individuos. El cruce de esta información con estudios previos sobre la dieta de *Leiolopisma telfairii* permite sugerir que la predación por el eslizón endémico ha podido ser un factor causal del descenso en la población invasora.

Palabras clave

Achatina fulica, Leiolopisma telfairii, especies introducidas, reintroducción

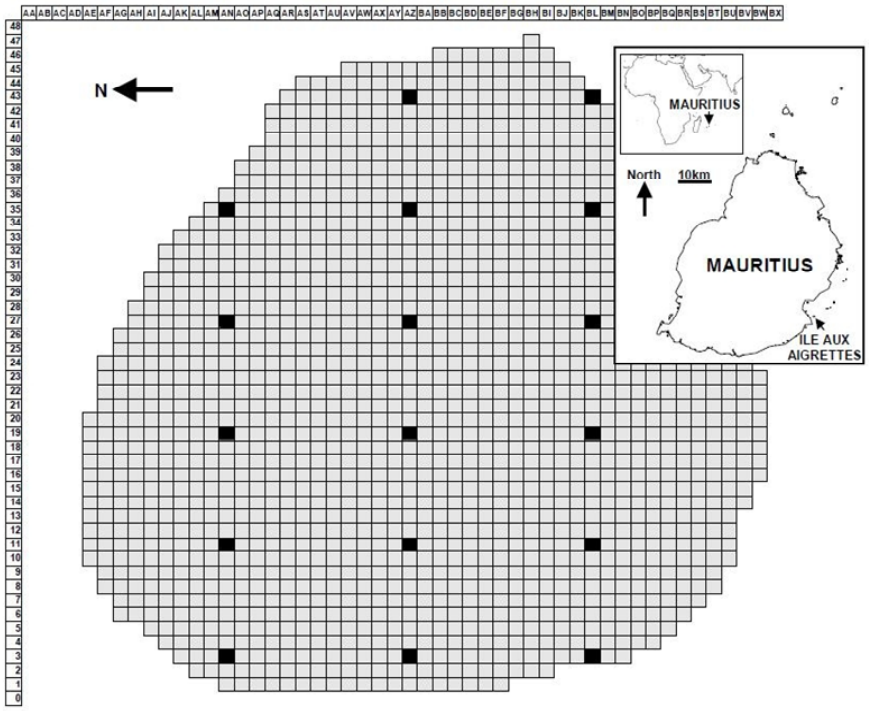

Figure 2. Map of the 12.5x12.5m grid system on Ile aux Aigrettes showing 17 sample squares. Inset showing location of study site in relation to Mauritius and Africa (adapted from Craze & Mauremootoo 2002).

were translocated to Ile aux Aigrettes from Round Island, 20km NE of Mauritius (Cole *et al.* 2009). In 2000, prior to the reintroduction of the skinks, there was a population of 37,300 to 45,100 giant African land snails on the island (Craze & Mauremootoo 2002).

Methods

In April 2008 and 2009 the introduced African land snail population on Ile aux Aigrettes was resurveyed using the same methodology as in 2000 (Craze & Mauremootoo 2002). A permanent grid of 1689, 12.5 m x 12.5 m quadrats was marked out with metal pegs prior to the 2000 survey. The same 17 grid squares used in 2000 were surveyed in 2008 and 2009. These grid squares were laid out in three lines in order to cover all vegetation types on the island (Fig. 2). Surveys were conducted between 8 am and 4 pm, at the end of the wet season as in 2000. From April 2007 to December 2008 prior to and during the repeated snail population surveys, 131 faecal samples were obtained from individual skinks on Ile aux Aigrettes. Invertebrate remains within the faeces were separated, identified and measured to obtain the volume of each category. To account for a bias arising from numerous small items being consumed by numerous individuals in comparison to a few very large items being consumed by a few individuals, the mean of the relative abundance, volume and occurrence the i^{th} prey category, where relative occurrence was the proportion of skinks that had consumed the i^{th} prey category was calculated to determine an importance value (IV) of each prey category (Gifford et al. 2000). The relative abundance of invertebrate prey items within the diet of the skinks was also compared to the relative abundance of invertebrate prey items on the island using Vanderploeg and Scavia's relativised electivity index (EI, Vanderploeg & Scavia 1979; Lechowicz 1982), where values range from + 1 to - 1 for the most and least selected prey items respectively, and values near zero represent neutral/random selectivity.

Climatic data for the southeastern region, including Ile aux Aigrettes were obtained directly from (Mauritius Meteorological Services) for the survey periods to examine whether climatic factors may have been responsible for changes in snail abundance recorded during this time. Mean temperature and humidity ranges for the year 2000, 2008 and 2009 during the three month period (March-May) encompassing the study periods (April/May) were 25-26 °C and 80-82%. Rainfall during the same period was higher in 2008 (201 mm) and 2009 (197 mm) than in 2000 (145 mm). This inverse relationship between snail

abundance and rainfall could not be examined statistically, although a relationship was evident.

Results

In 2008, there were 3.3 snails per grid square, producing a mean island population of 5,569 with ±95% CL (confidence limits) of 3,630 snails. In 2009, an initial estimate of 9.3 snails per grid square was calculated, although 55% of the snails encountered were found in just one of the 17 grid squares (AN03) sampled. Removing this unusually high count for one grid square produced an estimate of 3.8 snails per grid square and an island mean of 6,871 with ± 95% CL of 5,379 (Fig. 3).

The main invertebrate groups consumed by skinks consisted of Blattodea (IV=44.3%), African land snail (21.3%), Coleoptera (17.5%), Hymenoptera (8.8%), Lepidoptera (6.4%) and other (1.7%). In comparison to prey availability electivity values of items found within skink diet showed that only African land snails (EI=+0.68) were selected for with a slight avoidance of, but mostly random selection of Blattodea (EI=-0.25), moderate avoidance of Coleoptera (EI=-0.69) and almost complete avoidance of all other categories (EI<-0.98).

Discussion

In 2000 the average number of snails was calculated at 24.4 per grid square on Ile aux Aigrettes producing an estimate between 37,300 and 45,100 snails on the island (Craze & Mauremootoo 2002). The most recent surveys conducted in 2008 and 2009 showed that the population of the introduced African land snail on Ile aux Aigrettes was reduced to 13% (2008) and 17% (2009) of its population size in 2000. The significant drop in snail abundance followed the reintroduction of the endemic skink, *L. telfairii*. The skink is a generalist omnivore and whilst only invertebrate data are presented here 60% of skink diet consists of fruits, plant material and vertebrates and selection of preferred food categories varies seasonally (N. C. unpublished data-contact author for related data). However, there is clear evidence that skinks show a strong selection for African land snail predation in the studied area during the period studied , whilst other invertebrate groups are eaten at random or are avoided. These findings suggest that the skink has played a critical role in reducing the invasive snail population through direct predation.

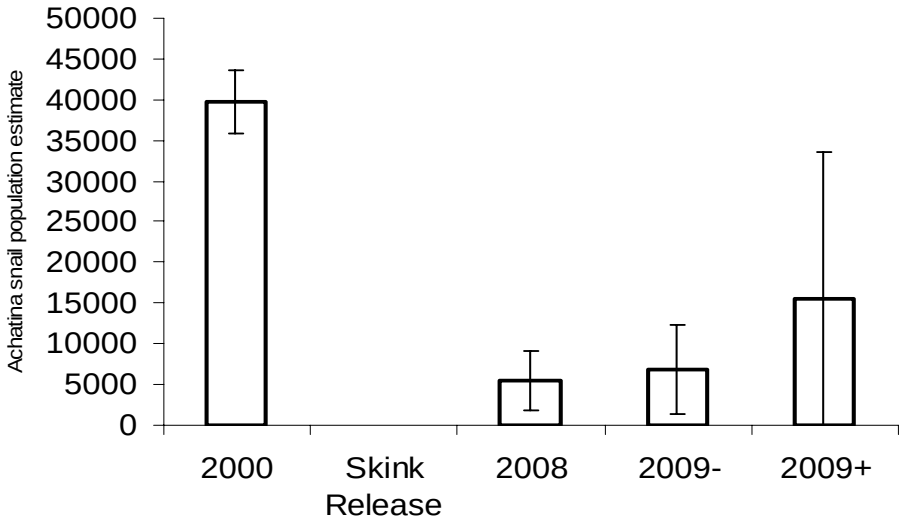

Figure 3. Estimated total population size (±95% CL) of the African giant land snail on Ile aux Aigrettes prior to (2000) and after (2008 and 2009) the reintroduction of *L. telfairii*. 2009+ figure represents population estimate including disproportionate abundance of snails in grid square AN03.

Predation by native species on the exotic African giant land snails has been recorded before. For example, predation by native hermit crabs on some Pacific atolls has been suggested as one reason for the low abundance of the introduced African land snails on these islands (Schotman 1989).

However, no similar studies could be found that document such a significant impact on these introduced gastropods by a reintroduced species.

Alternative explanations for the snail population decline include predation by other species, such as the native land crab, *Cardisoma carnifex* and the introduced musk shrew. Although no survey has yet been performed to determine the impact of the crabs on the introduced snails, the crabs are rarely encountered either during the day or night. The shrew population was considerably lower in 2008 and 2009 than before skinks were released. Chemical pesticides are not used on Ile aux Aigrettes and are therefore not responsible for snail decline. Introduced populations of *Achatina* spp. can experience population crashes after establishment (Eldredge 1988). The reasons for this decline are not well understood although disease has been suggested (Mead 1979; Cowie 1992). However, the species was introduced to Mauritius over 200 years ago (Griffiths & Florens 2006; Cheke & Hume 2008). It would seem surprising for the population to decline so dramatically for this reason, but coincidentally at the same time that an endemic predator was returned to the island.

Climatic data showed that mean values of temperature and humidity over three month period (March-May), encompassing the study periods (April/May), for the years 2000, 2008 and 2009 were not substantially different. Rainfall during the same period was higher in 2008 (201mm) and 2009 (197mm) than in 2000 (145mm). Higher rainfall should have benefited the land snail population, at least in terms of their observed abundance during the study period, although the reverse relationship was observed. Climatic conditions could not therefore adequately explain the decline in snail abundance.

The disproportionate abundance of snails (55% of the total) within one grid square (AN03) during the 2009 survey may be explained by the relatively deep-soil and substantial grass coverage found in this square, atypical to the rest of the island. Additionally building work was being carried out adjacent to the grid square AN03 during the 2009 survey and may have discouraged skinks from foraging in this area.

Conclusions

The findings of the current study suggest that the reintroduced skink *L. telfairii* may have played a significant role in reducing the population of the invasive snail *A. fulica* on Ile aux Aigrettes, Mauritius. While recognising the correlative nature of the data presented here, the fact that the skink is positively selecting the snail in its diet adds important weight to this interpretation conclusion. Further annual studies are required to ensure that the crash in snail population documented here was not related to some alternative factor. However, as alternative hypothesis have been considered within the current study we feel confident in making a causative link between skink predation and snail population decline. The reintroduction of more Telfair's skinks to Ile aux Aigrettes is currently being considered which it is hoped will lead to a further decline in snail abundance across the island. While it is unlikely the skink will eradicate the invasive snail from the island, based on the data presented here it is predicted that it will maintain snail densities at a low level.

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Bio-sketch

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