Rats on islands (and priority effects)

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Notes:

These slides were used for a guest lecture in the Invasion Biology course for MSc studies in Biology at the University of Copenhagen on May 24, 2016.

Please contact me if you would like to use these slides for any purpose.

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Outline

- Invasion of islands by rats
  - Global status
  - Priority effects – effect of arrival order
- Impact of rats on islands
  - Direct effects – predation
  - Indirect effects - community- & ecosystem-level impact
- Eradication of rats from islands
  - Continued improvement of methods
  - Ecosystem recovery after eradication
  - Reverse priority effects – effect of removal order

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Rattus rattus, black rat, roof rat, ship rat

South India -> Arabia, 4000 BP -> Europe -> Rest of world

Rattus norvegicus, Norway rat, brown rat

Southern China -> Europe in 1400's -> Rest of world



Rattus exulans, Polynesian rat, Pacific rat, kiore

Island of Flores, SE Asia -> rest of Pacific Islands, 2500 BP

Mus musculus, Mouse 

Iran -> Europe, 3000 BP -> rest of world



Rats present on 80% of archipelagos worldwide

Almost entirely human-assisted

Harper, G.A. & Bunbury, N. 2015. Invasive rats on tropical islands: their population biology and impacts on native species. Global Ecology and Conservation 3: 607–627.

http://www.pestdetective.org.nz

“Biotic interactions make things complicated and difficult to predict.”

- Sofie Stensgaard

Invasive European rats in Britain and New Zealand: same species, different outcomes

Carolyn M. King[1], Stacey Foster[1] & Steven Miller[2]

Journal of Zoology **285** (2011) 172–179

Abstract

Two species of European commensal murids, the Norway rat *norvegicus* and the ship rat *Rattus rattus*, have colonized two island archipelagos of comparable size and temperate climate but in opposite hemispheres and with opposite outcomes. Ship rats were common commensals in Britain until replaced by Norway rats; Norway rats were hugely abundant in native forests throughout New Zealand until widely replaced by ship rats. Interference explains the first case, as ship rats are smaller than Norway rats and are always vulnerable to aggressive competition from them, but some other explanation is needed for the second case. We used the marginal value theorem to investigate exploitation competition between these two species in arboreal habitats. We observed the climbing behaviour and 'giving-up time' of captive rats of both species searching for food at different heights above the ground. Our data confirmed that the smaller size and greater agility of *R. rattus* give it a competitive advantage in foraging for scattered small food items above ground. We propose that (1) the outcomes of the interactions between the two rat species in any given place depend on the distribution of food resources in structurally complex habitat, moderated by winter temperatures; (2) the different outcomes of invasions by the two species can be explained in Britain by interference competition, and in New Zealand by exploitation competition and by the absence of specialist arboreal rodents (squirrels).

Priority effects

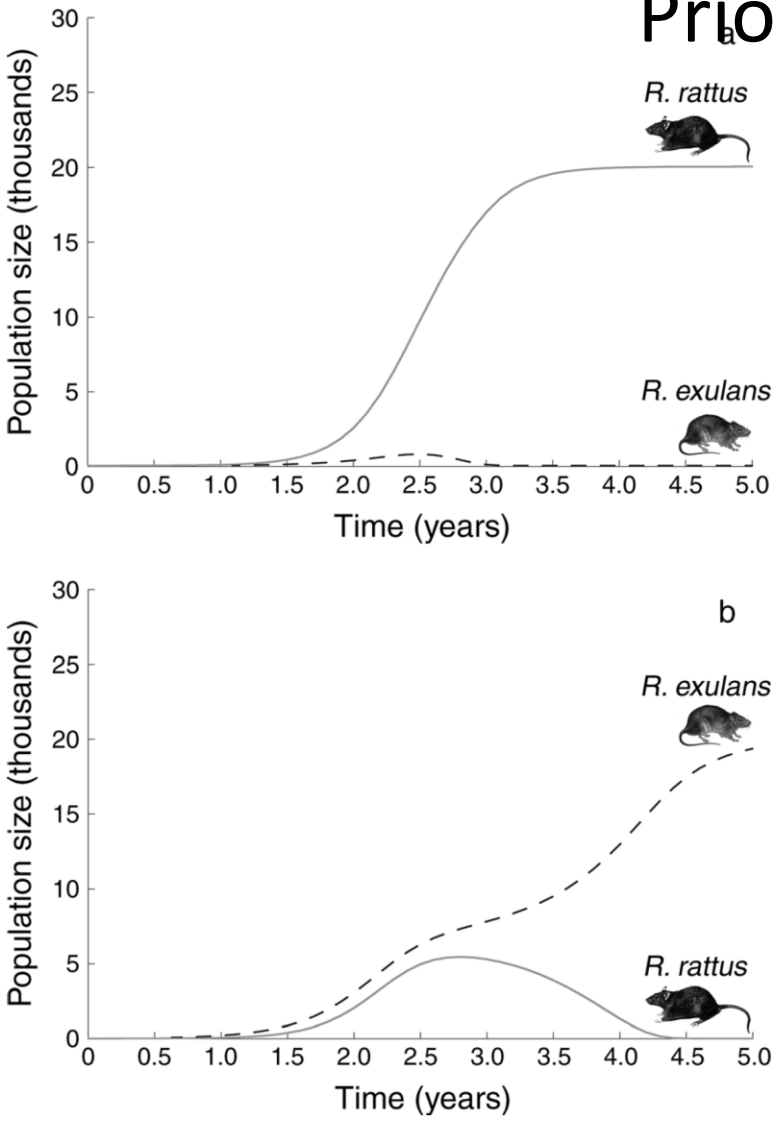


FIG. 3. Propagule pressure simulations of nonequilibrium system dynamics over time with (a) simultaneous colonization by *R. rattus* ($n = 1$) and *R. exulans* ($n = 1$), and (b) simultaneous colonization by *R. rattus* ($n = 1$) and *R. exulans* ($n = 10$). The dashed line is the projected *R. exulans* population, and the solid line is the *R. rattus* population.

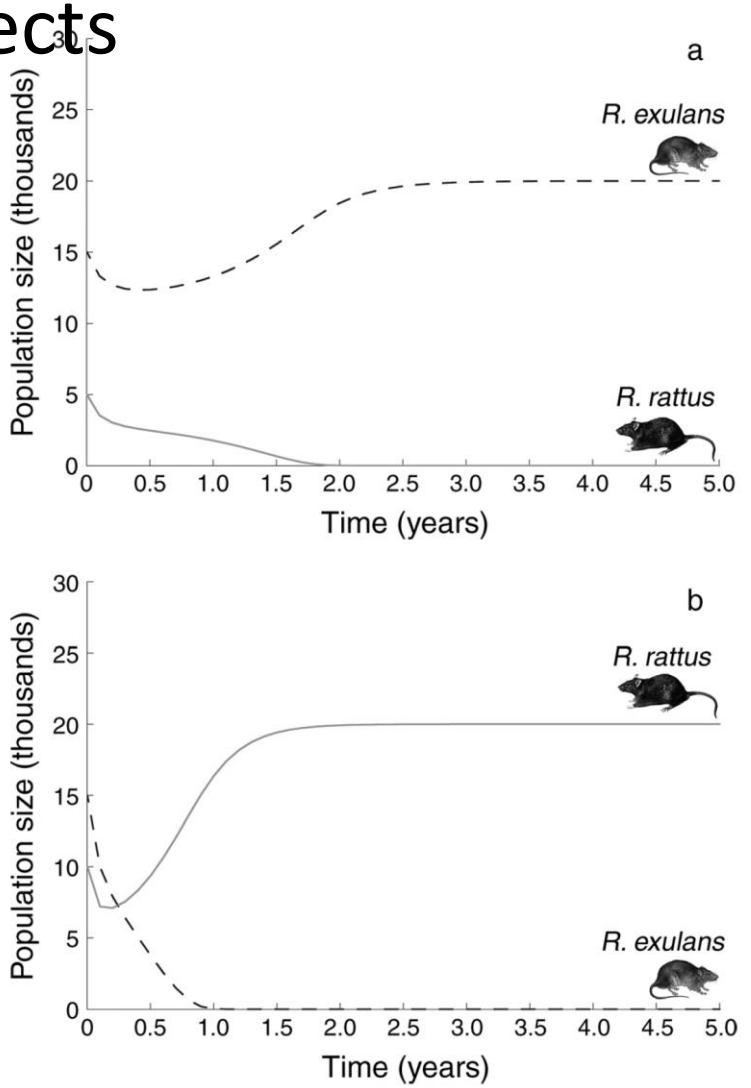


FIG. 4. Incumbent advantage simulations of nonequilibrium system dynamics over time with (a) colonization by *R. rattus* ($n = 5000$) when *R. exulans* is incumbent ($n = 15\,000$), and (b) colonization by *R. rattus* ($n = 10\,000$) when *R. exulans* is incumbent ($n = 15\,000$). The dashed line is the projected *R. exulans* population, and the solid line is the *R. rattus* population.

Russell, J. C. et al. (2014) Over-invasion by functionally equivalent invasive species. *Ecology* 95: 2268-2276

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Direct effects – predation

Have the harmful effects of introduced rats on islands been exaggerated?

David R. Towns[1,2,*], Ian A.E. Atkinson[3] & Charles H. Daugherty[2]

Biological Invasions (2006) 8: 863–891

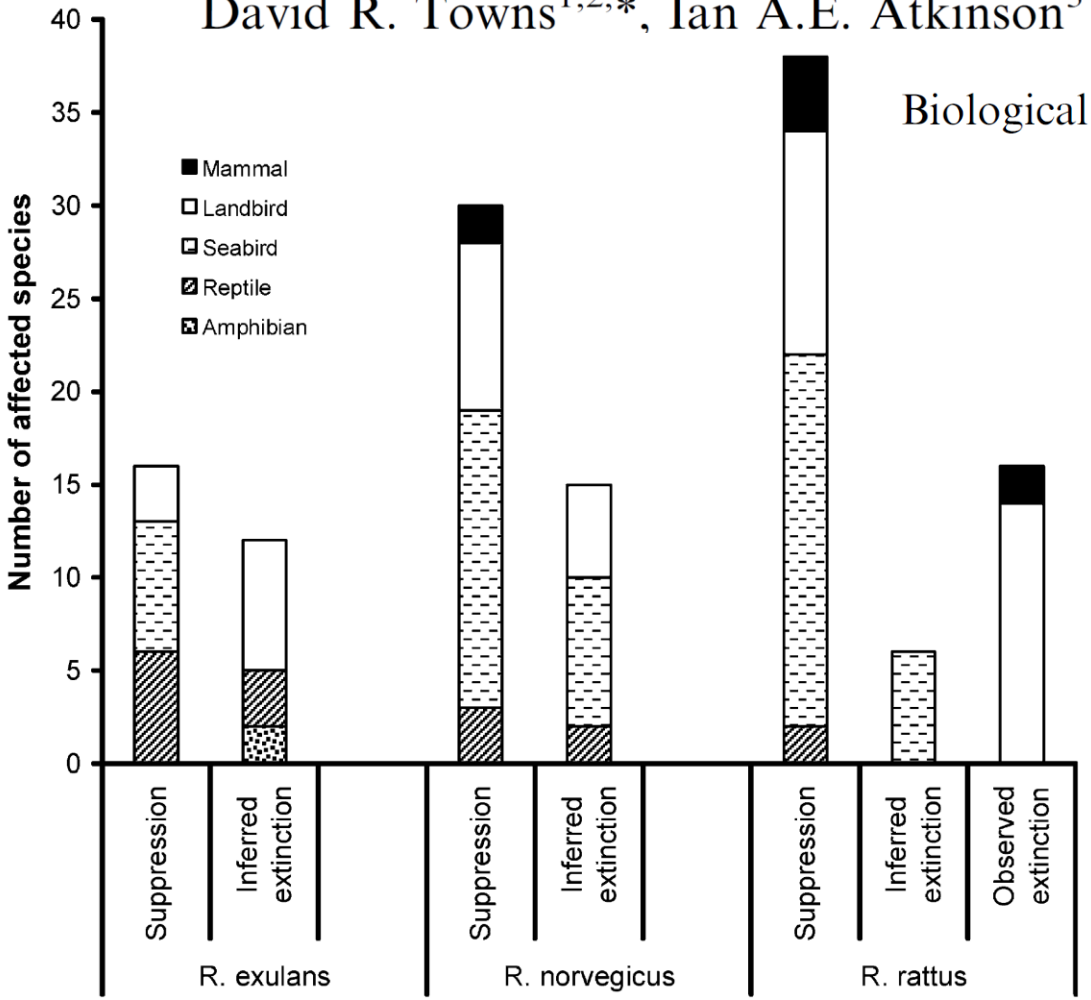


Figure 2. Credible reports of vertebrate species detrimentally affected by *Rattus exulans* ($n = 28$), *R. norvegicus* ($n = 45$), and *R. rattus* ($n = 60$), with seabird data including reports in Atkinson (1985) and assembled by H. Jones (pers. comm.). Suppression includes recruitment failure or population suppression, extinction includes local or total extinction, inferred extinction based on distributional data and observed extinction based on observed invasions.

Direct effects – predation

Great shearwater, *Puffinus gravis*





Fig. 9. A mouse predating on a temporarily neglected great shearwater egg (photo Ben Dilley).



Fig. 4. This great shearwater chick (here 10 days old) died 3.3 days after first being attacked by a mouse (photo Ben Dilley).

Dilley, B.J., D. Davies, A.L. Bond, and P.G. Ryan. 2015. Effects of mouse predation on burrowing petrel chicks at Gough Island. Antarctic Science 27: 543-553.

Direct effects – predation

Review

Severity of the Effects of Invasive Rats on Seabirds: A Global Review

Conservation Biology
Volume 22, No. 1, 2008

HOLLY P. JONES,* BERNIE R. TERSHY,† ERIKA S. ZAVALETA,‡ DONALD A. CROLL,†§
BRADFORD S. KEITT,† MYRA E. FINKELSTEIN,‡ AND GREGG R. HOWALD**

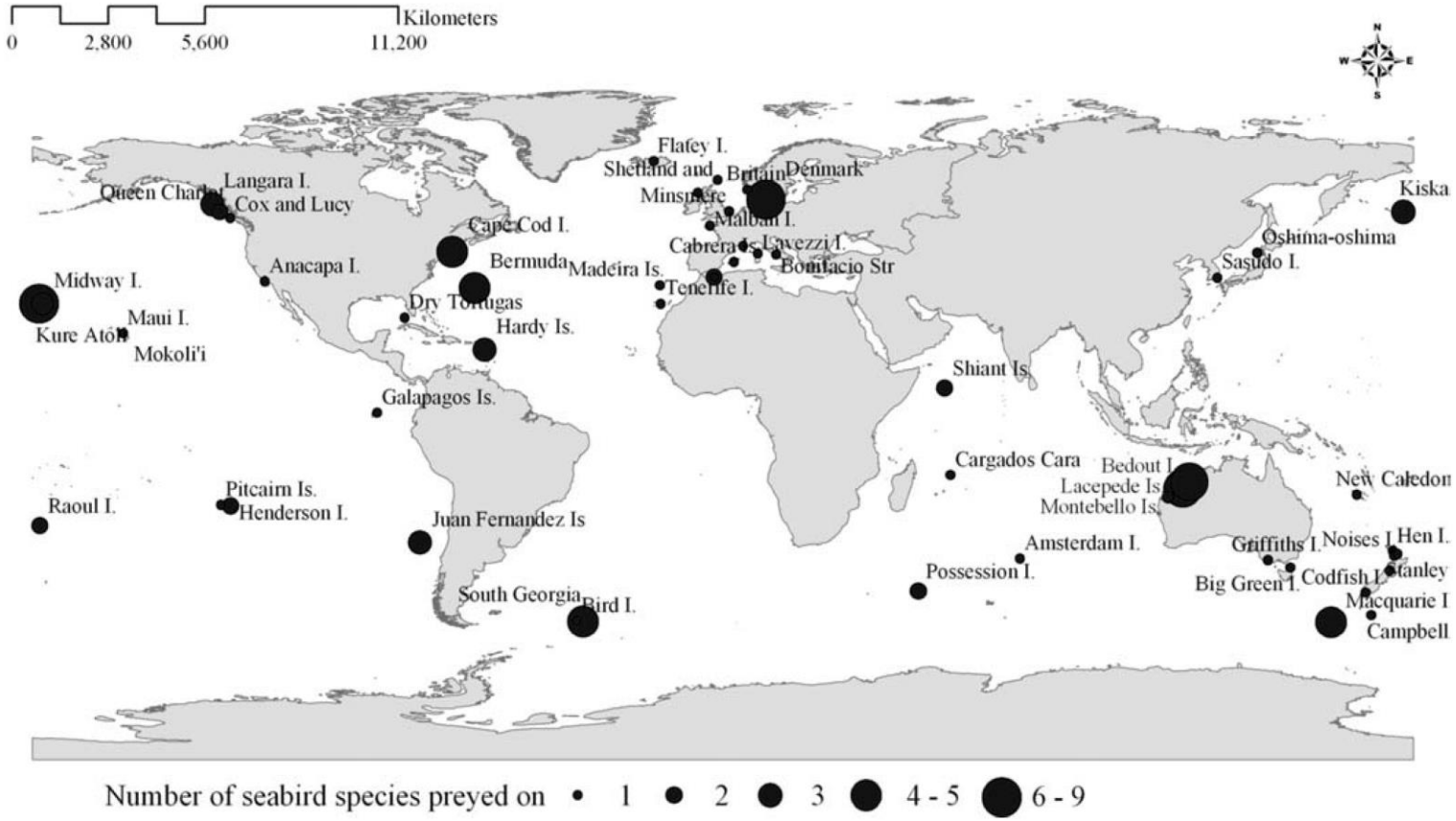


Figure 1. Locations of rat-seabird interactions reviewed for meta-analysis. Dot sizes indicate the number of seabird species affected.

Direct effects – predation



New Zealand fantail, *Rhipidura fuliginosa*

http://www.visitzealandia.com/



Rattus rattus in fantail nest

http://www.doc.govt.nz

Direct AND indirect effects – seed predation and dispersal

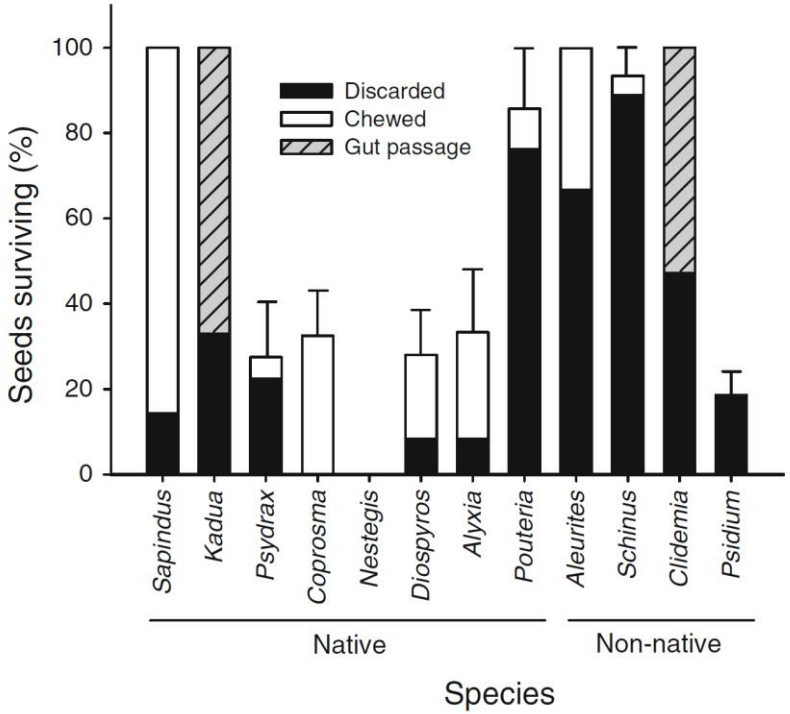


Fig. 3 Mean (SE) percentage of seeds surviving 24 h exposure to captive black rats ($n = 7$–12 rats) where the total number of seeds per fruit for each species was based on mean values described in Table 1. The three categories of seed survival include: discarded (not chewed or ingested), chewed, and gut passage. Error bars reflect total survival (all three categories combined)

Shiels, A.B. and D.R. Drake. 2011. Are introduced rats (*Rattus rattus*) both seed predators and dispersers in Hawaii? *Biological Invasions* 13: 883-894.

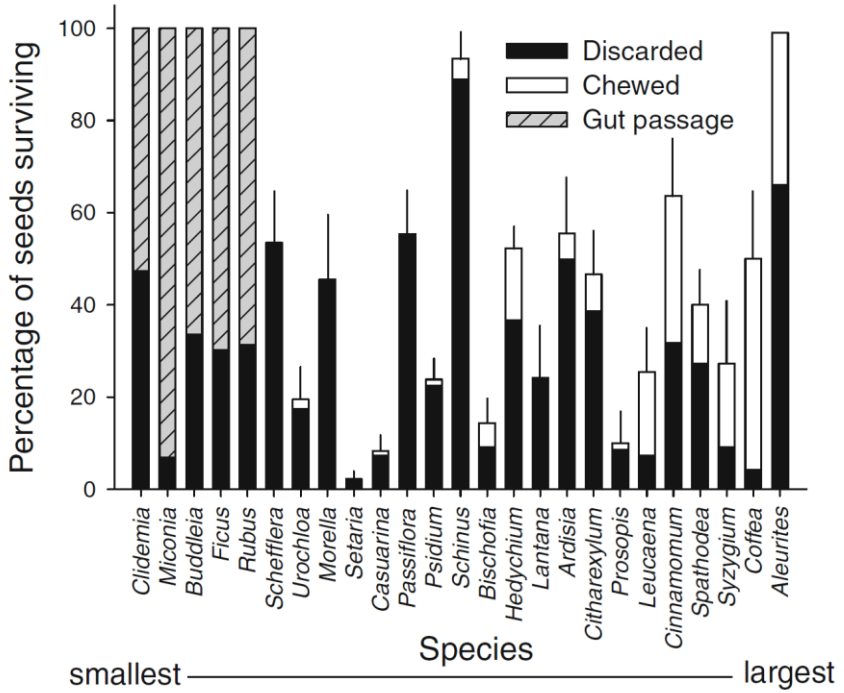


Fig. 2 Mean (SE) seed survival of 25 invasive plant species in Hawaii that were offered to captive *black rats* (9–12 rats for each trial; mean ± SE: 11.0 ± 0.1). The three categories of survival include: discarded (not chewed or ingested), chewed, and gut passage. *Error bars* reflect total survival (all three categories combined). Species ordering on the *horizontal axis* are arranged in ascending seed length

Shiels, A.B. 2011. Frugivory by introduced black rats (*Rattus rattus*) promotes dispersal of invasive plant seeds. *Biological Invasions* 13: 781-792.

Indirect effects – community- and ecosystem-level impact

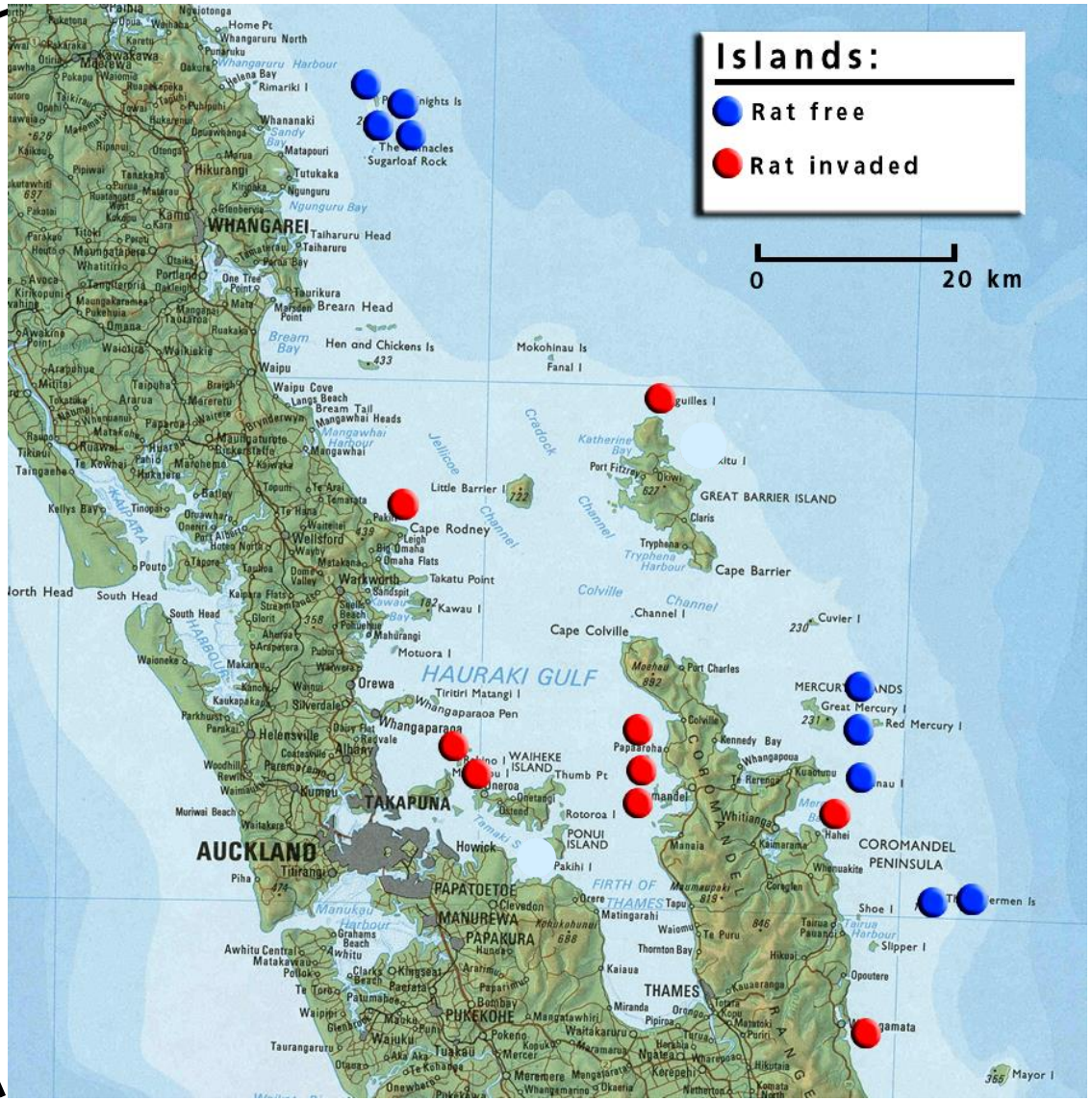
Ecology Letters, (2006) **9**: 1299–1307 doi: 10.1111/j.1461-0248.2006.00983.x

Above- and below-ground impacts of introduced predators in seabird-dominated island ecosystems

Tadashi Fukami,[1,2]* David A. Wardle,[1,3] Peter J. Bellingham,[1] Christa P. H. Mulder,[4] David R. Towns,[5] Gregor W. Yeates,[6] Karen I. Bonner,[1] Melody S. Durrett,[4] Madeline N. Grant-Hoffman[4] and Wendy M. Williamson[1,7]


South Pacific Ocean
Tasman Sea
Auckland
Hamilton
Tauranga
North Island
Gisborne
New Plymouth
Napier
Cook Strait
Palmerston North
WELLINGTON
Greymouth
South Island
Christchurch
South Pacific Ocean
Invercargill
Dunedin
Stewart Island
Antipodes Islands, Auckland Islands, Bounty Islands, Campbell Island, Chatham Islands, and Kermadec Islands are not shown.

New Zealand


Islands:
Rat free
Rat invaded
0
20 km
WHANGAREI
Hikurangi
Whangarei Harbour
Ngunguru Bay
Bream Bay
Mangawhai Harbour
Hen and Chickens Is
Mokohinau Is
Little Barrier I
Cape Rodney
GREAT BARRIER ISLAND
Cape Barrier
Cape Colville
Colville Channel
HAURAKI GULF
Whangaparaoa Pen
WAIHEKE ISLAND
Rotoroa I
PONUI ISLAND
Pakihi I
Howick
AUCKLAND
TAKAPUNA
Waitakere
Manukau Harbour
PAPATOETOE
MANUREWA
PAPAKURA
Awhitu
PUKEKOHE
Waiuku
Tuakau
Pokeno
Mercer
Meremere
Mangatawhiri
Waitakaruru
THAMES
Firth of Thames
COROMANDEL PENINSULA
Whitianga
Hahei
Great Mercury I
Red Mercury I
Cuvier I
Port Charles
Kennedy Bay
Shoe I
Slipper I
Mayor I





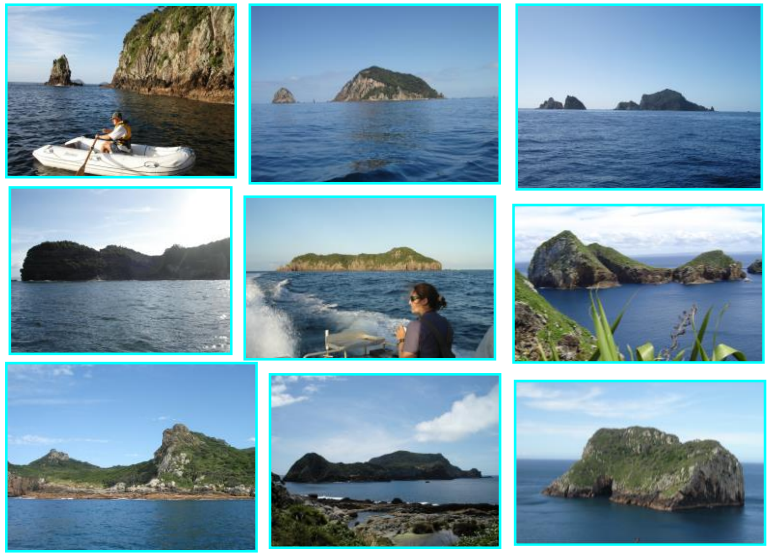


Seabird burrows on forest floor



Rat-invaded island

N=9



Rat-free

vs.

N=9



Rat-invaded

Island status






No Landing
Nature Reserve






Dave Towns









Nutrients from sea

Disturbance

Producer

Higher plants

Algae

Primary consumers

Herbivorous nematodes

#/g

10
5
0

***

Bacteria, fungi

SIR ($mgCO_2$-C/g/h)

1.5
1.0
0.5
0

ns

Minute snails

Log(#/m^2)

4
2
0

*

Secondary consumers

Enchytraeids

#/g

6
4
2
0

***

Microbe-feeing nematodes

#/g

15
10
5
0

***

Rotifers

#/g

20
10
0

**

Collembolans

Log(#/m^2)

4
2
0

*

Tertiary consumers

Predatory nematodes

#/g

8
4
0

ns

Rat-free

Rat-invaded

Island status

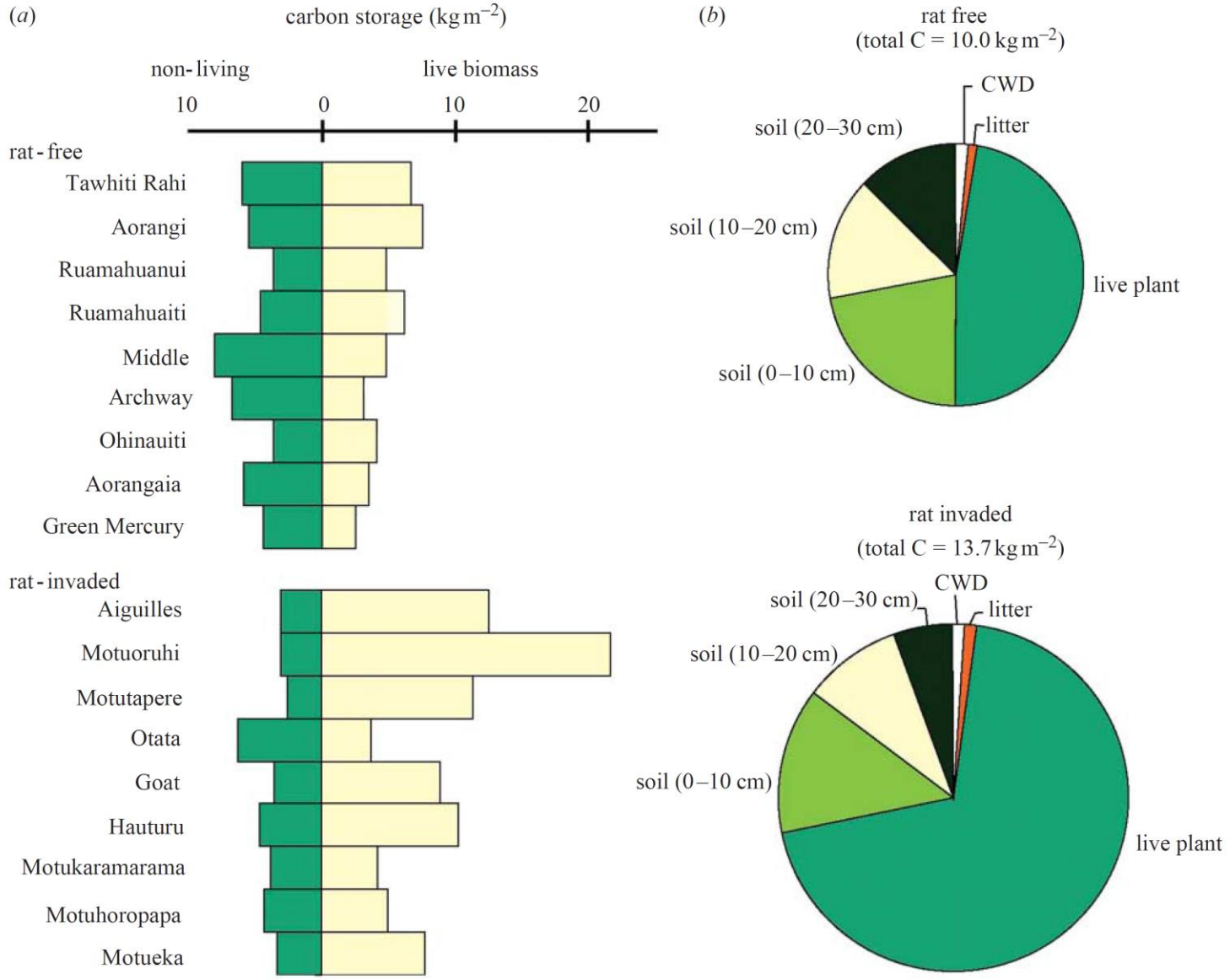


Figure 1. (*a*) Carbon storage in live plant biomass and in non-living pools (soil, litter and CWD) on nine rat-free (seabird-dominated) and nine rat-invaded islands. For both categories, islands are arranged in decreasing order of size. (*b*) Proportions of total ecosystem C stored in different pools for rat-free and rat-invaded islands. Data analyses and significance tests are presented in table 1.

Wardle DA, Bellingham PJ, Fukami T, and Mulder CPH (2007) Promotion of ecosystem carbon sequestration by invasive predators. Biology Letters 3: 479-482

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A helicopter is loaded with rat bait on Rabida Island of Galapagos Islands
Photo: AP
http://www.telegraph.co.uk/



Figure 1. A helicopter with baiting bucket applying rodenticide baits to Macquarie Island in 2011.

Broome, K.G.; Cox, A.; Golding, C.; Cromarty, P.; Bell, P.; McClelland, P.;. 2014: Rat eradication using aerial baiting: Current agreed best practice used in New Zealand (Version 3.0). New Zealand Department of Conservation internal document, Wellington, New Zealand.

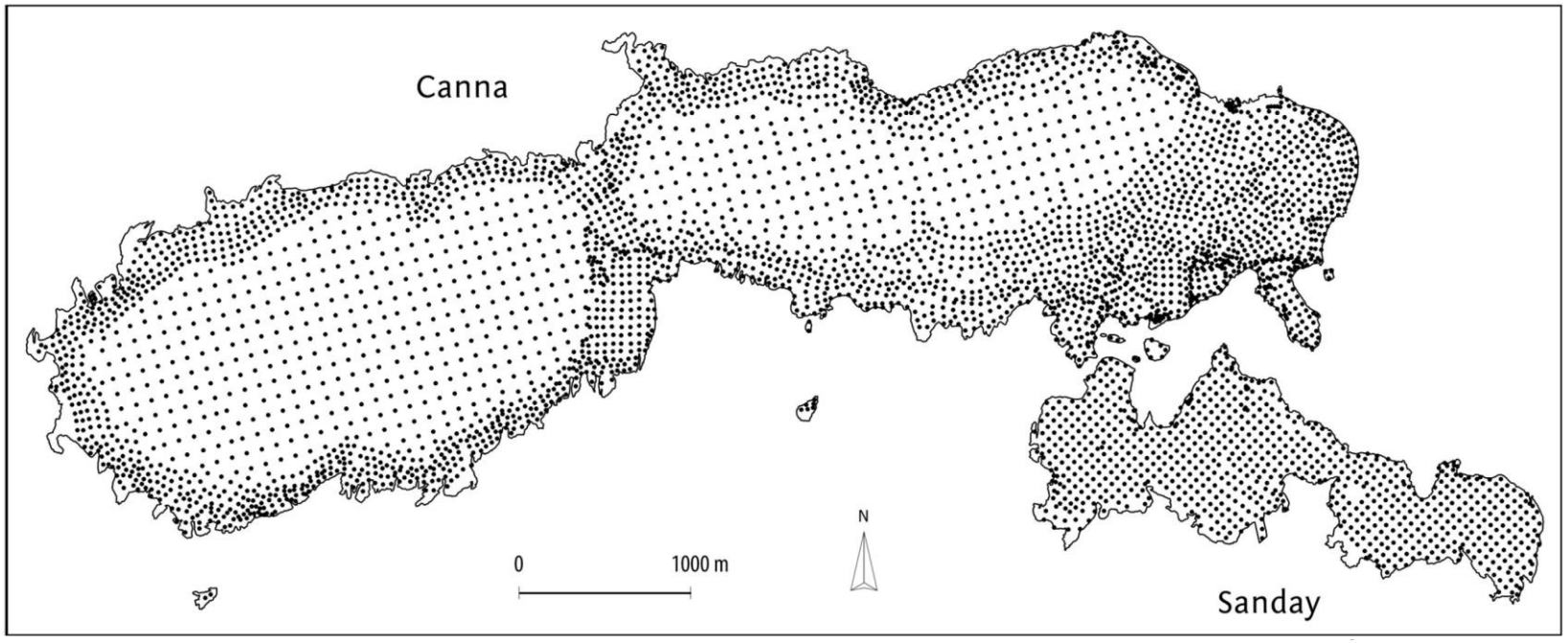


Fig. 2 Bait station grid on Canna and Sanday (bait station positions are marked by a black dot).

Bell, E.; Boyle, D.; Floyd, K. Garner-Richards, P.; Swann, B.; Luxmoore, R.; Patterson, A.; Thomas, R. 2011. The ground-based eradication of Norway rats (*Rattus norvegicus*) from the Isle of Canna, Inner Hebrides, Scotland. Pages 269-274 in Veitch, C.R.; Clout, M.N.; Towns, D.R. (Eds.). Island Invasives: eradication and management. IUCN, Gland, Switzerland.

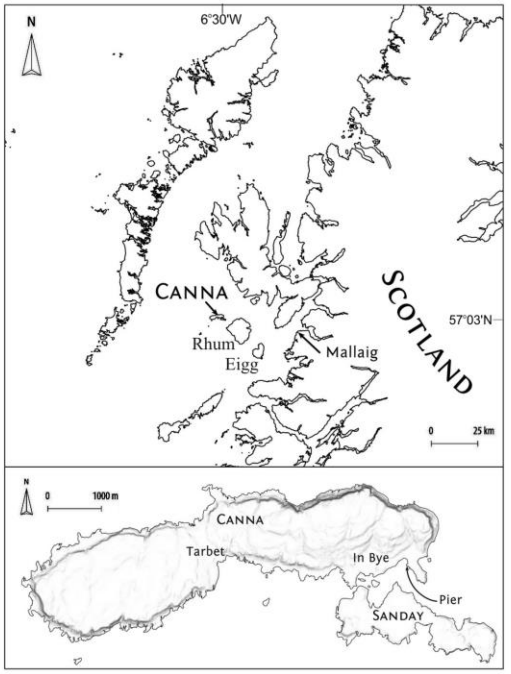


Fig. 1 Location of Isle of Canna, Inner Hebrides, Scotland.

New Zealand Journal of Ecology (2016) 40(2): 197-204

Fifty years of rodent eradications in New Zealand: another decade of advances

James C Russell[1,2,*] and Keith G Broome[3]

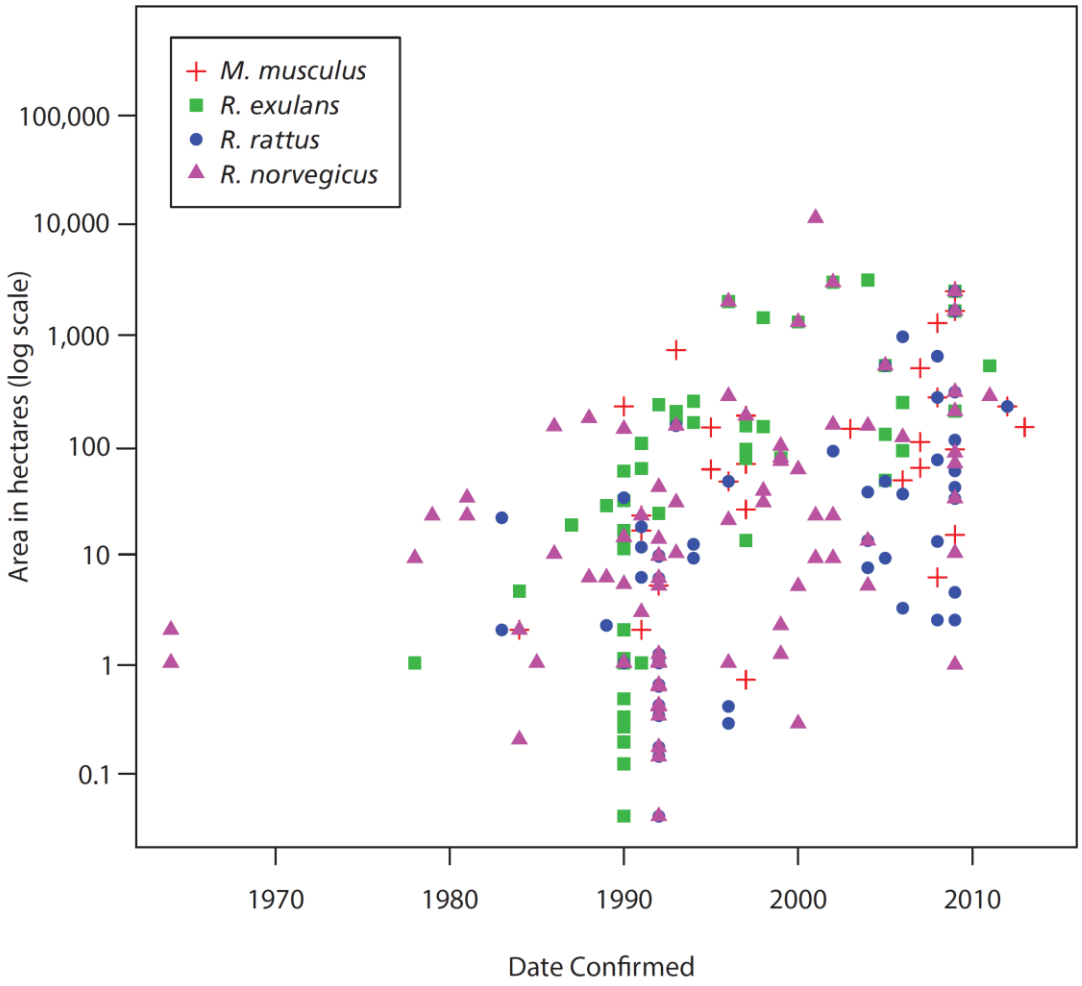
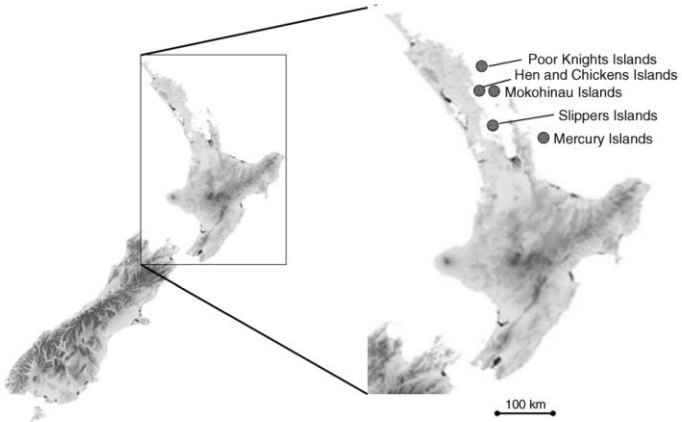


Figure 1. Fifty years of rodent eradications in New Zealand 1964-2014 (updated from Clout & Russell 2006).



Jones, H. P. (2010) Seabird islands take mere decades to recover following rat eradication. Ecological Applications 20, 2075–2080.

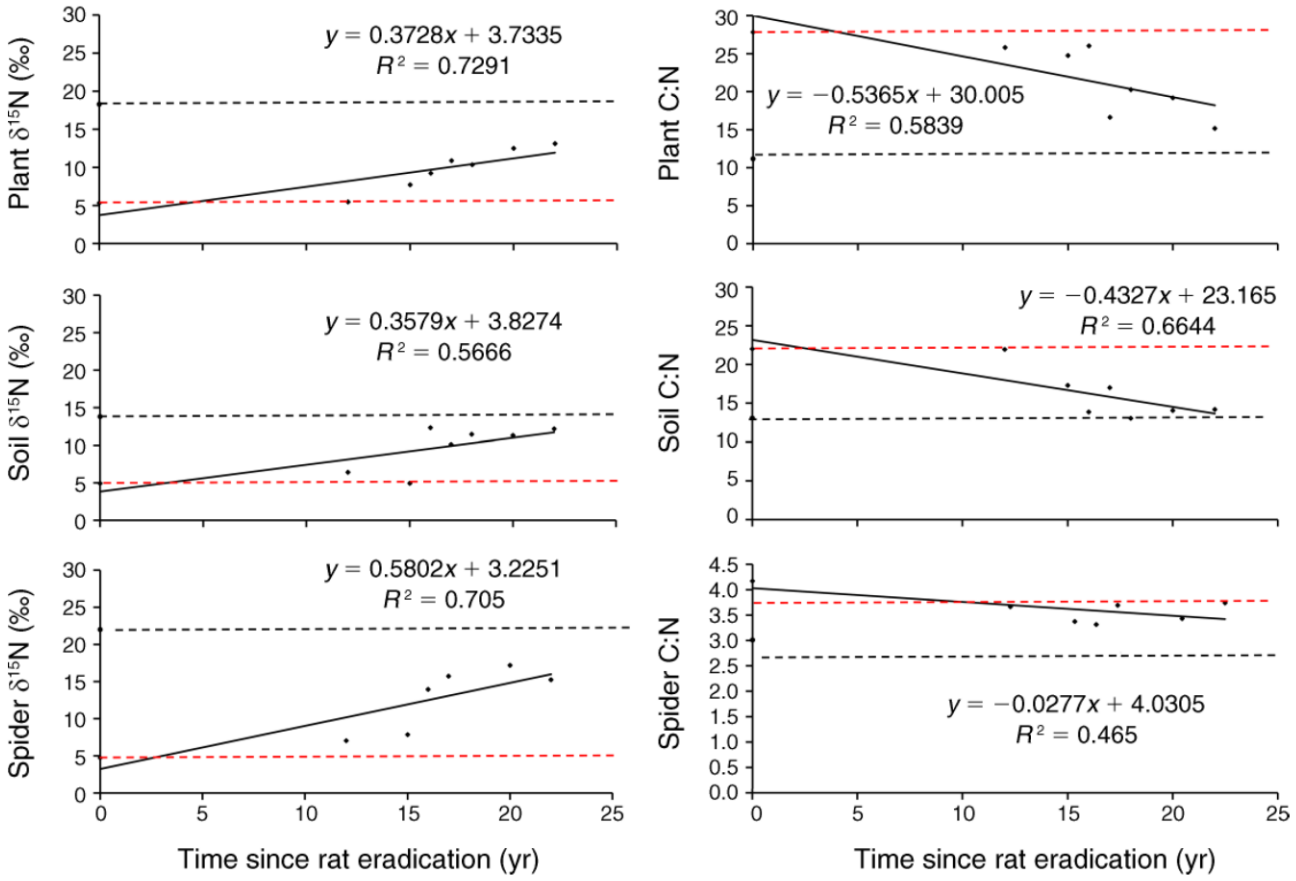
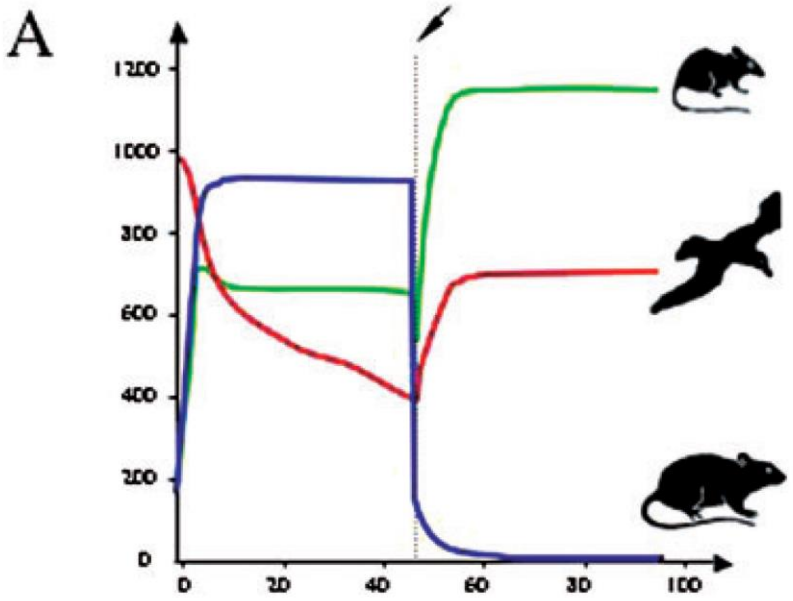


FIG. 2. Values for $\delta^{15}N$ (left panels) and C:N ratios (right panels) in plants, soil, and ground-dwelling spiders on northeastern New Zealand islands. The black dashed lines are average values for control islands that were never invaded, and the red dashed lines are average values for control islands that are currently invaded.



Caut S, Casanovas JG, Virgos E, Lozano J, Witmer GW, Courchamp F. 2007. Rats dying for mice: modelling the competitor release effect. Austral Ecology 32:858–868.

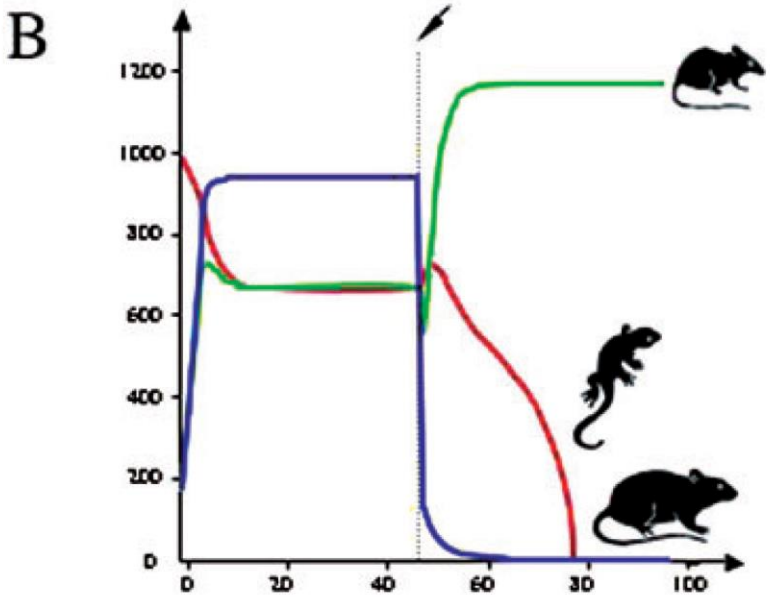


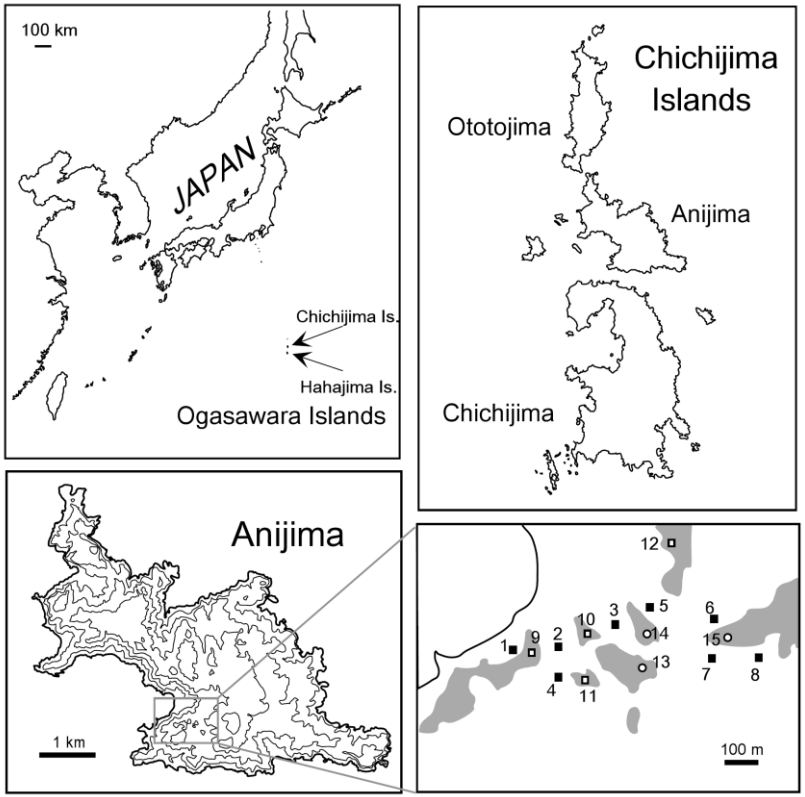
Fig. 4. Impact of the competitor release effect for the population of a prey shared (in red) by the two competitors. In (A), predation is equivalent for both rodents and the prey population avoids extinction but does not recover entirely. In (B), the predation of the mice is much higher than that of the rat and the competitor release causes extinction of the prey (higher in blue, lower in green). Parameter values are the following: $r_r = 0.75$, $r_m = 0.75$, $r_p = 0.5$, $K_r = 1000$, $K_m = 1500$, $K_p = 10000$, $\alpha_r = 0.10$, $\alpha_m = 0.90$, $\delta = 5$, $\omega = 0.85$, and (A): $\mu_r = 0.75$: $\mu_m = 0.9$, (B): $\mu_r = 0.35$: $\mu_m = 1.2$.

"Reverse priority effects?" – effect of removal order

Invasive Non-Native Species' Provision of Refugia for Endangered Native Species

SATOSHI CHIBA

Conservation Biology
Volume 24, No. 4, 2010



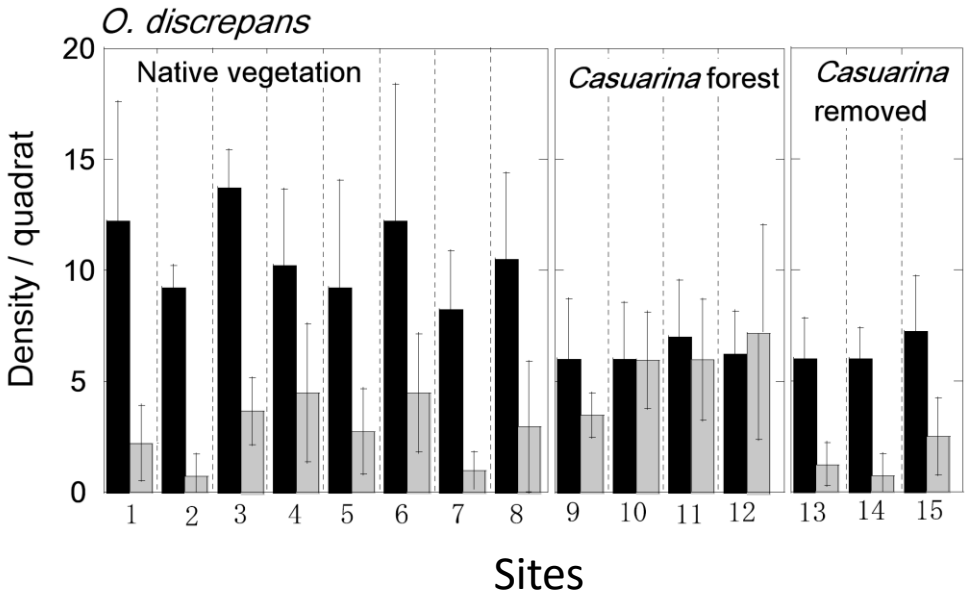


Figure 2. Mean density of the land snails Ogasawarana discrepans, O. capsula, *and* O. optima *at each study site in 2006 (black) and 2009 (gray). Error bars indicate standard deviations.*

"Reverse priority effects?" – effect of removal order

Conservation Biology
Volume 24, No. 4, 2010

Invasive Non-Native Species' Provision of Refugia for Endangered Native Species

SATOSHI CHIBA

Rattus rattus



Greg Calbert

Which one should we remove first?

Predation

Refuge from rats

Native land snails



http://ogasawara-info.jp/

Introduced invasive plants



http://stewartia.net/

Summary

- Rat invasions provide representative examples of complicated, wide-ranging impacts of invasive species on native species.
- Due to the complex web of interactions rats take part in in the ecosystems they invade, priority effects can be important to consider in understanding their invasion and consequences of eradication.