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ORIGINAL ARTICLE

Vegetation status on Nishi-jima Island (Ogasawara) before eradication of alien herbivore mammals: rapid expansion of an invasive alien tree, *Casuarina equisetifolia* (Casuarinaceae)

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Abstract Insular ecosystems can be dramatically affected by alien species, and records of pre-eradication status are essential to evaluate the effects of eradicating alien species. Nishi-jima Island is a small island of the Ogasawara group on which the first program of complete eradication of alien herbivorous mammals (black rats and feral goats) will be conducted. After eradication, the government plans to conduct ecosystem restoration on the island. This paper reports the angiosperm flora and vegetation of Nishi-jima Island before eradication of the rats and goats, with the objective of aiding ecosystem management after the eradication. Our surveys indicate that vegetation cover by the alien tree, *Casuarina equisetifolia* has expanded compared with its distribution in a 1974 aerial photograph of the island. The predominant vegetation in 2006 was *C. equisetifolia* forests and *Zoysia tenuifolia* grasslands, with fragmented native tree vegetation. The flora of the island comprised 69 angiosperm species (50 indigenous species) of which 30% were endemic, far less than for the Ogasawara Islands as a whole (45%). However, several populations of endangered plants remain. To restore the native ecosystem on Nishi-jima, eradication of *C. equisetifolia* is important in addition to eradication of alien herbivorous mammals.

Keywords Alien herbivorous mammals · Angiosperm flora · *Casuarina equisetifolia* · Oceanic island · Vegetation change

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Introduction

Invasive alien trees have a variety of negative effects on a native community (La Maitre et al. 1996; Ashton et al. 2005; Brown et al. 2006). These effects particularly occur on oceanic islands where the ecosystems are vulnerable to alien species. Indeed, alien trees greatly disturb insular ecosystems by altering community structure (Meyer and Florence 1996; Hughes and Denslow 2005; Tuttle et al. 2009), reducing the regeneration success of native trees (Cordell et al. 2009), and changing nutrient cycling (Hughes and Denslow 2005; Tuttle et al. 2009). In the Ogasawara Islands, small oceanic islands in Japan, several invasive alien trees have altered both plant (Shimizu and Tabata 1985; Yamashita et al. 2003) and insect (Sugiura et al. 2008) communities.

On the other hand, eradication programs have begun in the Ogasawara Islands to protect endemic species from invasive alien species. Eradication of the invasive tree *Bischofia javanica* was started in 2002 on several islands and was completed in 2006 on Otouto-jima Island. Control of alien goats (*Capra hircus*) has been conducted since 1973, and complete eradication had been achieved on the islands of Minami-shima, Muko-jima, Yome-jima, Nakoudo-jima, and Ani-jima by 2009 (Government of Japan

2010). In such restoration efforts, scientific monitoring is important to assess the degree of success (Yoccoz et al. 2001; Nichols and Williams 2006).

Nishi-jima Island is undergoing eradication of alien species. The eradication of goats began in 2002 and was complete in 2007 (Government of Japan 2010). The eradication of alien black rats (*Rattus rattus*) began in 2007 and the population density is decreasing. Both alien mammals are listed among the world's 100 worst invasive alien species (Lowe et al. 2000). This eradication program on Nishi-jima Island was the first trial of rat eradication in Japan. In addition, the government plans to undertake a process of integrated ecosystem management that includes the eradication of invasive plants (e.g. *Casuarina equisetifolia* and *Leucaena leucocephala*) on the island.

Previous studies have shown that eradication of herbivorous mammals enables rapid vegetation recovery (Hamann 1979), but alien plants sometimes increase unpredictably (Hata et al. 2006). Because records of Nishi-jima's vegetation and flora are very limited, we investigated the island's vegetation and flora before the 2006 eradication of feral goats and rats and also focused on recent vegetation changes. This information will be useful for future management of the ecosystem on Nishi-jima Island after eradication of the herbivorous mammals.

Methods

Study site

Nishi-jima Island (27°07′N, 142°10′E, 0.5 km^2, 100 m a.s.l) is situated next to Chichi-jima Island and is uninhabited by humans. The first settlement of the Ogasawara Islands occurred in the 1820s, and Nishi-jima Island was also settled and cultivated in the Meiji era (1868–1912) (F. Nobushima, personal communication). There are only a few available records about the island's biota and vegetation. For the status of the island in the 1970s, Okutomi et al. (1981) reported that the major vegetation of Nishi-jima was plantations of *Pinus luchuensis* and *C. equisetifolia*, and the remaining area was covered by a *Zoysia tenuifolia* community, which is secondary vegetation suppressed by goat grazing. The maximum population density of *R. rattus* in Nishi-jima was 90 individuals/ha before the eradication (Hashimoto 2009) and most fruits of native trees were damaged (Abe 2007).

Vegetation survey

The island's flora was surveyed using a route census by walking the entire island. Route census was conducted 8 times during the study period between 2004 and 2007.

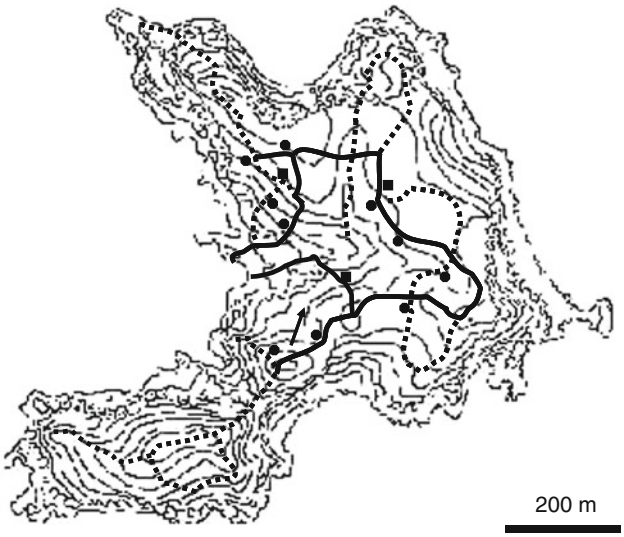

Fig. 1 Topographic map of Nishi-jima Island. *Circles* represent the 10 seedling plots and *squares* represent the census plots of every tree in *Casuarina* forests. *Solid lines* represent the census routes surveyed every time, and *dashed lines* are census routes surveyed occasionally. The *arrow* indicates the photograph direction in Fig. 2a

Several routes were walked every time, and other routes were surveyed at least once (Fig. 1). On the basis of observations made while walking the census routes, the abundance of each species was categorized as abundant, common, or rare. For calculation of the proportion of endemic species and alien species in the flora, we used the number of indigenous species as denominator.

To clarify the tree composition of *Casuarina* forests, a census of every tree was conducted in three 400-m^2 quadrats in September 2008. We measured diameter at breast height (DBH) for trees with a DBH of more than 10 cm. To describe the vegetation of the herbaceous layer, in May 2005 we surveyed the number of all seedlings of woody species and vegetation coverage (%) of herbaceous species in 40 quadrats (4 m^2) on the forest floor and 10 quadrats (4 m^2) in grassland. In addition, the number of seedlings of woody species less than 2 m high was counted in 10 circular plots with the diameter of 20 m (314 m^2) because the number of seedlings within the 4 m^2 quadrats was not enough to evaluate regeneration of woody species. This survey was conducted in May 2006.

An old vegetation map was drawn in 1979 (Environmental Agency 1979). The current vegetation map was drawn on the basis of field surveys and the satellite image from Google Earth, which was taken in the 2000s (probably 2001–2005). We made a vegetation map by walking census routes (Fig. 1) in 2006, and identified vegetation types and zones by their floristic composition and structure. There was no difficulty in identifying zones because the

species composition on the island is simple. Then, vegetation boundaries of particular places where we could not check in the field because of the time constraint and because of dangerous areas, for example coastal cliff, were identified using the satellite image. The shooting date was estimated on the basis of the fact that Google Earth satellite images were taken during last 5 years in this area. In addition, satellite images are updated at specific intervals. The image was downloaded on 28 February 2008, and when we accessed Google Earth again on 15 October 2009, the image of Nishi-jima had been updated with a new image taken soon after typhoon no. 14 in 2006 (easily identified from intense forest damage over the whole island). So, we estimated that the image used in this paper was taken before 2006 at the earliest.

Areas of each vegetation type were measured using free software made by use of the macro-function on MS Excel (http://www.vector.co.jp/soft/win95/art/se312811.html).

Results

The forest vegetation of Nishi-jima Island is predominantly *C. equisetifolia* (Fig. 2a, b). Tree species composition was very simple in the forests, with most sites being dominated by *C. equisetifolia* and some *Pandanus boninensis* (Table 1). Native woody species were found in small forest patches, where most native trees were less than 10 m high and their crowns were not dense. A native *Terminalia catappa* (Combretaceae) forest was found on the southern part of the island. Other native forests were composed of *Ochrosia nakaiana* (Apocynaceae), *Hibiscus glaber* (Malvaceae), *T. catappa*, *Livistona chinensis* var. *boninensis* (Palmae), and *Neolitsea sericea* var. *aurata* (Lauraceae). These native forests were scattered around the central valley and occupied only approximately 3% of the island area. These patches of native forests seem to have been omitted from the 1979 vegetation map (Fig. 3), probably because their patch sizes were too small. Although the understory of native and *Casuarina* forests was not very dark, the vegetation cover of the herbaceous layer was usually low. In *Casuarina* forest, occasional seedlings of *C. equisetifolia* were found (Table 2) and alien *Lagestroemia subcostata* (Lythraceae) was found in the central valley and eastern part of the island. In the remaining native forests there were several seedlings of *H. glaber*, *L. chinensis* var. *boninensis*, *N. sericea* var. *aurata*, and *T. catappa*, but the most prevalent seedling was invasive *C. equisetifolia* (Table 2). Alien plants such as *Acacia confusa* and *L. subcostata* partially dominated, along with *C. equisetifolia*.

Grassland vegetation was found along the coastal edge and on the southwestern peninsula. This community was dominated by *Z. tenuifolia* (Graminaceae) (Fig. 2c), and *Paspalum orbiculare* (Graminaceae) also appeared at high frequency (Table 2).

According to the aerial photograph taken in 1974 there were several patchy grasslands or bare lands in the forest

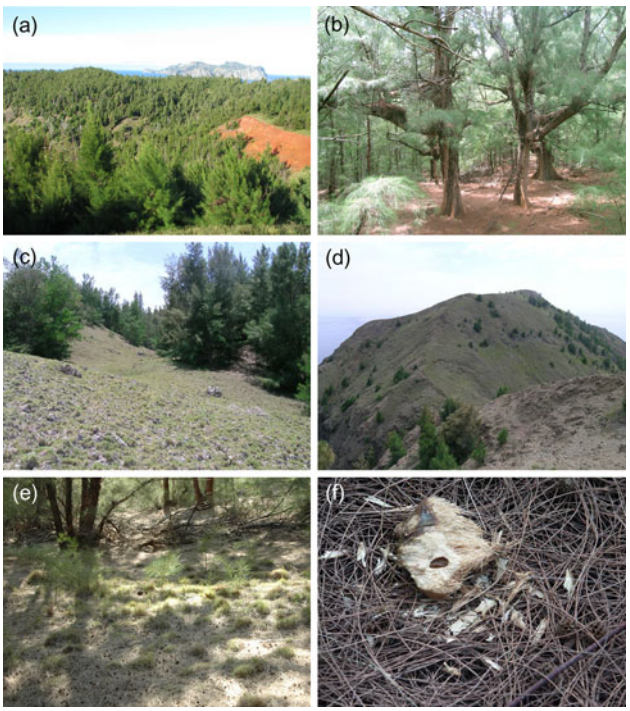

Fig. 2 Various locations on Nishi-jima Island. **a** Landscape of *Casuarina* forests, **b** pure forest of *Casuarina equisetifolia*, **c** *Zoysia tenuifolia* grasslands, **d** grassland landscape on the southeastern peninsula, **e** seedlings of *C. equisetifolia* on remnant *Z. tenuifolia*, **f** a fruit of *Pandanus boninensis* predated by alien *Rattus rattus*

Table 1 Results of every-tree census in *Casuarina equisetifolia* forests

Plot	Measurements	*Casuarina equisetifolia*	*Pandanus boninensis*
Plot 1	N	85	3
	BA	12727	220
Plot 2	N	84	0
	BA	12762	0
Plot 3	N	94	0
	BA	9647	0
Total	N	263	3
	BA	35136	220
% Total	N	98.9	1.1
	BA	99.4	0.6

The number of component species with a DBH of more than 10 cm was only two

N the number of individuals, *BA* basal area at breast height (cm^2)

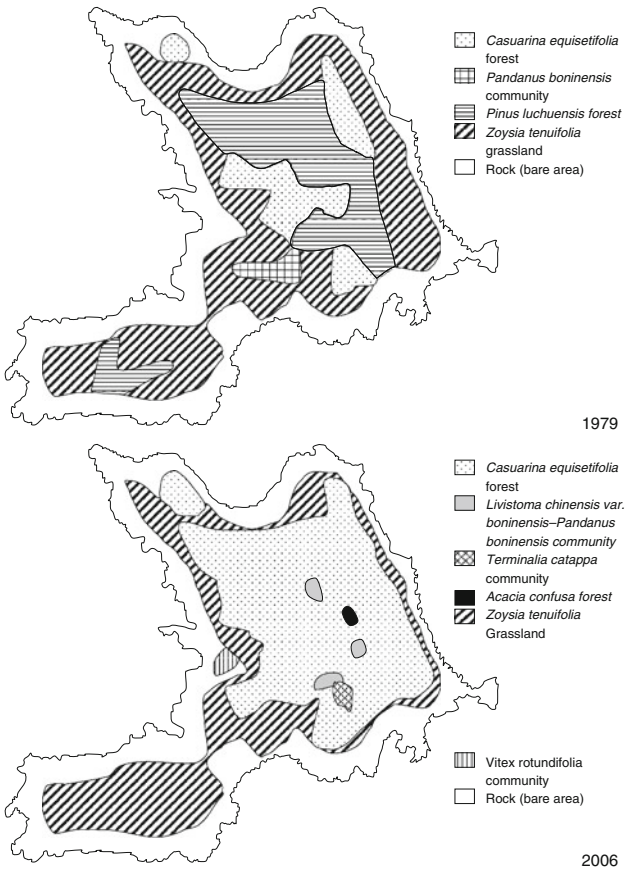

Fig. 3 Vegetation changes that occurred over about 30 years on Nishi-jima Island. The vegetation map in 1979 was redrawn from Environmental Agency (1979). The vegetation map in 2006 was drawn on the basis of a field survey and a satellite image from Google Earth

areas (Fig. 4), but these patches had been replaced by *Casuarina* forests in the 2006 vegetation map (Fig. 3). The 1979 vegetation map showed that *P. luchuensis* forests and *Zoysia* grasslands occupied a large area of the island. On the basis of comparisons of the positions of vegetation patches in the 1974 aerial photograph and the 1979 vegetation map, the forests in which the crown was not closed in the 1974 photograph would be *Pinus* forests. But these *Pinus* forests had nearly disappeared by 2006, and many had become *Casuarina* forests (Fig. 3). On the southwestern peninsula of the island, *Pinus* forests had become *Zoysia* grasslands and *C. equisetifolia* had invaded the northern slope of the peninsula (right side of Fig. 2d). Several area of *Zoysia* grasslands had been replaced by *Casuarina* forests (Figs. 2e, 3). The *Pandanus* community in the 1979 map had also been replaced by *Casuarina* forests. In the field survey, many diebacks of *P. boninensis* were found in this area. In total, the area of *Casuarina* forests increased 2.8-fold (from 4.6 to 17.6 ha) during 27 years, whereas *Pinus* forests and *Zoysia* grasslands decreased from 9.2 to 0.0 ha and from 16.1 to 12.2 ha, respectively (Fig. 5).

Sixty-nine angiosperm species were found on Nishi-jima (see Appendix). Alien angiosperm species accounted for 38% of the flora, whereas endemics accounted for 30%. Other species were common natives that are widely distributed in other regions. The most diverse taxa belonged to the Compositae (9 species), followed by Gramineae (8 species). Five endangered species listed in the Red List (Ministry of the Environment 2007) were found and populations of the alien *Lagestroemia subcostata* are only endangered in the original range (the Ryukyu Islands). Among the four native endangered species, *Cirsium boninense*, *Fimbristylis longispica* var. *boninensis*, *Myrsine maximowiczii*, and *Psilotum nudum* were rare on the island whereas *Drypetes integerrima* occurred frequently.

Discussion

The vegetation of Nishi-jima Island has changed greatly during the past 30 years. The two dominant vegetation types, *C. equisetifolia* forest and *Z. tenuifolia* grassland, are not natural vegetation. The great decrease noted for the alien *P. luchuensis* was probably caused by the pine wood nematode (Shimizu 1986), which resulted in quick colonization by alien *C. equisetifolia* that successfully invaded the open *Pinus* forest understory. Expansion by invasive trees generally requires disturbances killing crown trees in the previous forest (Fine 2002; Bellingham et al. 2005; Brown et al. 2006). Although detailed records of the original vegetation on Nishi-jima do not exist, one possible natural vegetation is likely to be dry forests composed of *L. chinensis* var. *boninensis*, *O. nakaiana*, and *P. boninensis* which are remnants of the *L. chinensis* var. *boninensis–P. boninensis* community. *Zoysia* grassland is secondary vegetation that has been maintained by goat grazing (Mueller-Dombois and Fosberg 1998). With the eradication of goats, *Zoysia* grassland would be likely to change into *Casuarina* forest. The vegetation zone with scarce *Z. tenuifolia* was often found in the *Casuarina* forest understory, which suggests that the previous vegetation was *Z. tenuifolia* grassland and that *C. equisetifolia* colonized the open grassland. *Casuarina* forests occupied a large area of the island and the number of woody species in the community was low. Although we surveyed only three quadrats for every-tree census, the result that species diversity was low in *Casuarina* forests agreed with previous studies (Parrotta 1995; Hata et al. 2009). Regeneration of native woody species would not be expected in Nishi-jima because competitive *C. equisetifolia* seedlings were the vast majority compared with seedlings of native woody species in all types of vegetation (Table 2). In addition,

Table 2 Vegetation of the herbaceous layer in each vegetation type: (a) 4 m^2 quadrat plots; mean (±SE) numbers of individuals in woody seedlings are converted to values per ha, and values of herbaceous plants are mean (±SE) vegetation cover (%); (b) 314 m^2 circular plots; mean (±SE) numbers of individuals are converted to values per ha

(a) Species	Origin	Casuarina forests (25)	Native forests (15)	Grassland (10)
Woody species				
Acacia confusa	A		500 ± 627	
Casuarina equisetifolia	A	2000 ± 2350	1833 ± 1431	500 ± 471
Lagestroemia subcostata	A	100 ± 224	333 ± 393	
Neolitsea sericea var. *aurata*	C		167 ± 289	
Herbs				
Cyclosorus parasiticus	C		0.0 ± 0.0	
Euphorbia pilulifera	A			0.2 ± 0.3
Gahnia aspera	C		0.7 ± 0.8	
Ophioglossum petiolatum	C			0.0 ± 0.0
Oplismenus compositus	C	1.3 ± 2.0	21.7 ± 7.2	1.5 ± 1.5
Oxalis comiculata var. *trichocaulon*	C		0.0 ± 0.0	2.0 ± 2.8
Paspalum orbiculare	A	0.2 ± 2.9	0.5 ± 0.4	36.5 ± 11.8
Pennisetum sordidum	C		0.1 ± 0.1	2.6 ± 1.9
Zoysia tenuifolia	C	1.8 ± 2.0	0.0 ± 0.0	60.3 ± 14.0

(b) Species	Origin	Casuarina forests (5)	Native forests (3)	Grassland (2)
Acacia confusa	A	0	85 ± 85	0
Callicarpa subpubescens	E	0	11 ± 11	0
Casuarina equisetifolia	A	1127 ± 356	2006 ± 1276	414 ± 414
Hibiscus glaber	E	0	127 ± 127	0
Lagestroemia subcostata	A	1096 ± 1096	372 ± 372	0
Livistona chinensis var. *boninensis*	E	0	159 ± 80	0
Neolitsea sericea var. *aurata*	C	0	149 ± 149	0
Rhapiolepis umbellata	C	0	32 ± 18	0
Terminalia catappa	C	0	149 ± 149	0
Trema orientalis	C	51 ± 37	85 ± 85	0

Numbers in parentheses are the number of plots

A, alien; *C*, common (native but not endemic); *E*, endemic (to Ogasawara Islands)

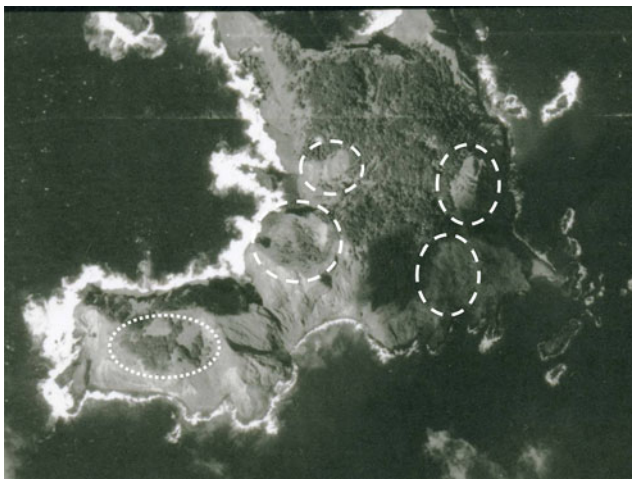

Fig. 4 Aerial photograph of Nishi-jima Island taken in 1974. *Broken circles* indicate the areas where tree coverage had increased by 2006, and the *dotted circle* indicates the area where tree coverage had decreased by 2006

regeneration of native woody species in *Casuarina* forests is difficult probably because of lack of seed rain of native woody species and accumulation of thick litter of *C. equsetifolia* (Parrotta 1995; Hata et al. 2009). These facts suggest that native vegetation might not recover after eradication of alien herbivorous mammals.

Alien rats (*R. rattus*) are harmful seed predators and twig cutters on Ogasawara Islands (Fig. 2f; Abe 2007; Yabe et al. 2010; Abe and Umeno 2011). In addition, grazing pressure of feral goats has great effects on insular vegetation (Coblentz 1978; Courchamp et al. 2003; Hata et al. 2007). Few seedlings of native woody species were found despite rich fruit production, suggesting that these alien herbivorous mammals also have negative effects on the regeneration of native plants. The amount of endemic Nishi-jima flora (30%) was far less than that of the flora of the Ogasawara Islands as a whole (45%). The low species richness and low level of endemic Nishi-jima flora may indicate decline of native plant communities that can be caused by these alien herbivore mammals

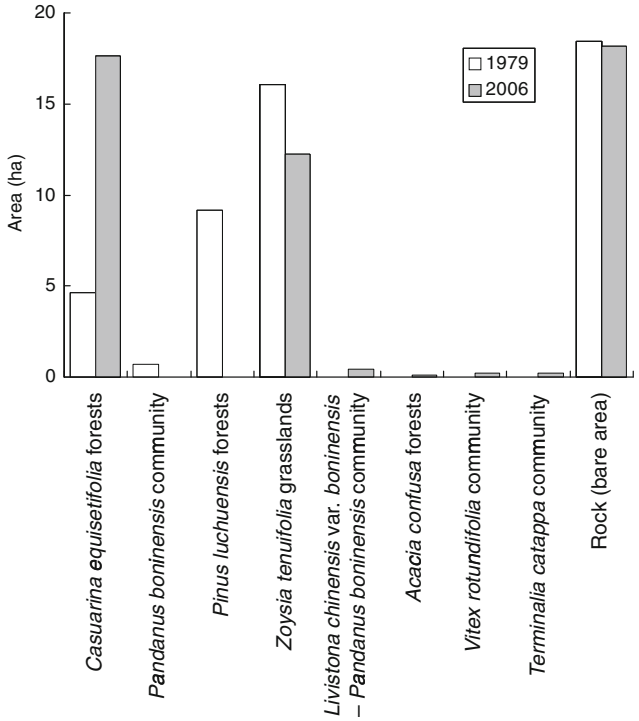

Fig. 5 Change of vegetation area between 1979 and 2006

(Abe 2007; Hata et al. 2007) and expansion of invasive *C. equisetifolia* (Hata et al. 2009). However, several remaining endangered species enhance the value of conserving this island ecosystem. Endangered *C. boninense* remains on a cliff on the southwestern peninsula, where plants escaped the grazing pressure from goats. Endangered land snails of the genus *Hirasea* also survive under the leaves of *L. chinensis* var. *boninensis* (S. Chiba, personal communication), and patches of such environments remain on the island. Also, endemic insects that were extinct on neighboring inhabited islands are still found on Nishi-jima (Sugiura et al. 2009). But the abundance of these endangered species would have declined with the expansion of *C. equisetifolia* (Parrotta 1995; Hata et al. 2009). To conserve these endangered species, eradication of *C. equisetifolia* and rats and goats is a task of immediate importance.

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Appendix

See Table 3.

Table 3 Flora list of angiosperms on Nishi-jima Island before eradication of the alien herbivorous mammals

Family	Species[a]	Origin[a]	Abundance	RL
Psilotaceae	*Psilotum nudum*	C	R	NT
Ophioglossaceae	*Ophioglossum petiolatum*	C	C	
Dennstaedtiaceae	*Microlepia strigosa*	C	R	
Lindsaeaceae	*Sphenomeris biflora*	C	C	
Oleandraceae	*Nephrolepis hirsutula*	C	R	
Pteridaceae	*Pteris boninensis*	E	C	
Dryopteridaceae	*Cyrtomium falcatum*	C	R	
Thelypteridaceae	*Cyclosorus parasiticus*	C	C	
Pinaceae	*Pinus luchuensis*	A	R	
Casuarinaceae	*Casuarina equisetifolia*	A	A	
Ulmaceae	*Celtis boninensis*	E	R	
	Trema orientalis	C	R	
Moraceae	*Morus australis*	A	R	
Portulacaceae	*Portulaca pilosa*	A	R	
Lauraceae	*Cinnamomum pseudopedunculatum*	E	R	
	Neolitsea sericea var. *aurata*	C	C	
Guttiferae	*Calophyllum inophyllum*	C	C	
Papaveraceae	*Corydalis heterocarpa* var. *brachystyla*	C	–[b]	
Pittosporaceae	*Pittosporum boninense*	E	–[c]	
Rosaceae	*Rhaphiolepis umbellata*	C	C	
Leguminosae	*Acacia confusa*	A	A	
	Leucaena leucocephala	A	C	
Oxalidaceae	*Oxalis corniculata* var. *trichocaulon*	C	C	
Euphorbiaceae	*Drypetes integerrima*	E	C	VU
	Euphorbia pilulifera	A	C	
	Phyllanthus debilis	C	C	
Rutaceae	*Boninia grisea*	E	R	
Meliaceae	*Melia azedarach*	C	R	
Malvaceae	*Abutilon indicum*	A	R	
	Hibiscus glaber	E	C	
Lythraceae	*Lagestroemia subcostata*	A	A	NT[d]
Combretaceae	*Terminalia catappa*	C	A	
Myrsinaceae	*Myrsine maximowiczii*	E	R	VU
Primulaceae	*Lysimachia rubida*	E	R	
Sapotaceae	*Planchonella obovata*	C	C	
Oleaceae	*Osmanthus insularis*	C	R	
Apocynaceae	*Ochrosia nakaiana*	E	A	
	Trachelospermum asiaticum f. *intermedium*	C	R	
Convolvulaceae	*Ipomoea pes-caprae*	C	C	

Table 3 continued

Family	Species[a]	Origin[a]	Abundance	RL
Verbenaceae	*Callicarpa subpubescens*	E	R	
	Lantana camara	A	R	
	Vitex rotundifolia	C	R	
Solanaceae	*Solanum nigrum*	C	R	
Myoporaceae	*Myoporum boninense*	E	R	
Goodeniaceae	*Scaevola frutescens*	C	C	
Compositae	*Ageratum conyzoides*	A	C	
	Cirsium boninense	E	R	VU
	Conyza sumatrensis	A	C	
	Erigeron canadensis	A	C	
Compositae	*Gnaphalium pensylvanicum*	A	C	
	Sonchus oleraceus	C	C	
	Tridax procumbens	A	C	
	Vernonia cinerea	A	C	
	Youngia japonica	C	C	
Gramineae	*Chloris barbata*	A	C	
	Digitaria ciliaris	C	C	
	Echinochloa colona	C	–[e]	
	Eleusine indica	C	C	
	Oplismenus compositus	C	A	
	Paspalum dilatatum	A	C	
	P. orbiculare	C	A	
	Pennisetum sordidum	C	C	
	Sporobolus diander	C	R	
	Sporobolus virginicus	C	R	
	Zoysia tenuifolia	C	A	
Palmae	*Livistona chinensis* var. *boninensis*	E	C	
Pandanaceae	*Pandanus boninensis*	E	C	
Cyperaceae	*Fimbristylis* sp.	A	C	
	Fimbristylis cymosa	C	R	
	Fimbristylis longispica var. *boninensis*	E	R	VU
	Gahnia aspera	C	C	
	Scirpus lineolatus	C	R	

Abbreviations of origin follow those in Table 2

A abundant, *C* common, *R* rare, *RL* Red List (Ministry of the Environment 2007), *VU* vulnerable, *NT* near threatened

[a] Scientific name and species origin follow Toyoda (2003)

[b] This species was found on 11.5.1989 by Takaya Yasui, but was not recorded in this study

[c] This species was found on 11.7.1982 by Takaya Yasui, but was not recorded in this study

[d] Population in native distribution range (southwestern Japan) are designated

[e] This species was recorded by Enomoto (1992)

References

Abe T (2007) Predator or disperser? A test of indigenous fruit preference of alien rats (*Rattus rattus*) on Nishi-jima (Ogasawara Islands). Pac Conserv Biol 13:213–218

Abe T, Umeno H (2011) Pattern of twig cutting by introduced rats in insular cloud forests. Pac Sci 65:27–39

Ashton IW, Hyatt LA, Howe KM, Gurevitch J, Lerdau MT (2005) Invasive species accelerate decomposition and litter nitrogen loss in a mixed deciduous forest. Ecol Appl 15:1263–1272

Bellingham PJ, Tanner EVJ, Healey JR (2005) Hurricane disturbance accelerates invasion by the alien tree *Pittosporum undulatum* in Jamaican montane rain forests. J Veg Sci 16:675–684

Brown KA, Scatena FN, Gurevitch J (2006) Effects of an invasive tree on community structure and diversity in a tropical forest in Puerto Rico. For Ecol Manag 226:145–152

Coblentz BE (1978) The effects of feral goats (*Capra hircus*) on island ecosystems. Biol Conserv 13:279–286

Cordell S, Ostertag R, Rowe B, Sweinhart L, Vasquez-Radonic L, Michaud J, Cole TC, Schulten JR (2009) Evaluating barriers to native seedling establishment in an invaded Hawaiian lowland wet forest. Biol Conserv 142:2997–3004

Courchamp F, Chapuis JL, Pascal M (2003) Mammal invaders on islands: impact, control and control impact. Biol Rev 78:347–383

Enomoto T (1992) Weeds and alien plants in Chichi-jima and Haha-jima, Ogasawara Islands. Ogasawara Kenkyu Nenpo 16:3–17 (in Japanese)

Environmental Agency (1979) The 2nd national survey on the natural environment (vegetation). Environmental Agency, Tokyo (in Japanese)

Fine PVA (2002) The invasibility of tropical forests by exotic plants. J Trop Ecol 18:687–705

Government of Japan (2010) Nomination of the Ogasawara Islands for inscription of the World Heritage List. Government of Japan, Tokyo

Hamann O (1979) Regeneration of vegetation on Santa Fé and Pinta Islands, Galápagos, after the eradication of goats. Biol Conserv 15:215–236

Hashimoto T (2009) Eradication and ecosystem impact of rats in the Ogasawara Islands. Chikyu Kankyo 14:93–101 (in Japanese)

Hata K, Kachi N, Ichikawa S (2006) Invasion process of alien woody species, *Leucaena leucocephala* after the eradication of feral goats in the Naoudo-jima Island. Ogasawara Kenkyu Nenpo 29:7–17 (in Japanese)

Hata K, Suzuki J, Kachi N (2007) Vegetation changes between 1978, 1991 and 2003 in the Nakoudojima Island that had been disturbed by feral goats. Ogasawara Res 32:1–8

Hata K, Kato H, Kachi N (2009) Community structure of saplings of native woody species under forests dominated by alien woody species, *Casuarina equisetifolia*, in Chichijima Island. Ogasawara Res 34:33–50

Hughes PF, Denslow JS (2005) Invasion by a N_2-fixing tree alters function and structure in wet lowland forests of Hawaii. Ecol Appl 15:1615–1628

La Maitre DC, van Wilgen BW, Chapman RA, McKelly DH (1996) Invasive plants and water resources in the western Cape Province, South Africa: modeling the consequences of a lack of management. J Appl Ecol 33:161–172

Lowe S, Browne M, Boudjelas S, De Poorter M (2000) 100 of the World's worst invasive alien species: a selection from the Global Invasive Species Database. ISSG and IUCN, Auckland

Meyer JY, Florence J (1996) Tahiti's native flora endangered by the invasion of *Miconia calvescens* DC. (Melastomataceae). J Biogeogr 23:775–781

Ministry of the Environment (2007) Red list of plants and Red Data Book. Official web site of Ministry of the Environment. Available via http://www.biodic.go.jp/rdb/rdb_f.html. Accessed 24 Sept 2008 (in Japanese)

Mueller-Dombois D, Fosberg FR (1998) Vegetation of the tropical Pacific islands. Springer, New York

Nichols JD, Williams BK (2006) Monitoring for conservation. Tree 21:668–673

Okutomi K, Iseki T, Hioki Y (1981) Vegetation of the Chichi-jima Archipelago and Haha-jima Archipelago (Ogasawara). Tokyo Vegetation Research Society, Tokyo (in Japanese)

Parrotta JA (1995) Influence of overstory composition on understory colonization by native species in plantations on a degraded tropical site. J Veg Sci 6:627–636

Shimizu Y (1986) Serious damage to *Pinus luchuensis* by the attack of the pine wood nematode at Chichijima in the Bonin (Ogasawara) Islands. J Fac Lett Komazawa Univ 44:169–178

Shimizu Y, Tabata H (1985) Invasion of *Pinus lutchuensis* and its influence on the native forest on a Pacific island. J Biogeogr 12:195–207

Sugiura S, Tsuru T, Yamaura Y, Hasegawa M, Makihara H, Makino S (2008) Differences in endemic insect assemblages among vegetation types on a small island of the oceanic Ogasawara Islands. Entomol Sci 11:131–141

Sugiura S, Tsuru T, Yamaura Y, Makihara H (2009) Small off-shore islands can serve as important refuges for endemic beetle conservation. J Insect Conserv 13:377–385

Toyoda T (2003) Flora of the Bonin Islands, 2nd edn. Aboc sha Co. Ltd, Kamakura (in Japanese)

Tuttle NC, Beard KH, Pitt WC (2009) Invasive litter, not an invasive insectivore, determines invertebrate communities in Hawaiian forests. Biol Invasions 11:845–855

Yabe T, Hashimoto T, Takiguchi M, Aoki M, Fujita M (2010) Twig cutting by the black rat, *Rattus rattus* (Rodentia: Muridae) on the Ogasawara Islands. Pac Sci 64:93–97

Yamashita N, Tanaka N, Hoshi Y, Kushima H, Kamo K (2003) Seed and seedling demography of invasive and native trees of subtropical Pacific islands. J Veg Sci 14:15–24

Yoccoz NG, Nichols JD, Boulinier T (2001) Monitoring of biological diversity in space and time. Tree 16:446–453