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Successful eradication of invasive rodents from a small island through pulsed baiting inside covered stations

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Abstract

We show the results of an eradication campaign against *Rattus rattus* developed in Rey Francisco Island (12 ha), Chafarinas islands, southwestern Mediterranean. Rat population size was estimated by snap trapping in up to 93.47 ind./ha and a trapping index of 9.58 captures/100 traps-night. We think that population was underestimated because of the number of traps found strung but without capture. Several products were tested in order to define the method of eradication. In 1992, we selected a second generation anticoagulant, pelleted brodifacoum 50 ppm into 5 l plastic containers as baiting stations. Bait consumption reached zero after three pulses, and intensive searching of tracks and signals were unsuccessful. After more than two years of absence of signals and sightings, in 1995, rat scats were observed in Rey Francisco, and the population rose dizzily. After several snap-trapping sessions in 1996, 1997 and 1999, when trapping success reached 37 captures/100 trap-nights, a new campaign started in autumn–winter 1999–2000 using flocoumafen 50 ppm inside 180 baiting stations. Eradication occurred with a very low risk for non-target fauna, setting less than 1 kg/ha of bait each time. Monitoring, both with snap traps and baiting at a lower intensity assures the absence of reinvasion.

Introduction

Introduced predator and herbivore species are one of the main threats affecting threatened bird species in the world, with a much higher proportion of species being at risk on islands (Collar et al. 1994, pp. 24–25); in fact, 90% of extinction cases have occurred on islands (Courchamp et al. 1999, p. 282). Invasive alien mammals have well known effects on previously predator-free isolated ecosystems, being the major cause of extinction and risk (Moors and Atkinson 1984; Atkinson 1985; King 1985; Fritts 1998; Courchamp et al., in press). Seabirds can be seriously affected by alien predators, and they have put some species on the brink of extinction (Collar et al. 1994, pp. 33–37; Menezes and Oliveira 2002; Pierce 2002). Rats are the introduced predators that have reached most islands (Atkinson 1985) and caused most of birds' extinction there (King 1985). They affect many species in most terrestrial vertebrate or invertebrate groups, through depredation and competition for shelter or food (Courchamp et al. 1999, p. 283).

Mediterranean islands have suffered the flow of introductions since pre-Neolithic times with the consequent homogenisation of biodiversity through the extinction of original fauna (Masseti 2002). Throughout the centuries, rats have conditioned the distribution and abundance of seabirds, the effect being more evident on smaller than on bigger islands (Martin et al. 2000).

Several methods have been used to fight commensal rodents on islands, in order to protect native biota (see the review in Orueta and Aranda 2001). The most commonly used method is poisoning with anticoagulants. Second generation anticoagulants were developed to assure a single dose poisoning, because first generation anticoagulants allowed the development of resistance in rats (Greaves and Rennison 1973; Hadler and Shadbolt 1975; Meehan 1984; Greaves et al. 1987). As death takes some days to occur, rodents can continue consuming bait, thus getting an overdose in their tissues and, especially, in their guts which is dangerous to predators and scavengers (Kaukeinen 1982; Merson et al. 1984). To overcome this threat, pulsed baiting is proposed as a method to reduce the amount of poison available in the field, thus minimising secondary hazard. This technique consists in setting the dose that can be consumed in a single event and lets the poison act during several days before subsequent pulses (Dubock 1984).

Chafarinas archipelago (Djafaren) (35°20′ N, 2°25′ W) lies north of Ras el Ma (Cabo de Agua), in the northern coast of Morocco, in the southwestern Mediterranean. Rey Francisco (12 ha) is the easternmost and the smallest of the three islets, very close to Isabel II which is inhabited. It is elongated in shape with four small land masses connected by a narrow isthmus. Vegetation is conditioned by a semi-arid climate, guano and sea influx, with *Lycium intricatum*, *Atriplex halimus* and *Suaeda vera* as dominant species. Several reptiles inhabit the isle, and it has the second most important *Larus audouinii* population in the world.

Chafarinas islands have a whole lot of characteristics that made them suitable for holding rat populations (Atkinson 1985).

To reduce the threat to nesting seabirds and other native fauna, it was decided to use poison with an anticoagulant (Coulter et al. 1985; Moors 1985; Greaves et al. 1987) chiefly a second generation product (Greaves and Rennison 1973; Hadler and Shadbolt 1975; Meehan 1984; Greaves et al. 1987).

In 1992, we carried out a trial to reduce the rat population, and our results were more successful than expected. In order to run the lowest risk for non-target species, we employed pulsed baiting and covered baiting stations. During 1999, a permanent team was present in the archipelago, and there was a longer term commitment to achieve rat eradication.

Materials and methods

Population size estimation

The population size was estimated by snap trapping on four occasions: 1992, 1996, 1997 and 1999. In February 1992, three grids of traps were installed on the island, and traps were layed every 10 m; the networks were formed by $5 * 10$ traps on the northern part of the island, covering 0.36 ha, $5 * 8$ traps in the central section (0.28 ha) and $10 * 10$ in the southern area (0.81 ha). We calculated regression lines of daily captures vs cumulated captures. We then also compared the whole grid vs the 'inner grid' resulting from the elimination of the data of the perimeter traps, to calculate the effect of immigration in the captures. Differences between both sets of data were analysed with the χ^2 test.

The remaining three years, during the last week of September, three lines of 10 trapping stations (with two snap traps each) were used. As in 1992, traps were placed at sunset and reviewed at dawn when any set trap was sprung to avoid undesired effects on birds and reptiles.

All traps were numbered and tied to a wooden peg by a 15 cm string. The bait was unrefined fish oil mixed with sugar and flour to make it stickier, soaked on a piece of lamp wick. Trapping effort was 950 trap-nights in 1992, 300 trap-nights in 1996 and 1999 and 240 trap-nights in 1997.

For all the trapping events, the ratio of captures/100 trap-nights was also calculated. In order to compare with other studies, the index was also transformed following the 'corrected trap-night' index (Houston 2002):

$$\frac{\text{captures}}{\text{trap-nights} - \frac{\text{captures+sprung traps}}{2}} * 100$$

After the poisoning campaign of 1999–2000, trapping has been continued in the same manner and for the same time.

Selection of baits and baiting stations

In 1992, brodifacoum 50 ppm was chosen because of its single dose efficacy (Meehan 1984) and availability. It was accessible in two forms with different appearances: 20 g wax blocks and pelleted fodder in bulk. We also wanted to test two models of baiting stations: (1) wood boxes divided into two longitudinal chambers by a 5 cm high partition: the first chamber with one door on each side and the other where the bait can be set threaded on a tightened wire; (2) 5 l plastic prism shaped containers set horizontally.

During two consecutive nights, we compared consumption of pelleted bait in plastic containers and blocks in a wooden box, both having a similar quantity. During the following two nights, we switched baits, and during the last two nights, both station models were baited with pellets. We recorded whether the bait was totally consumed or not.

In 1999, the bait preferred in 1992 was no longer available. Thus, three second generation anticoagulants were tested: brodifacoum 50 ppm in 20 g wax blocks, bromadiolone impregnated cereal grains in 25 g bags and flocoumafen in 16 g wax–cereal blocks. Ten series of three baiting stations were set: one station in each group containing a dose of one of the baits, changing the order. In a second test, we placed 3 lines of 10 stations, switching the relative situation of each bait.

Poisoning

In 1992, we installed 148 baiting stations on the islet, averaging 25–30 m in distance. Every baiting station was mapped and labelled. One hundred and twenty grams of poison was left inside the station, and after six nights, the remaining bait was measured and removed. Three pulses were done in April, August and October.

In 1999, we installed 180 baiting stations, one for every 25 m. In addition to the plastic containers, we also used plastic boxes with one 50 mm hole on one side. Eleven consecutive pulses were maintained between November 1999 and February 2000.

After this campaign, 66 stations have been permanently set during summer, autumn and winter to monitor achievements.

Results

Population size estimation

Only shot traps with rats or rat remains (depredation ranked 16.7–87.5% of captures) were considered for the analysis.

In 1992, captures were as shown in Table 1. The grid on the central part of the island was not considered to calculate densities. We judged that the differences between the central and the border traps were too big to consider the whole network as representative of the area. Capture rates per 100 trap-nights were 9.58% (1992), 31.33% (1996), 27.5% (1997) and 37% (1999). The highest 'corrected trap-nights' index was 54.01 in 1999.

Between 2000 and spring 2003, no captures were recorded by trapping and neither sightings nor signs of rats detected.

Choice of bait and baiting stations

In 1992, pellets were totally consumed after two nights in whichever station they were installed. Wax blocks were only consumed partially, less than one half in every case. Results from 1999 can be seen in Table 2.

Poisoning

In 1992, the bait load was 17,520 g for the first pulse and 16,800 g for the third one (five stations

Table 1. Analysis of captures taken in 1992 at three different sectors of Rey Francisco Island.

Sector	Captures whole grid	Captures inner grid	χ^2	Regression line	Density, rats/ha
North	34	15	n.s.	$y = -0.8x + 26.92, r^2 = 1$	93.47
Middle	14	3	$P < 0.001$	$y = -0.89x + 11.98, r^2 = 0.99$	–
South	43	22	n.s.	$y = -0.84x + 34.77, r^2 = 0.99$	51.09

Table 2. Results of different bait tests done in 1999.

	Day 1		Day 2		Day 3	
	%	W	%	W	%	W
First test						
Brodifacoum wax-block	0	0	75	15	90	18
Bromadiolone cereal	48	12	83	20.75	95	23.75
Flocoumafen wax–cereal block	10	1.7	100	16	100	16
Second test						
Brodifacoum wax-block	3	0.6	13	2.6	93	18.6
Bromadiolone cereal	55	13.75	78	19.5	100	25
Flocoumafen wax–cereal block	93	14.88	100	16	100	16

were lost). The total consumption was 992.5 g/ha. After this campaign, there were no signs of rats during 2 years, until 1995.

As during 1992, bait consumption was much smaller than the loaded bait, we used a smaller quantity of bait per pulse during 1999. To start with, the bait load was 2880 g (one block per station), but after two pulses with consumption close to 100% it was increased to 8592 g (three blocks per station). During this campaign, the total bait consumption was 702.75 g/ha. Detailed results can be seen in Tables 3 and 4. Since the summer of 2000, no consumption of bait has been recorded.

Discussion

Population size estimation

The grid method used in 1992 allowed us to define regressions to calculate densities; they ranked between 93.47 individuals/ha in the northern part of the island and 51.09 in the south. Several facts, such as detected cannibalism on rat corpses and the amount of traps sprung without a catch, indicate that this could be an underestimation, probably due in part to trap-shyness and learning. So, in late winter, the population of black rats can reach very high densities (ca. 100 ind./ha), at least locally.

Trapping during the rest of the years cannot be directly compared with these densities, because we used double traps at each point, and the season was different. Anyway, in 1996, 1997 and 1999, the total amount of captures was much bigger in the same sector of the island that gave 93.47 rats/ha in 1992 (up to 111 rats in 300 trap-nights in 1999 vs 34 rats in 250 trap-nights in 1992). Although we cannot suppose a direct proportion, we can guess that density in the northern part of Rey Francisco at the beginning of autumn could be much greater than 100 rats/ha.

If we compare the capture rate obtained during these last three years with other studies, we see that García et al. (2002) obtained 0.63 rats/trap-hour at Monito island (Puerto Rico); we obtained, approximately, 3 rats/trap-hour in 1999. At Saint-Paul island, Micol and Jouventin (2002) calculated between 5 and 100 rats/ha depending on the location. Hooker and Innes (1995) calculated rat density in a sector of North Island, New Zealand; Shanker (2000) got up to 44 rats/ha in continental locations in India.

The corrected trap-nights index is smaller than figures calculated on a small (5.2 ha) flat island in Fiji for *Rattus exulans* being 65.93 (Houston 2002) to 114.3 (Watling 2002).

Table 3. Results of the campaign done in 1992.

1992	April	August	October
Total load (g)	17,520	17,160	16,800
Consumption (g)	5550	5850	510

Table 4. Results of the campaign done in 1999 and 2000.

1999–2000	1	2	3	4	5	6	7	8	9	10	11
Total load (g)	2880	2880	2880	8592	8624	5216	8160	8640	8640	8218	8256
Consumption (g)	2880	2848	1584	928	144	16	0	0	0	16	32

Bait and baiting stations

As one of the targets of the campaigns was to leave as less poison as possible available in the rats' guts, we considered positive the fact that flocoumafen wax-cereal blocks were consumed faster than the others. This is due to both its palatability (at least as palatable as the cereal alone and very much more than wax blocks) and to the smaller dose. Cereals could be more easily taken by ants and introduce the product into the non-target food chain.

Although our baiting stations were costlier than others such as pipes or plastic bottles (Garcia et al. 2002; Merton et al. 2002), it was considered that they were safe enough to avoid all non-target risks.

Poisoning

In 1992, close to 992 g/ha of brodifacoum 50 ppm was consumed. The fact that during two years there were no signs of rats and, after first tracks in 1995 a demographic explosion occurred, allows us to think that eradication was probably successful but re-colonisation happened. In fact, the inhabited Isabel II island is less than 200 m close to Rey Francisco. At the time of this first campaign, a dump was very close to the closest point between the two islands. By 1994, the dump was translated to the other side of Isabel II, and incineration became general for organic items. Unfortunately, we were not able to monitor the period after this campaign, and recovery of the rat population, either by remnants or re-colonisation, occurred.

It is notable that in the northern part of the island, where the trapping grid occupied most of the surface in 1992, consumption was quite smaller. Snap-trapping can notably reduce the rat population if the area is small. This was already noted by Moors (1985) in an islet where baiting was unnecessary after trapping.

In the 1999–2000 campaign, about 700 g/ha of flocoumafen 50 ppm was consumed in total, while the maximum amount of poison available at each moment was about the same quantity. Merton et al. (2002) used approximately 600 g/ha of brodifacoum 50 ppm at a first pulse, killing apparently most of the rats and approximately 2 kg/ha in total. In open air poisoning campaigns, the available bait at any moment is higher than that inside baiting stations. The doses used on Rey Francisco Island campaigns ranged 35–50 mg of anticoagulant per hectare, and García et al. (2002) used 24.5 mg/ha of brodifacoum. Normal rates for anticoagulants in aerial application exceed 200 mg/ha. For example, in Saint-Paul (Micol and Jouventin 2002), the rate ranked from 10 to 40 kg/ha; bromadiolone 20 ppm was spread at 10 kg/ha on Browns Island (Veitch 2002a) and on Fanal Island, the dose was 10 kg/ha of brodifacoum 20 ppm (Veitch 2002b).

The use of covered baiting stations and pulsed baiting notably reduced the amount of bait exposed in the field, although it is more work costly. In Chafarinas, it was cost effective because at least two people have to be present anyway on the archipelago permanently. This task could be accomplished easily among their other duties during autumn and winter, when there are less activities to be done. It can be used for small islands, although probably it could be useful at a bigger scale if personnel are available. In Congreso, one of the islands of the archipelago, despite a similar effort, we did not arrive at a solution to eradicate the population; this was mainly because of the inaccessible cliffs, although the effect on seabirds was highly positive (Orueta et al. 2002) and that several indexes (snap traps, bait consumption) proved that the population was very close to being exterminated. It is worth highlighting the lack of corpses although research was done to recover any possible dead rats. No secondary data on non-target deaths were registered in any of the campaigns. It is possible that the disappearance of some baits during the last two pulses in 2000 after three pulses with no consumption at all (Table 4) could be due to *Larus michahellis*, but it is not sure that consumption occurred. Anyway, we did not find any corpse of this very common species during the campaigns and monitoring.

Monitoring of trapping has been conducted since 2000, and no rats have been recorded. There are also 60 baiting stations homogeneously distributed on the island, and no bait consumption was registered up to spring 2003.

In 1999, the greater density of baiting stations and the proximity of pulses (without letting the population to recover) were factors contributing to success. The continuity of baiting throughout the years is a guarantee against re-invasion, but an intensive poisoning campaign should be done in Isabel II, as well as quarantine measures should be taken to minimise risk in the future.

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