

# Evaluating alternative rodenticides for island conservation: roof rat eradication from the San Jorge Islands, Mexico

C. Josh Donlan<sup>a,\*</sup>, Gregg R. Howald<sup>a</sup>, Bernie R. Tershy<sup>a,b</sup>, Donald A. Croll<sup>a,c</sup>

<sup>a</sup>Island Conservation & Ecology Group, University of California Long Marine Laboratory, 100 Shaffer Road, Santa Cruz, CA 95060, USA

<sup>b</sup>Institute of Marine Science, University of California Long Marine Laboratory, 100 Shaffer Road, Santa Cruz, CA 95060, USA

<sup>c</sup>Department of Ecology and Evolutionary Biology, University of California Santa Cruz, Long Marine Laboratories, 100 Shaffer Road, Santa Cruz, CA 95060, USA

Received in revised form 22 November 2002; accepted 24 November 2002

## Abstract

Introduced commensal rats (*Rattus* spp.) are a major contributor to the extinction and endangerment of island plants and animals. The use of the toxin brodifacoum to completely eradicate rats from islands is a powerful conservation tool. However, brodifacoum is toxic to animals other than rats and on some islands its use may not be feasible without prohibitively expensive mitigation. As part of a regional conservation program, we experimentally tested brodifacoum and two less toxic rodenticides, diphacinone and cholecalciferol, in eradicating *Rattus rattus* from three small islands in the northern Gulf of California, Mexico. All three rodenticides were successful in eradicating rats, suggesting that the less toxic diphacinone and cholecalciferol may be useful alternatives to brodifacoum for some island eradication programs. However, the choice of rodenticide must be balanced between efficacy and the risks to non-target species. Applied field research is needed on less toxic rodenticides, as well as improving palatability of baits. This may prove invaluable in preventing extinctions and in restoring larger and more diverse island ecosystems.

© 2003 Elsevier Ltd. All rights reserved.

**Keywords:** Brodifacoum; Cholecalciferol; Diphacinone; Eradication; Exotic mammals; Gulf of California; Introduced species; Invasive species; Non-target poisoning; *Rattus rattus*; Seabird conservation

## 1. Introduction

Commensal rats (*Rattus* spp.) introduced to islands have contributed to a large percentage of animal extinctions (Atkinson, 1985; Ebenhard, 1988; Groombridge et al., 1992). They are now found on over 90% of the world's island groups (Atkinson, 1985), where they continue to threaten insular plants, invertebrates, reptiles, mammals, and birds (Daniel and Williams, 1984; Atkinson, 1985; Stone et al., 1994; Palmer and Pons, 1996; Sugihara, 1997; Daltry et al., 2001; Herrera-Montalvo and Flores-Martinez, 2001; Towns et al., 2001). Until recently, it was widely accepted that invasive rats were a permanent part of these island ecosystems, and management was limited to control efforts.

However, in the last 20 years, techniques pioneered by New Zealand conservationists have been developed to eradicate invasive rats [Roof (*Rattus rattus*), Norway (*Rattus norvegicus*) and Polynesian (*Rattus exulans*) rats] from islands with the select use of rodenticides (Taylor and Thomas, 1989, 1993). These techniques are powerful tools for preventing extinctions and they have recently been improved with the advent of new rodenticide delivery techniques, such as aerial broadcast. Using these techniques, invasive rats have been removed from over 90 islands worldwide, including most recently islands in North America (Towns and Ballantine, 1993; Donlan et al., 2000; Dunlevy et al., 2000; Taylor et al., 2000; US National Park Service, 2000; Atkinson, 2001). As the science of invasive rat eradication develops, eradication programs are being conducted on increasingly larger and more biologically complex islands (e.g. Campbell Island, New Zealand of 11,300 ha and Anacapa Island, USA of 300 ha with an endemic rodent; P. McClelland, personal communication; US National

\* Corresponding author at: Department of Ecology and Evolutionary Biology, Corson Hall, Cornell University, Ithaca, NY 14853-2701, USA. Tel.: +1-607-254-4230; fax: +1-607-255-8088.

E-mail address: [cjd34@cornell.edu](mailto:cjd34@cornell.edu) (C.J. Donlan).

Park Service, 2000). Further, the techniques are being adopted for controlling rats in large areas of much larger islands (i.e., main islands of New Zealand; Saunders and Norton, 2001).

The majority of invasive rat eradications have been achieved using the second generation anticoagulant brodifacoum (3-[3-(4'-bromo-[1,1'-biphenyl]-4-yl)-1,2,3,4-tetrahydro-1-naphthalenyl]-4-hydroxy-2H-1-benzopyran-2-one). Like other anticoagulants, brodifacoum acts by blocking the synthesis of the vitamin K dependent clotting factors in the liver of vertebrates (Hadler and Sahdbolt, 1975). Death results from uncontrolled bleeding after a threshold level of the active ingredient concentrates in the liver. Brodifacoum and other second generation anticoagulants have greater persistence and potency than some other toxins used to kill rats and consequently can cause death after a single dose, a desirable characteristic for rat eradications (Eason et al., 1994; Eason and Spurr, 1995). However, this greater persistence and potency also increases the risk of primary and secondary poisoning of non-target animals (Eason and Spurr, 1995).

Brodifacoum is toxic to all vertebrates to varying degrees. Primary and secondary poisoning from feeding on anticoagulant-killed rodents is well known and has been demonstrated both in the lab (Townsend et al., 1981; Newton et al., 1990) and field (Eason and Spurr, 1995; Joermann, 1998; Howald et al., 1999). During rat eradications, there are clear risks to (1) non-target primary poisoning of herbivorous and omnivorous birds by consumption of cereal-based baits and (2) secondary poisoning to avian predators and scavengers (Eason and Spurr, 1995; Howald et al., 1999). While less known, insectivorous birds, bats, and lizards may also be at risk to non-target poisoning (Daniel and Williams, 1984; Godfrey, 1984; Merton, 1987). In prior rodent eradication campaigns, the risks of non-target poisoning have been short-term and outweighed by the long-term benefits of rat removal (Townsend, 1994; Empson and Miskelly, 1999), with native species recovering quickly to pre-eradication levels or higher (Davidson and Armstrong, 2002). However, invasive rats threaten native species on a number of large biologically diverse islands where primary or secondary brodifacoum poisoning could severely impact populations of native species, and where effective mitigation may be difficult and expensive. The use of less persistent or less toxic rodenticides in island eradication campaigns could help minimize non-target poisoning risks. This would only be an effective conservation strategy if these alternative toxins are 100% efficacious against invasive rats.

Diphacinone (2-(diphenylacetyl)-1,3-indandione), a first generation anticoagulant, is similar to brodifacoum in toxicology and pathology. However, it is virtually non-toxic to birds, as well as much less persistent in tissues (Buckle, 1994). Cholecalciferol (9,10-seocholesta-

5,7,10(19)-trein-3 betaol), also known as Vitamin D3, is a subacute rodenticide that causes mobilization of calcium stores from bones to the bloodstream; death results from hypercalcaemia and calcification of the blood vessels (Buckle, 1994). Lab evidence suggests that cholecalciferol is significantly less toxic to birds than brodifacoum (Eason et al., 1994). Diphacinone has recently been used successfully to eradicate rats from Buck Island (72 ha), Virgin Islands (G. Witmer, personal communication). While cholecalciferol has been used for rodent and other exotic vertebrate control, it has never been used for an island eradication program.

As part of a regional island conservation program (Carabias-Lillo et al., 2000; Donlan et al., 2000; Tershy et al., in press), we removed roof rats from the San Jorge Islands, Mexico (Fig. 1). Exploiting the experimental opportunity of conservation action on three adjacent islands (sensu Donlan et al., 2002), we used three rodenticides: brodifacoum, diphacinone and cholecalciferol, one on each of the islands. Brodifacoum was used on the larger island, while diphacinone and cholecalciferol were used on adjacent, smaller islands. Here, we suggest and provide field evidence that the rodenticides diphacinone and cholecalciferol may be feasible alternatives to brodifacoum in certain island rat eradication programs.

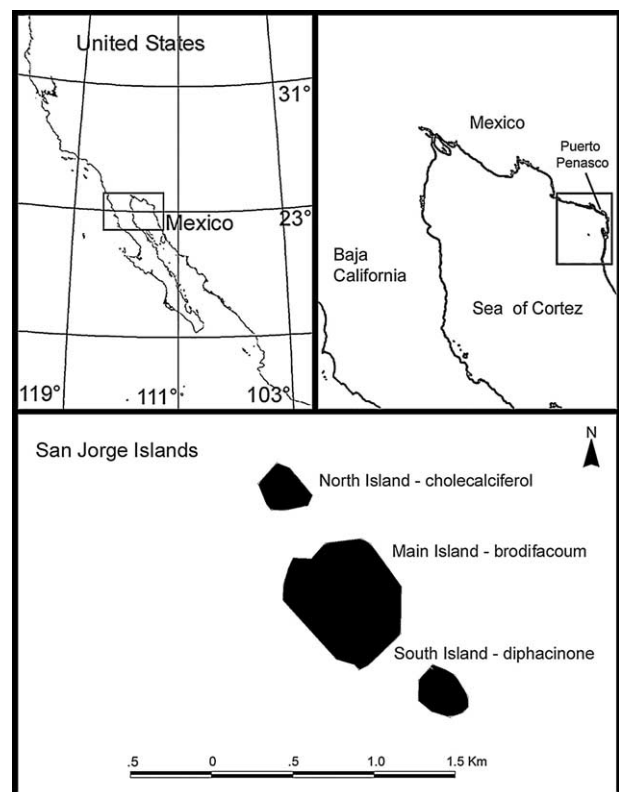


Fig. 1. San Jorge Islands, Sonora, Mexico. Three rodenticides were used to eradicate roof rats: brodifacoum from the main island and diphacinone and cholecalciferol from adjacent islands.

## 2. Background, methods, and results

The San Jorge Islands are located in the northern Gulf of California, approximately 41 km from Puerto Penasco, Sonora, Mexico (Fig. 1). The island group consists of one main island (c. 14 ha) with two smaller islands (c. 5 ha) connected to the main island during maximum spring low tides by a narrow isthmus (c. 200 m). While roof rats are capable of swimming substantial distances, we suspect there was little movement between islands (see Discussion). The islands are arid, steep and rocky with no terrestrial plants. There are no native nonvolant mammals or reptiles. The endangered fish-eating bat (*Myotis vivesi*) is present and is known to be vulnerable to rat predation (Herrera-Montalvo and Flores-Martinez, 2001). The islands are an important seabird colony in the region, including nesting brown boobies (*Sula leucogaster*), double-crested cormorants (*Phalacrocorax auritus*), Heerman's gulls (*Larus heermanni*) and red-billed tropicbirds (*Phaethon aetherus*) (Velarde and Anderson, 1994). Craveri's murrelets (*Synthliboramphus craveri*) have been recorded historically (DeWeese and Anderson, 1976) and have likely been extirpated due to rat predation as observed elsewhere in the region for the genus (McChesney and Ter-shy, 1998).

Roof rats were introduced to the islands in the mid-1800s during guano mining operations (Bowen, 2000). Two trips to the islands (November 1996, August 1997) confirmed their presence and removal efforts began in August 2000. The timing of the removal was selected to minimize physical disturbance of nesting seabirds and California sea lions (*Zalophus californianus*). A bait-station approach was adopted (sensu Taylor and Thomas, 1989). Bait stations were made from 50-cm lengths of 100 mm diameter plastic pipe and placed on the islands in a 25×25 m grid. In areas inaccessible due to steep cliffs, bait was broadcast by hand. Rats could enter the bait stations from open sides and freely remove bait. Stations were placed out two days prior to bait deployment so that rats could acclimate to the novel structures in their environment (Taylor and Thomas, 1989).

Three rodenticides were used in the removal. Brodifacoum (50 ppm, Final<sup>®</sup> Blox<sup>™</sup> Bell Laboratories, Madison, Wisconsin, USA) was used on the main island, cholecalciferol (50 ppm, Ditrac<sup>®</sup> Blox<sup>™</sup> Bell Laboratories, Madison) on the north island, and diphacinone (750 ppm, Quintox<sup>®</sup> Bell Laboratories) on the south island (Fig. 1). Brodifacoum and diphacinone bait were in 20 g extruded cereal wax blocks, while cholecalciferol bait was only available in cereal pellet form and dispensed in 10 g packages. Stations were monitored and bait replenished at regular intervals for a month (August–September 2000, daily for 5–10 days and once a week thereafter), after which stations were

checked five times over the next 2 years (October 2000, January 2001, April 2001, July 2001, March 2002). In addition to monitoring bait uptake from the bait stations, snap-traps and indicator blocks were used to monitor rats just prior, during, and after the eradication campaign.

Rats occurred on all three islands prior to eradication. Trap success on the islands during the three days prior to poisoning was between 38 and 62% (number of traps: main island = 38, north island = 20, south island = 20). Rats began removing poison from stations within days of baiting (Table 1). On the main island, brodifacoum uptake peaked (66%) between 5 and 10 days and ceased after 24 days (Table 1, Fig. 2). On the north (cholecalciferol) and south (diphacinone) islands, bait uptake ceased around 10 days (Table 1, Fig. 2). Cholecalciferol uptake peaked early (day 2 = 27%) and declined consistently; while, diphacinone uptake peaked around day five (Fig. 2).

Roof rats were successfully eradicated from all three islands. Monitoring of the islands after the month of baiting showed no sign of rat presence on any of the three islands. During visits to the island over the next 2 years (October 2000, January 2001, April 2001, July 2001, March 2002), we failed to detect rats or rat sign on any of the islands with both snap-trapping and indicator blocks (main island: 340 trap nights/916 indicator block nights; south island: 163/536; north island 140/430).

## 3. Discussion

All three of the rodenticides tested in this study were 100% efficacious against roof rats. We cannot rule out the possibility that rats on the diphacinone and cholecalciferol islands crossed over to the brodifacoum island and consumed bait. Given that rats on San Jorge were observed feeding in the intertidal and roof rats are known to expand their ranges when territories become unoccupied (I.A.E. Atkinson, personal communication), such inter-island movement might be expected.

Table 1  
Activity of bait stations on the San Jorge Islands, Mexico

	Brodifacoum	Diphacinone	Cholecalciferol
Total number of bait stations	95	17	16
Percent of active bait stations	81	53	93
Mean lag time from baiting to activity (days)	4.1 <sup>a</sup>	3.3	2.6 <sup>a</sup>
Mean duration of activity (days)	8.5 <sup>b</sup>	4.9 <sup>b</sup>	7.4 <sup>b</sup>
Total amount of bait used (weight)	2063 (412 kg)	293 (59 kg)	241 (24 kg)

<sup>a</sup> Kruskal–Wallis ANOVA, Bonferroni,  $P < 0.001$ .

<sup>b</sup> Kruskal–Wallis ANOVA, Bonferroni,  $P < 0.04$ .

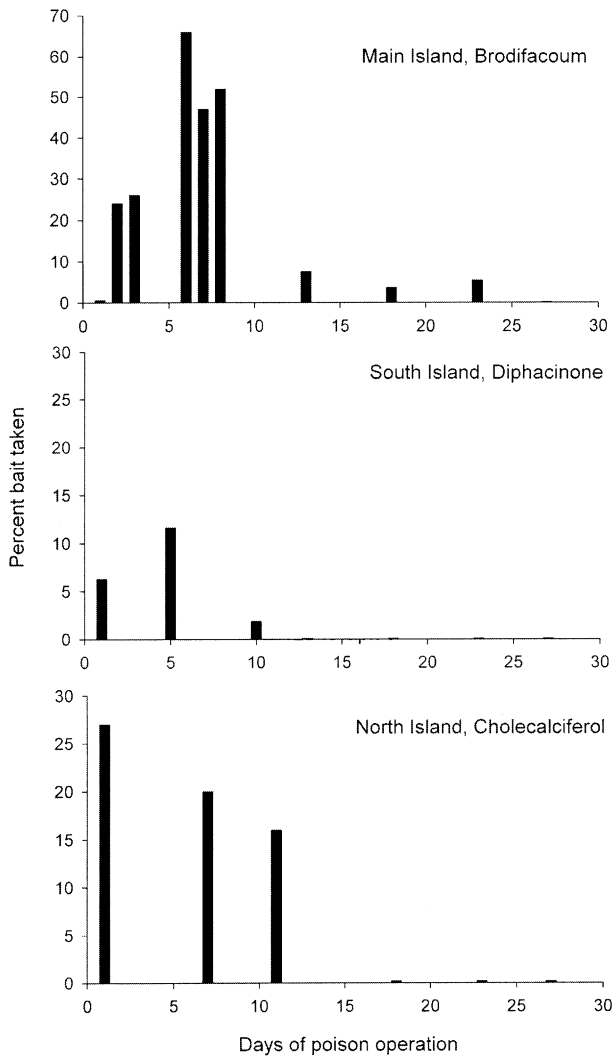


Fig. 2. Bait uptake on the San Jorge Islands, Mexico.

However in this case, we believe it is unlikely for several reasons. First, while the Gulf of California possesses large tidal ranges, stations were armed during a neap tidal cycle. Further, when stations were armed, the low-low of the mixed-semidiurnal tides occurred during the day, thus initially minimizing the time the islands were connected when rats were active. Second, if inter-island movement did occur, it would likely to have, at least initially, only affected a small number of rats whose home ranges are in close proximity to adjacent islands. Third, while roof rats are capable of swimming, intentional translocations of radio-collared roof rats on the Anacapa Island, California to adjacent islets revealed no movement between islands (similar to San Jorge, Anacapa is made up of three adjacent islands separated by short distances; B. Fitz-Earle and G.R. Howald, unpublished data). And lastly, the differing patterns in bait uptake, including the nearly immediate uptake and timing of the uptake peaks (Fig. 2), suggest that the dynamics of the rodenticide effects were different on the three islands and thus a real comparison was achieved.

On the larger brodifacoum island, bait uptake and lag time to activity were similar to other rat eradication campaigns, showing a single pulse uptake event with a lag time of a few days (Taylor and Thomas, 1993; Taylor et al., 2000). On the diphacinone island, mean activity time was less than the brodifacoum island (Table 1). This is opposite of what might be expected given that diphacinone is a multi-dose anticoagulant. Two scenarios may account for these observations. First, rats may have been in low densities on the diphacinone island and cached enough bait to result in eventual mortality. Second, high rat densities were present on the larger brodifacoum island and there was selective cohort killing, thus lengthening the mean activity time of the bait stations. Rat cohorts would have to wait for the previous dominant cohort to die off before gaining access to bait stations. On the cholecalciferol island, bait uptake was nearly immediate, peaked early, and ceased around 10 days. This pattern is expected given the high concentration (750 ppm) and the acuteness of cholecalciferol (Buckle, 1994).

Invasive rat eradication is only possible if each individual rat makes the transition from local food sources to bait containing rodenticide. Rats can be neophobic and may be hesitant to feed on a novel resource, consuming small quantities at first (Barnett, 1988). For example on Lucy Island, Canada, armed bait stations were in place for nine days before rats began removing bait (Kaiser et al., 1997). Clearly, this is not always the case and rats can be often eradicated in a few days as this study demonstrates. Nonetheless, from an efficacy standpoint, the bait should have the ability to kill the target species after a single feeding and to prevent the possibility of selecting for individuals that avoid bait. Cholecalciferol has the potential to induce bait shyness in a population of rats because symptomatic effects of poisoning can be felt after ingestion of a sub-lethal dose (Prescott et al., 1992). However, it was successful in eradicating roof rats from this small c. 5 ha island. Brodifacoum and diphacinone both cause a delayed onset of toxic symptoms which minimizes the risk of bait shyness. A major difference between the two rodenticides is their metabolic sensitivity. In the liver, both diphacinone and brodifacoum bind to the vitamin-K reductase enzyme impairing the production of active clotting factors resulting in death from internal hemorrhaging. Brodifacoum binds tightly to the enzyme and is insensitive to metabolism, giving it the ability to kill a rat after a single feeding. Conversely, diphacinone fails to bind tightly to the enzyme and hence is sensitive to metabolism. Rats must feed on diphacinone bait for seven to ten days before the anticoagulant effect takes hold; ingestion rate must exceed the rate of metabolism. Despite the metabolic sensitivity, and hence multi-dose requirement, of diphacinone, it was successful in eradicating rats from the south island (c. 5 ha).



For successful island rat eradications, the fundamental requirement is that every rat is removed. The appropriate use of rodenticides can eliminate 100% of an island rat population (Taylor and Thomas, 1989, 1993; Taylor et al., 2000). Brodifacoum is one of the most efficacious rat toxins and a proven effective conservation tool. Alternative toxins, such as diphacinone and cholecalciferol used in this study, can reduce the risks of primary and secondary poisoning of non-target species. However, their use increases the risk of failing to eradicate rats due to the metabolic sensitivity of diphacinone and the potential bait shyness of cholecalciferol. As we adopt ecosystem and food web approaches to conservation and management (sensu Power, 2001; Zavaleta et al., 2001), the choice of rodenticide must be balanced between efficacy and the risks to non-target species.

The San Jorge islands are depauperate with little alternate food sources outside of seasonal seabirds and intertidal invertebrates. The lack of year-round abundant food resources may have played a role in the success of diphacinone and cholecalciferol. Nonetheless, these results are encouraging and warrant further experiments to test the use of toxins in addition to brodifacoum that can be used to successfully eradicate invasive rats from islands. Baits with combinations of select rodenticides may prove highly efficacious, while still minimizing the risk of non-target poisoning. Applied field research on less toxic rodenticides, as well as improving palatability of baits, is invaluable in facilitating the prevention of extinctions and the restoration of increasingly complex island ecosystems.

### Acknowledgements

This conservation action would not have been possible without the help of many. We thank our conservation partners the Reserva Islas del Golfo de California and CEDO Intercultural, who provided logistic support. We also thank our field assistants: H. Avila-Villagas, N. Bodorff, T. Comendant, L. F. Lozano-Román, C. Morales, O. Morales, Z. Morales-Gonzalez, R. Galván de la Rosa, and the *busos* of the Puerto Penasco community. We thank P. Boyer, R. Boyer, R. Cudney-Bueno, A. L. Figueroa, J. A. Sanchez, and D. Spight for their support. N. Biavaschi assisted with figures. Comments by R. Taylor and I. Atkinson improved this manuscript. This work was greatly facilitated by the dedication to conservation of the Director and staff of the Sonoran Office of the Reserva Islas del Golfo de California. Funding was provided by Farallon Island Foundation. This research was conducted under permit 4538 *Secretaría del Medio Ambiente, Recursos Naturales*.

### References

- Atkinson, I.A.E., 1985. The spread of commensal species of *Rattus* to oceanic islands and their effect on island avifaunas. In: Moors, P.J. (Ed.), *Conservation of Island Birds*. International Council for Bird Preservation, Cambridge.
- Atkinson, I.A.E., 2001. Introduced mammals and models for restoration. *Biological Conservation* 99, 81–96.
- Barnett, S.A., 1988. Exploring, sampling, neophobia and feeding. In: Prakash, I. (Ed.), *Rodent Pest Management*. CRC Press, Boca Raton, pp. 295–320.
- Bowen, T., 2000. *Unknown Island: Seri Indians, Europeans, and San Esteban Island in the Gulf of California*. University of New Mexico Press, Albuquerque.
- Buckle, A.P., 1994. Rodent control methods: chemical. In: Buckle, A.P., Smith, R.H. (Eds.), *Rodent Pests and Their Control*. CAB International, Cambridge, UK, pp. 127–160.
- Carabias-Lillo, J., Maza-Elvira, J.d.I., Gutierrez-Carbonell, D., Gomez-Cruz, M., Anaya-Reyna, G., Zavala-Gonzalez, A., Figueroa, A.L., Bernudez-Almada, B., 2000. Programa de Manejo Area de Protection de Flora y Fauna Islas de Golfo de California, Mexico. Comision Nacional de Areas Naturales Protegidas, Mexico City, Mexico.
- Daltry, J.C., Bloxam, Q., Cooper, G., Day, M.L., Hartley, J., Henry, M., Lindsay, K., Smith, B.E., 2001. Five years of conserving the 'world's rarest snake', the Antiguan racer *Alsophis antiguae*. *Oryx* 35, 119–127.
- Daniel, M.J., Williams, G.R., 1984. A survey of the distribution, seasonal activity and roost sites of New Zealand bats. *New Zealand Journal of Ecology* 7, 9–25.
- Davidson, R.S., Armstrong, D.P., 2002. Estimating impacts of poison operations on non-target species using mark-recapture analysis and simulation modeling: an example with saddlebacks. *Biological Conservation* 105, 375–381.
- DeWeese, L.R., Anderson, D.W., 1976. Distribution and breeding biology of Craveri's Murrelet. *San Diego Society of Natural History Transactions* 18, 155–168.
- Donlan, C.J., Tershy, B.R., Croll, D.A., 2002. Islands and introduced herbivores: conservation action as ecosystem experimentation. *Journal of Applied Ecology* 39, 235–246.
- Donlan, C.J., Tershy, B.R., Keitt, B.S., Wood, B., Sanchez, J.A., Weinstein, A., Croll, D.A., Alguilar, J.L., 2000. Island conservation action in northwest Mexico. In: Browne, D.H., Chaney, H., Mitchell, K. (Eds.), *Proceedings of the Fifth California Islands Symposium*. Santa Barbara Museum of Natural History, Santa Barbara, California, USA, pp. 330–338.
- Dunlevy, P.A., Campbell, E.W., Lindsey, G.D., 2000. Broadcast application of a placebo rodenticide bait in a native Hawaiian forest. *International Biodeterioration & Biodegradation* 45, 199–208.
- Eason, C.T., Henderson, R.J., Thomas, M.D., Framptom, C.M., 1994. The advantages and disadvantages of sodium monofluoroacetate and alternative toxins for possum control. In: Swright, A.A., Eason, C.T. (Eds.) *Proceedings of the Science Workshop on 1080*. The Royal Society of New Zealand Miscellaneous Series. pp. 159–160.
- Eason, C.T., Spurr, E.B., 1995. Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. *New Zealand Journal of Zoology* 22, 371–379.
- Ebenhard, T., 1988. Introduced birds and mammals and their ecological effects. *Swedish Wildlife Research Viltrevy* 13, 1–107.
- Empson, R.A., Miskelly, C.M., 1999. The risks, costs and benefits of using brodifacoum to eradicate rats from Kapiti Island, New Zealand. *New Zealand Journal of Ecology* 23, 241–254.
- Godfrey, M.E.R., 1984. Non-target and secondary poisoning hazards of "second generation" anticoagulants. *Acta zoologica fennica* 173, 209–212.
- Groombridge, B., 1992. *World Conservation Monitoring Centre*,

- British Museum (Natural History), International Union for Conservation of Nature and Natural Resources, 1992. Global biodiversity: status of the earth's living resources: a report. Chapman & Hall, London.
- Hadler, M.R., Sahdbolt, R.S., 1975. Novel 4-hydroxy-coumarin anticoagulants active against resident rats. *Nature* 253, 277–282.
- Herrera-Montalvo, L.G., Flores-Martinez, J.J., 2001. Conserving fishing bats in the Sea of Cortez. *Bat Conservation International* 19, 7–11.
- Howald, G.R., Mineau, P., Elliott, J.E., Cheng, K.M., 1999. Brodifacoum poisoning of avian scavengers during rat control on a seabird colony. *Ecotoxicology* 8, 431–447.
- Joermann, G., 1998. A review of secondary-poisoning studies with rodenticides. *Bulletin OEPP* 28, 157–176.
- Kaiser, G.W., Taylor, R.H., Buck, P.D., Elliot, J.E., Howald, G.R., Dever, M.C., 1997. The Langeria islands seabird habitat recovery project: eradication of Norway rats—1993–1997. Technical Report Series No. 304. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.
- McChesney, G.J., Tershy, B.R., 1998. History and status of introduced mammals and impacts to breeding seabirds on the California Channel and northwestern Baja California Islands. *Colonial Waterbirds* 21, 335–347.
- Merton, D., 1987. Eradication of rabbits from Round Island Mauritius a conservation success story. *Dodo* 24, 19–43.
- Newton, I., Wyllie, I., Freestone, P., 1990. Rodenticides in British barn owls. *Environmental Pollution* 68, 101–118.
- Palmer, M., Pons, G.X., 1996. Diversity in Western Mediterranean islets: effects of rat presence on a beetle guild. *Acta Oecologica* 17, 297–305.
- Power, M.E., 2001. Field biology, food web models, and management: challenges of context and scale. *Oikos* 94, 118–129.
- Prescott, C.V., El-AMin, M., Smith, R.H., 1992. Calciferols and bait shyness in the laboratory rat. In: Borrecco, J.E., Marsh, R.E. (Eds.). Proceedings of the 15th Vertebrate Pest Conference, Newport Beach, CA.
- Saunders, A., Norton, D.A., 2001. Ecological restoration at Mainland Islands in New Zealand. *Biological Conservation* 99, 109–119.
- Stone, C.P., Pratt, L.W., Stone, D.B., 1994. Hawaii's plants and animals: Biological Sketches of Hawaii Volcanoes National Park. Hawaii Natural History Association: National Park Service: University of Hawaii Cooperative National Park Resources Studies Unit: Distributed by University of Hawaii Press, Honolulu, Hawaii.
- Sugihara, R.T., 1997. Abundance and diets of rats in two native Hawaiian forests. *Pacific Science* 51, 189–198.
- Taylor, R.H., Kaiser, G.W., Drever, M.C., 2000. Eradication of Norway rats for recovery of seabird habitat on Langara Island, British Columbia. *Restoration Ecology* 8, 151–160.
- Taylor, R.H., Thomas, B.W., 1989. Eradication of Norway rats *Rattus rattus* from Hawea Island, Fjordland, using brodifacoum. *New Zealand Journal of Ecology* 12, 23–32.
- Taylor, R.H., Thomas, B.W., 1993. Rats eradicated from rugged Breaksea island (170 HA), Fiordland, New Zealand. *Biological Conservation* 65, 191–198.
- Tershy, B.R., Donlan, C.J., Keitt, B., Croll, D., Sanchez, J.A., Wood, B., Hermosillo, M.A., Howald, G. Island conservation in northwest Mexico: a conservation model integrating research, education and exotic mammal eradication. In: Veitch, C.R., Clout, M.N. (Eds.). Turning the Tide: The Eradication of Invasive Species. Invasive Species Specialist Group of the World Conservation Union (IUCN), Auckland, New Zealand (in press).
- Towns, D.R., 1994. The role of ecological restoration in the conservation of Whitaker's skink (*Cyclodina whitakeri*), a rare New Zealand lizard (Lacertillia: Scincidae). *New Zealand Journal of Zoology* 21, 457–471.
- Towns, D.R., Ballantine, W.J., 1993. Conservation and restoration of New Zealand island ecosystems. *Trends in Ecology and Evolution* 8, 452–457.
- Towns, D.R., Daugherty, C.H., Cree, A., 2001. Raising the prospects for a forgotten fauna: a review of 10 years of conservation effort for New Zealand reptiles. *Biological Conservation* 99, 3–16.
- Townsend, M.G., Fletcher, M.R., Odam, E.M., Stanley, P.I., 1981. An assessment of the secondary poisoning hazard of warfarin to tawny owls. *Journal of Wildlife Management* 45, 242–248.
- US National Park Service, 2000. Anacapa Island Restoration Project, Final Environmental Impact Statement, Ventura, California.
- Velarde, E., Anderson, D.W., 1994. Conservation and management of seabird islands in the Gulf of California: setbacks and successes. In: Nettleship, D.N., Burger, J., Gochfeld, M. (Eds.), Seabirds on Islands: Threats, Case Studies and Action Plans. *Birdlife International*, Cambridge, United Kingdom, pp. 229–243.
- Zavaleta, E.S., Hobbs, R.J., Mooney, H.A., 2001. Viewing invasive species removal in a whole-ecosystem context. *Trends in Ecology and Evolution* 16, 454–459.