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論　文（Original article）

High population densities of an exotic lizard, *Anolis carolinensis* and its possible role as a pollinator in the Ogasawara Islands.

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Abstract

It has been postulated that an ongoing decline of endemic insects in the Ogasawara Islands since the 1970's may be mainly due to predation by an exotic lizard, *Anolis carolinensis* from North America. Population density of *A. carolinensis* found on Chichijima Island in the Ogasawaras was much higher than that reported in Saipan and the Bahamas. This may explain why insect populations have declined in the Ogasawaras but not in Saipan. Some males were observed to have pollen of Rosewood, *Schima mertensiana*, an endemic tree to the islands on their heads. This pollen may be attached to their heads when *A. carolinensis* is sucking nectar, as is the case for other known lizard pollinators.

Key words : Ogasawara, exotic *Anolis*, endemic insect, decline, density, pollinator

Photo. 1. A male green anole, *Anolis carolinensis* showing attached yellow pollen on the nose

Introduction

Invasion of alien predators to oceanic islands sometimes cause mass extinctions of endemic species (Blackburn et al., 2004; Cowie & Cook, 2001; Elton, 1958; Hopper & Smith, 1992), and this can be the case even if the alien species is a reptile (Savidge, 1987). The green anole, *Anolis carolinensis*, originally distributed in North America, and Caribbean Islands (Conant, 1958), is such an alien species on Pacific Islands. Recently, the Caribbean populations of the *A. carolinensis* were treated as several different species, but we treat them here as '*A. carolinensis*' in terms of an '*A. carolinensis* subgroup' since they are closely related allopatric species (Glor et al., 2005). *A. carolinensis* was introduced into the Ogasawara Islands in the early 1960's via Guam (Hasegawa et al., 1988). Recently, it has been postulated that an ongoing decline of endemic insects such as dragonflies, butterflies, bees and longicorn beetles in the Ogasawara's since the 1970's may be mainly due to lizard predation, because this decline has only occurred since the invasion and the increase in population density of the lizards, and the declining insects are limited to diurnal species (Karube and Suda, 2004; Makihara et al., 2004; Yoshimura & Okochi, 2005). Since these declining insects include major pollinators, this decline may change the ecological and evolutionary processes of the island ecosystems. However, *A. carolinensis* has also invaded other Pacific islands such as Guam, Saipan and Hawaii, where severe declines of endemic insects have not been reported. We hypothesized that the decline of the insects in the Ogasawara islands may have occurred because of the very high population density of lizards observed in the island compared to that in the other islands. Therefore, we estimated the population density of the lizard and the observation rate per unit time to

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compare with the available data in other islands where the lizard is present. We also discuss the possibility of *A. carolinensis* acting as a pollinator in relation to a hypothesis that pollination by lizard evolve when its density is high in an island.

Methods and study area

Densities of lizard populations were estimated from June 7 to 12, 2004 at 11 sites in Chichijima Island, the largest island in the Ogasawara Islands. Tree height at the study sites varied from 1.3 m to 8 m. Three sites were located in *Leucaena* forest stands dominated by an introduced tree species, *Leucaena leucocephara*. The other sites were in native evergreen broadleaf forest, mainly dominated by native trees. Size of study sites ranged from 63 m^2 to 150 m^2 depending on site condition, which was mainly related to tree height. *A. carolinensis* individuals were captured using a fishing rod and hook and using a mealworm as bait. The rate of new captures decreased as time passed, so after three hours collecting at each site we moved to another. We measured lizard Snout Vent Length (SVL) and verified their sex as determined by observation of post-anal scales, and then marked them with a number written on the body with white marker. Recapture was done the next day using the same method. Density at each site was estimated by the Chapman modification of the Petersen method (Ito & Murai, 1977; Young & Young, 1998).

To enable us to compare densities in the Ogasawara Islands with data from Saipan (Wiles & Guerrero, 1996), we also calculated the observation frequency from 06:00 to 17:00 on September 14, 2003 at Hatsuneura on Chichijima Island. Observations were made by slowly walking along a forest pathway (Wiles & Guerrero 1996). Using this observation method, sex could be determined only from body size, though we were able to distinguish between adult males and hatchlings, but not between females and young males.

In five native forest sites along Tasumi road and two *Leucaena* scrub sites in Kominato we also verified if the heads of lizards were yellow in appearance while we marked and recaptured them. Samples of this yellow material were taken by soft paper and brought back to the mainland to be examined under a microscope.

Results

Estimated densities of individuals of both sexes varied from 600 to 2570 individuals per ha in Chichijima (Table. 1). Density estimates were not correlated with tree height. Densities of *A. carolinensis* in *Leucaena* stands did not differ from those in native forest stands. Estimated densities of each sex are also shown in Table 1. Male densities varied from 440 per ha to 1920 per ha with no significant correlation to tree height. Female density and its 95% confidence limit was only able to calculated for one stand, with an estimate of 640 ± 220 females per ha.

Observation frequencies at the Hatsuneura site were 5.8 large males per hour, 5.0 females and young males per hour, and 0.8 hatchlings per hour. In total, 11.6 individuals were observed per hour.

Yellow-headed individuals were observed only in native forest stands in Tatsumi road and all of them were males. The heads of nine out of 27 males at Tatsumi road were yellow in color, while four females observed at these sites did not show yellow colouring. The 19 males and five females observed at the *Leucaena* sites in Kominato were not yellow-headed. The

Table 1. Estimated densities in 11 populations of *Anolis carolinensis* in Chichijima Island

			All individuals			Males			Females		
Location	Vegetation	Tree height (m)	Density (nos./ha)	95% C. L.*	n**	Density (nos./ha)	95% C. L.*	n**	Density (nos./ha)	95% C. L.*	n**
Asahi-daira	Native forest	1.3	1360	510	9	1000	290	7	-	-	−
Asahi-daira	Native forest	2.5	2570	950	22	1920	830	16	640	220	6
Tasumi road	Native forest	4	1190	270	6	1190	270	6	-	-	−
Tasumi road	Native forest	4	930	160	7	830	190	6	-	-	−
Mt. Mikazuki	*Leucana* shrub	4	1780	530	10	1220	310	7	-	-	−
Tasumi road	Native forest	6	1000	720	8	670	410	6	-	-	−
Tasumi road	Native forest	6	670	290	7	440	140	5	-	-	−
Tasumi road	Native forest	6	930	410	7	930	570	6	-	-	−
Kominato	*Leucana* shrub	6	1120	450	10	840	280	8	-	-	−
Kominato	*Leucana* shrub	6	600	140	6	600	140	6	-	-	−
Tasumi road	Native forest	8	1800	1470	12	1600	1280	11	-	-	−
Average			1270			1020					

Estimated densities were calculated using the Chapman modification of the Petersen method.
Female density could not be calculated because of there were no or few recaptures except at a single site.
*: 95% confidence limit
**: Number of captured individuals

most conspicuous flowers in the native forest stands in June were of the Rosewood, *Schima mertensiana*, an endemic tree to the islands which mainly flowers during this season (Abe et al., 2004).

We found our observation note on sucking behavior of *A. carolinensis* in which an individual of *A. carolinensis* with a yellow head was observed at 8:30 am on June 13, 1998 pushing its head into an androecium of a *S. mertensiana* flower and seemed to be sucking the nectar. After sucking it did not move for a few minutes.

Discussion

Density of *A. carolinensis* in island populations is generally higher than those in mainland populations (Schoener & Schoener, 1980). Therefore, we compared the density of the lizard in the Ogasawaras to those in the Bahama Islands, which have a similar latitude and where *A. carolinensis* is endemic. Schoener & Schoener (1980) showed that the densities of *A. carolinensis* at many sites on several Bahamian islands ranged from 0 to 1420 individuals per ha, with an average of 480 individuals per ha. The density of *A. carolinensis* in the Ogasawaras was much higher, with an average of 1,270 per ha. However, *A. carolinensis* is not the only species of *Anolis* that occurs on the Bahama Islands. The most frequently observed species in the Bahamas is *A. sagrei*, with an average density of 3600 per ha (Schoener & Schoener, 1980). The density of *A. carolinensis* in the Ogasawaras is therefore only about half of the density of *A. sagrei* in the Bahamas. However, it can also be considered that the body size of *A. segrei* is much smaller than that of *A. carolinensis*. Hence, the density of *A. carolinensis* in the Ogasawaras can be thought to be of a similar level in terms of ecological impact with that in the Bahamas. The density in the Ogasawaras is also similar to those of tropical Caribbean species (Bennett & Gorman, 1979; Heckel & Roughgarden, 1979; Roughgarden, 1995), which are some of the highest densities of lizards known (Schoener & Schoener, 1980).

Frequency of observation of *A. carolinensis* on Chichijima Island in this study was very similar to that recorded at Hahajima Island from 1995 to 1997 (range 3 to 13 individuals per hour, Suzuki, 2000). However, this density is much higher than those recorded in Saipan, where observation frequencies range from 0.0 to 0.7 per hour (Wiles & Guerrero, 1996). If the density of *A. carolinensis* in the other Mariana Islands is similar to those in Saipan, this difference in densities between the Marianas and the Ogasawaras may explain why *A. carolinensis* has caused a severe decline of endemic insects only in the Ogasawara Islands. On the other hand, the density of *A. carolinensis* in the Ogasawaras does not appear to be greatly higher than that in the Bahama Islands. Therefore, the rapid decline of endemic insects in the Ogasawaras can not only be due to the lizard density. Before the invasion of *A. carolinensis* into the Ogasawaras 40 years ago, only one species of small skink, *Cryptoblepharus boutonii*, was native as a diurnally active lizard (Suzuki, 1999). Since this skink is small and not adapted to arboreal life compared with *A. carolinensis*, it is suggested that the inexperience of endemic insects in relation to specialist arboreal lizard predation may also be an important reason for the rapid decline of these insects in the Ogasawara Islands.

Nectar consumption and pollination by lizards has been reported previously (Eifler, 1995; Pérez-Mellado & Casas, 1997; Nyhagen et al., 2001; Traveser & Sáez, 1997). High population density and lower availability of prey on islands is thought to be the reason for the evolution of fruit and nectar consumption by lizards and which leads to pollination and seed dispersion by them (Olesen and Valido, 2003). The observations here of pollen-carrying by *A. carolinensis* in the Ogasawara islands seems to fit this hypothesis since the population density has become very high. However, there is a major difference between this case and previous reports. All previous reports have been of pollination of native flowers by native lizards, but in this case we observed pollination of a native flower by an alien lizard. The flowers of *S. mertensiana* are known to be ornithophilous and entomophilous, but the main pollinator is the Japanese white eye, *Zesterops japonica* (Tanaka 1993). This implies that the pollen of *S. mertensiana* easily attaches to the bird's bill and the quantity of nectar is enough to satisfy a bird, a much larger and more voracious feeder than an insect. Thus the adaptation of *S. mertensiana* to ornithophily may enable *A. carolinensis* to become a pollinator. In this case, the substantial amount of floral nectar attracts the lizard (which faces a food shortage due to its high population density), and the pollen, which is adapted to attaching to bird beaks also easily attaches to the lizard's face. Therefore, this may be a new step for an alien lizard to become a pollinator in a new ecosystem where much of the endemic insect pollinator fauna has been destroyed by the lizard itself. However, this may not necessarily benefit *S. mertensiana* since male *A. carolinensis* are territorial and so may seldom carry pollen to other trees and *S. mertensiana* can be pollinated by birds. Female does not carry pollen in our observation, probably because of male's activity to monopolize a nectar resource. Further investigations to elucidate the possible role of *A. carolinensis* as a new pollinator in the Ogasawara Islands ecosystems are required.

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References

Abe, T., Yasui, T., Wada, T., Wada, M., Kato, Y., Makino, S. and Okochi, I. (2004) Observation records of flowering period of plants in the Ogasawara Islands, Bulletin of FFPRI, **3**(3), 249-257. (In Japanese with English summary)

Bennet, A. F. and Gorman, G. C. (1979) Population density and energetics of lizards on a tropical islands, Oecologia, **42**, 339-358.

Blackburn, T. M., Cassey, P., Duncan, R. P., Evans, K. L. and Gaston, K. J. (2004) Avian extinction and mammalian introduction on oceanic islands, Science, **305**, 1955-1958.

Conant, R. C. (1958) A field guide to reptiles and amphibians of eastern and central North America, Houghton Mifflin Co., Boston, 429p.

Cowie, R. H. and Cook, R. P. (2001) Extinction or survival: partulid tree snails in American Samoa, Biodiversity and Conservation, **10**, 143-159

Eifler, D. A. (1995) Patterns of plant visitation by nector-feeding lizards, Oecologia, **101**, 228-233.

Elton, C. S. (1958) The ecology of invasions by animals and plants, Chicago press, 181p.

Glor, R. E., Losos, J. B. and Larson A. (2005) Out of Cuba: overwater dispersal and speciation among lizards in the *Anolis carolinensis* subgroup, Molecular Ecology, **14**, 2419-2432.

Hasegawa, M., Kusano, T., and Miyashita, K. (1988) Range expansion of *Anolis carolinensis* on Chichi-jima, the Bonin Islands, Japan, Japanese Journal of Herpetology, **12**(3),115-118.

Heckel D. G., & Roughgarden J. (1979) A technique for estimating the size of lizard populations, Ecology, **60**, 966-975.

Hooper, D. R. and Smith, B. D. (1992) Status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920, Pacific Science, **46**(1), 77-85.

Ito, K., and Murai, M. (1977) Research method of animal ecology (1), 268pp., Kokon Shoin, Tokyo , 268p. (In Japanese)

Karube, H., and Suda, S. (2004) A preliminary report on influence of an introduced lizard, *Anolis carolinensis* on the native insect fauna of the Ogasawara Islands, Research Report of Kanagawa Prefectural Museum Natural History, (12), 21-30. (In Japanese with English title)

Makihara, H., Kitajima. H., Goto, H., Kato, T., and Makino, S. (2004) An evaluation of predation impact of the introduced lizard *Anolis carolinensis* on the endemic insect fauna of the Ogasawara Islands based on insect collection records and feeding experiments, with special reference to longicorn beetles (Insecta: Coleoptera: Cerambycidae), Bulletin of FFPRI, **3**(2), 165-183. (In Japanese with English summary)

Nyhagen, D. F., Kragelund, C., Olesen, J. M., and Jones, C. (2001) Insular interactions between lizards and flowers: flower visitation by an endemic Mauritian gecko, Journal of Tropical Ecology, **17**, 7555-7761.

Olesen, J.M. and Valido, A. (2003) Lizards as pollinators and seed dispersers: an island phenomenon. TRENDS in Ecology and Evolution, **18**(4): 177-181

Pérez-Mellado, V. and Casas, J. L. (1997) Pollination by a lizard on a Mediterranian Island, Copeia, **1997**(3), 593-595.

Roughgarden J. (1995) *Anolis* lizards of the Caribbean, Oxford University Press, Oxford, 200p.

Savidge, J. A. (1987) Extinction of an island forest avifauna by an introduced snake, Ecology, **68**(3), 660-668.

Shoener, T. W. and Schener, A. (1980) Densities, Sex ratios, and population structure in four species of Bahamian Anolis lizards, Journal of Animal Ecology, **49**, 19-53.

Suzuki, A. (1999) Habitat utilization of the native lizard, *Cryptoblepharus boutonii* nigropunctutus, in areas with and without the introduced lizard, *Anolis carolinensis*, on hahajima, the Ogasawara Islands, Japan, In Tropical Island Herpetofauna, Ota, H., ed., Elsevier Science, Amsterdam, 155-168.

Suzuki, A. (2000) Relationship between two species of lizards, native and introduced species, in the Ogasawara Islands, Thesis of Nara Women's University, 76p.

Tanaka, H. (1993) Pollination ecology of flowers in the Ogasawara Islands (I), Ogasawara Kenkyu Nenpo, **17**, 25-38. (In Japanese)

Traveser, A. and Sáez, E. (1997) Pollination of Euphorbia dendroides by lizards and insects: Spation-temporal variation in patterns of flower visitation, Oecologia, **111**, 241-248.

Yoshimura, M., and Okochi, I. (2005) A decrease in endemic odonates in the Ogasawara Islands, Japan, Bulletin of FFPRI, **4**(1), 45-51.

Young, L. J., and Young, J. H. (1998) Statistical Ecology, 565pp. Kluwer Academic Publischers, Boston, Dordrecht, London.

Wiles, G. J. and Guerrero, J. P. (1996) Relative abundance of lizards and marine toad on Saipan, Mariana Islands, Pacific Science, **50**(3), 274-284.

小笠原諸島における外来種グリーンアノールの高い個体群密度と、花粉媒介者となる可能性

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要 旨

小笠原諸島における 1970 年以降の固有昆虫類の減少は、北米からの外来種であるグリーンアノール（*Anolis carolinensis*）の捕食によるのではないかと考えられている。小笠原諸島父島におけるグリーンアノールの密度（再捕獲法で 600 - 2570/ha, 平均 1270/ha、ラインセンサス法で 3 - 13/hour）は、サイパン（外来種。ラインセンサス法で 0.0 - 0.7/hour）やバハマ（最近では近縁の別種とされ、在来種。再捕獲法で 0 - 1420/ha, 平均 480/ha）の報告よりずっと高い。サイパンで見られなかった昆虫の減少が小笠原で生じたのは、グリーンアノールの密度が上記のように高くなったことと、このような樹上性のトカゲが小笠原にいなかったために昆虫類が適応していなかったことが原因と思われる。雄の一部は、小笠原固有樹種ムニンヒメツバキ（*Schima mertensiana*）の花粉を頭部につけていた。個体群密度の高い場合に生じる既知の花粉媒介性のトカゲ同様、グリーンアノールが花蜜を吸っていた際に花粉が頭部についたものと考えられる。しかし、本種の行動特性から見ると、花粉媒介の効果は低いだろう。

キーワード：小笠原、外来生物、アノール、昆虫、減少、密度、花粉媒介

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