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Selectivity of Perch Diameter by Green Anole (*Anolis carolinensis*) for Trapping in Ogasawara

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Abstract: In the Ogasawara Islands adhesive traps are the primary means of controlling non-native *Anolis carolinensis*. If the types of tree trunks most frequently used by this lizard are identified, trapping efficiency can be improved by concentrating traps at such points. To analyze selectivity by trunk diameter, the diameters of 270 tree trunks used by the lizards and 1,024 tree trunks in the study area were measured. The analysis indicated the lizards avoided trunks of 1 cm or less in diameter. On the other hand, trunks with diameters over 2 cm appeared to be used randomly, regardless of diameter size. The diameter class distribution of trees varies by region and by forest. The range of tree trunk diameters commonly used by lizards is thus expected to vary by location. It would be advantageous to develop a capture technique that is effective for trunks and branches of various diameters.

Key words: Anolis; Control; Field survey; Invasive species; Resource selection function

Introduction

The green anole (*Anolis carolinensis*) is an introduced arboreal lizard and one of Japan's designated invasive alien species. Degradation of indigenous arthropod fauna on the Ogasawara Islands is attributed to predation by this lizard (Makihara, 2004; Abe et al., 2008; Karube, 2010). Predation and habitat shift to avoid the lizard have been cited as factors in the population decline of the native skink, *Cryptoblepharus boutonii nigropunctatus* (Suzuki and Nagoshi, 1999; Toda et al., 2010; Sugiura, 2016).

Ecomorphs are defined as "species with the same structural habitat/niche, similar in morphology and behavior, but not necessarily close phyletically" (Williams, 1972). Among the six ecomorphs originally stated for the Caribbean *Anolis* species (crown-giant, trunk-crown, trunk, twig, trunk-ground, and grass-bush [Losos, 2009]), *A. carolinensis* is classified as a trunk-crown type (Lister, 1976), which uses a wide range of microhabitats, including leaves, twigs and trunk, and the ground.

Setting adhesive traps on tree trunks is a key technique for the management and monitoring of this lizard on the Ogasawara Islands. If the conditions of the tree trunks most frequently used by the lizard are identified, trapping efficiency can be improved by concentrating traps in such places.

On Chichijima Island in the Ogasawara chain, *A. carolinensis* indicated a preference

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for the screw pine, as a perching tree (Mitani et al., 2020). However, it is not yet clear whether the lizards in Ogasawara frequently use perches with a specific diameter range. Elsewhere, no consensus has been formed about the presence or absence of selectivity of perch diameter by *A. carolinensis*. It has been reported that the lizard uses random tree diameters distributed in its habitat (Mattingly and Jayne, 2004). However, another study concluded it showed selectivity in relation to tree diameter or a correlation between body size and preferred perch diameter (Jenssen et al., 1998).

This study focuses on diameter selectivity in perches, especially for tree trunks where traps are typically set. The angle of each branch is different, but the trunks are consistently vertical, making them suitable for analyzing selectivity by diameter. For the following two purposes, the data obtained from the field survey conducted on Chichijima Island (Mitani et al., 2020) were recalculated. The first purpose is to identify the diameters of tree trunks that *A. carolinensis* used most frequently in the study area. Targeting this diameter for setting traps is expected to improve capture efficiency. In the previous study, the diameter of all perching trees, including branches and aerial roots, was analyzed. The results suggested that the perches used by juveniles tend to be thinner than those used by adults (Mitani et al., 2020). However, it is possible that this does not indicate different diameter selectivity between adults and juveniles. This could be an effect of juveniles preferring lower areas or peripheral branches to avoid large males, which may prey on or injure them (Irschick et al., 2005b). To be able to estimate suitable diameters for trap setting, the data from that study were recalculated to illustrate the relative frequency of each diameter range of tree trunks used by the lizards.

The second purpose is to determine whether *A. carolinensis* selects perch by stem diameter. By calculating the resource selection functions (RSFs) (Manly et al., 2002), diameter classes were identified that were used significantly more or less by lizards than when each diameter class was used randomly. In this study, the relative frequency of tree trunks of each diameter class used by the lizards was used for the proportion of usage; and the relative frequency of tree trunks of each diameter class as a proportion of availability was used.

The Conclusion centers on a discussion of the implications for controlling *A. carolinensis* from the results obtained from the analysis of diameter selectivity.

Materials and Methods

Field surveys

Line transect surveys along a fixed route (1.23 km in total) were conducted 25 times on Chichijima Island (Mitani et al., 2020). The routes were set in the Ogamiyama (Mt. Ogami) area, the hilly part of Ogamiyama Park. Surveys were conducted twice a day, early in the morning and around noon, in spring (May), summer (July, August, September), and autumn (October) from 2014 to 2018. Lizards were searched for within 3 m of the edge of both sides of the path. Surveyors (mean 4.6, range 3–6) walked very slowly to minimize missing any lizards and stopped at appropriate points to fully observe each tree. Each survey took about four hours (234±36 min, mean±SD, about 0.3 km/h). The substrate types that lizards were perched upon were divided into seven categories and recorded: tree trunk, branch, aerial root, leaf, dead tree/leaf, artifact, and rock/ground. Except for the first survey in August 2014, the diameters of the trunk or branch at the point where the lizard perched were measured in millimeters using a diameter caliper (Haglöf, Mantax Blue) or estimated by eye if the point was out of reach. However, those that were damaged and did not retain their cylindrical shape were excluded from the measurements. The heights were also measured but were not used in the analysis. The lizards were divided into adults and juveniles according to estimation by eye of snout-vent length (SVL). Lizards with an SVL of greater than 40 mm were classified as adults (Hamlett, 1952). Sex was not identified because there is

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no reliable method of identification without capturing the lizard.

The relative frequency by diameter class was calculated from the data on the trunks used by the lizards. This is referred to as the proportion of usage. To determine the relative frequency by diameter class of tree trunks in the study area, i.e., the proportion of availability, the diameters of tree trunks along the same routes were surveyed at 1 m intervals in June 2015. The interval distance was measured using a tape measure placed along the center of the path; the closest tree to the 1-m interval point was selected for the survey, skipping sites without a tree within 1 m. For trees taller than about 1.3 m, diameter at breast height (DBH) was measured; for trees shorter than about 1.3 m, the diameter was measured at a constant thickness. Trees here included bamboo.

Data analysis

The selectivity of perch by diameter was evaluated using the resource selection function (RSF) (Manly et al., 2002; Kiyota et al., 2005). In this analysis, resources are divided into categories, and the ratio of "proportion of usage" to "proportion of availability" for each category is used as the resource selection function. If there is no selectivity, the proportion of availability and the proportion of usage of each category are the same, i.e., RSF=1. If it is preferred, the RSF is greater than 1, and if it is avoided, it is less than 1. These values also indicate the relative degree of selectivity. If the confidence interval does not include 1, it is determined to be significantly selective. The resource categories were divided into diameter classes at 1-cm intervals. However, those exceeding 12 cm were placed into one category. The resource selection function (RSF, $\widehat{w}_i$) is estimated by

$$\widehat{w}_i = o_i/\pi_i,$$

where o_i is the proportion of resource unit in category I of all used resource units and π_i is the proportion of resource unit in category I of all available resource units. Because $\widehat{w}_i$ corresponds to the proportion of availability to usage, $\widehat{w}_i$ of a resource category with neither selectivity nor avoidance is 1. The standard error of $\widehat{w}_i$ is calculated as

$$se(\widehat{w}_i) = \sqrt{o_i(1-o_i)/(u\pi_i^2)},$$

where u is the number of units in category I in a sample of used units.

The Bonferroni corrected confidence interval is evaluated by

$$\widehat{w}_i \pm z_{\alpha/2}\, se(\widehat{w}_i),$$

where α is the standardized RSF, $\widehat{w}_i/\sum_{i=1}^{I}\widehat{w}i$. Selectivity is suggested if the confidence interval does not include 1.

Statistical analysis was performed using R software (R Development Core Team, 2019), and the Resource Selection Program (Okamura et al., 2004) was used for the calculation of RSF.

Results

From the field survey, the 759 data items on perching substrates used by the lizards were divided into seven categories. They perched on tree trunks (37.7%), branches (12.9%), and air roots (6.1%), leaves (20.2%), dead trees/leaves (10.9%), artifacts (7.5%), and rocks/ground (4.7%). The diameters of the perches used by the lizards, where it was not possible to determine whether they were adults or juveniles, were excluded from the analysis. The diameters of the tree trunks used by the lizards were measured for a total of 270 lizards: 213 adults and 57 juveniles.

To collect data on resource availability, the trunk diameters of 1,024 trees of 42 species were measured in the study area. Of those measured, 420 (41.0%) were thin trunks with a diameter of 1 cm or less (Fig. 1). Trunks of 1 cm or less in diameter were observed in 15 tree species, 74.8% of which were dominated by two tree species: fish pole bamboo, *Phyllos-*

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TABLE 1. Composition of tree species in trunks with a diameter of 1 cm or less in the study area

Tree species	Composition	Number
Phyllostachys aurea	46.2%	194
Leucaena leucocephala	28.6%	120
Osteomeles boninensis	3.8%	16
Trachelospermum asiaticum	3.3%	14
Pleioblastus simonii	3.3%	14
Rhaphiolepis umbellata	2.9%	12
Planchonella obovata	1.7%	7
Morus australis	1.4%	6
Osmanthus insularis	1.2%	5
Hibiscus glaber	1.0%	4
Dendrocalamus latiflorus	1.0%	4
Lantana camara	0.5%	2
Ficus microcarpa	0.2%	1
Hibiscus sp.	0.2%	1
Syzygium chleyeraefolium	0.2%	1
Not identified	4.5%	19
Total	100.0%	420

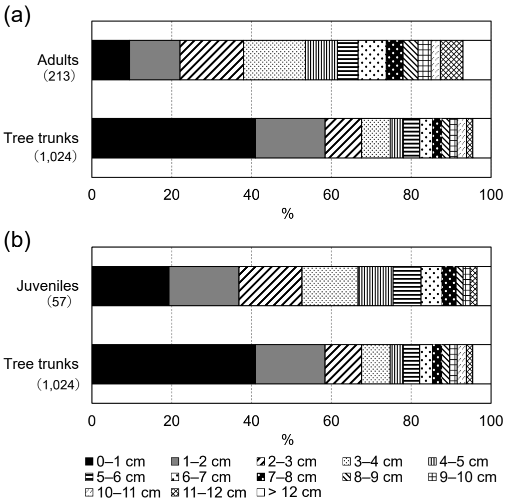

FIG. 1. Comparison of the relative frequency of tree trunk diameters in the study area and those used by the lizards.

tachys aurea, (46.2%), and white popinac, *Leucaena leucocephala*, (28.6%) (Table 1). The results of a preference study by tree species at this study area suggests that lizards avoided these two species (Mitani et al., 2020). Therefore, two patterns of resource selection functions for selectivity by trunk diameter were calculated, one for all tree species and the other for species other than fish pole bamboo or white popinac.

Frequency of use by perch diameter in the field

The proportion of usage was compared to the proportion of the availability (Fig. 1). The proportion of usage refers to the relative frequency of tree trunks of each diameter class used by lizards. The proportion of availability is the relative frequency of tree trunks of each diameter class in the study area. For the diameter class of 0–1 cm, the proportion of usage was lower for adults and juveniles (9.4% and 19.3%, respectively) than the proportion of availability (41.0%). For the diameter class of 3–4 cm, the proportion of availability was 7.1%, while the ratios of usage for adults and juveniles were higher at 15.5% and 14.0%, respectively.

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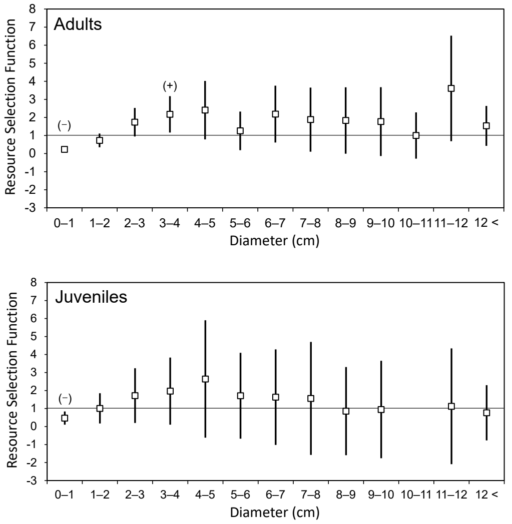

FIG. 2. Resource selection function by tree trunk diameter for each diameter class. Vertical lines represent confidence intervals. Plus and minus signs in parentheses respectively indicate significant preference or avoidance.

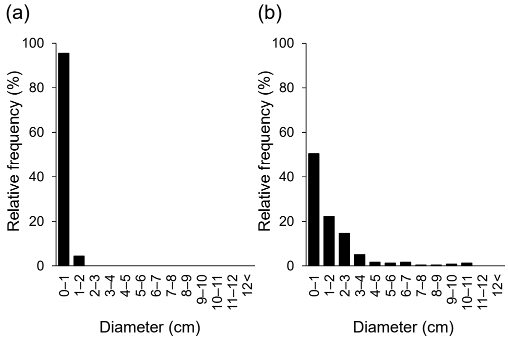

FIG. 3. The relative frequency of tree trunk diameters of fish pole bamboo (a) and white popinac (b).

Resource Selection Function for each diameter class

The selectivity of the tree trunk for each diameter class was evaluated by RSFs (Fig. 2). For adults, the RSF at 0–1 cm was 0.23, indicating significant avoidance; for 3–4 cm, the RSF was 2.17, indicating significant preference. No significant selectivity was observed for other diameter classes. The RSFs for diameter classes greater than 2 cm ranged from 1.5 to 3.6, and the confidence intervals for each diameter class overlapped. For juveniles, the RSF at 0–1 cm was 0.5, which was significantly aversive. RSFs for other diameter classes ranged from 0.8–2.6, but were not significantly selective, and their confidence intervals overlapped.

Diameter class distribution of fish pole bamboo and white popinac and RSF for each diameter class excluding these two tree species

The trunk diameters of 203 fish pole bamboo and 238 white popinac specimens were measured. The percentages of trunks with a diameter of 1 cm or less were 95.6% for fish pole bamboo and 50.4% for white popinac (Fig. 3). The RSFs were calculated excluding fish pole bamboo and white popinac (Fig. 4). In the calculation, the measurements of these two tree species were excluded from both the diameter of tree trunks in the study area (availability) and the diameter of tree trunks used by lizards (usage). The diameter measurements for 583 tree trunks in the study area and those for 155 tree trunks used by adults and 40 tree trunks used by juveniles were used in the calculations.

For adults, the RSFs of 0–1 cm and 1–2 cm diameters were 0.1 and 0.5, respectively, which were significantly aversive. There was no significant selectivity for the other diameter classes. For juveniles, there was no significant selectivity for any of the diameter classes, but the RSF for 0–1 cm diameter was 0.7, i.e., lower than 1.

DISCUSSION

The RSFs for all tree species suggested that lizards avoided using thin trunks of 1 cm or less in diameter. However, in the study area, the majority of thin trunks of 1 cm or less in diameter were dominated by two species: fish pole bamboo and white popinac. In a previous study, the RSFs of these two tree species were significantly below 1, suggesting avoidance in a comparison of selectivity by tree species

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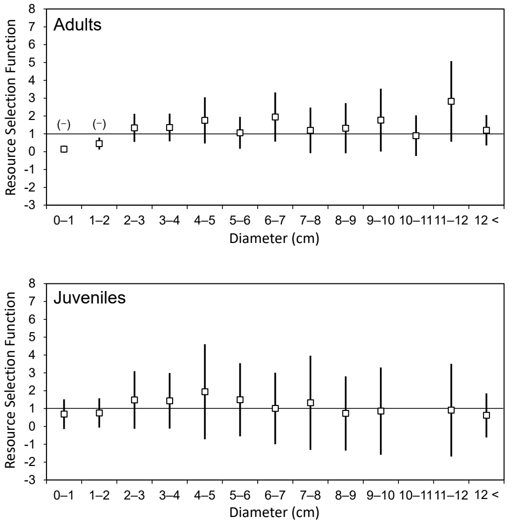

FIG. 4. Resource selection function by tree trunk diameter for each diameter class with fish pole bamboo and white popinac excluded. Minus signs in parentheses indicate significant avoidance.

(Mitani et al., 2020). The marked bias in the species composition of this diameter class may have affected the results of the analysis of selectivity by diameter.

The RSF was therefore calculated using only the diameter measurements of other tree species, excluding these two species. The results suggested that adults avoided trunks thinner than 1 cm, even for tree species other than fish pole bamboo and white popinac. The picture was not clear for juveniles. It appeared that at least adults avoided trunks thinner than 1 cm, regardless of tree species.

On the other hand, the RSFs of diameter classes greater than 2 cm did not suggest clear selectivity for a particular diameter class. The RSF for all tree species indicated that adults had a significant preference for 3–4 cm. However, RSFs of 3–4 cm were comparable to RSFs of other diameter classes above 2 cm, and yet the confidence intervals overlapped. Lizards in the study area showed no diameter preferences for trunks over 2 cm in diameter, suggesting that they use them randomly.

It is difficult to discuss why *A. carolinensis* in the study area avoids thin trunks of less than 1 cm. However, in a habitat where predators and other individuals are present, it is possible that jumping ability and sprinting speed are critical factors in the lizards' selection of perch. It appears that perches above a certain thickness could be disadvantageous to clinging performance (Kolbe, 2015), but advantageous for jumping and sprint speed (Spezzano and Jayne, 2004; Jones and Jayne, 2012). It has been reported that *Anolis* lizards tend to use a specific range of perch diameters that allow for maximum sprinting speed (Irschick and Losos, 1999).

The results of a previous study reported the RSFs of fish pole bamboo and white popinac to be significantly lower than 1, suggesting that they were avoided (Mitani et al., 2020). Following the results of this study, conversely, one of the reasons for the lower RSFs of these two tree species in the comparison of selectivity by species could be that nearly all of the trunks of the fish pole bamboo and approximately half of the trunks of the white popinac were 1 cm or less in diameter.

Conclusion and suggestions for efficient capture

Selectivity for trunk diameters over 2 cm was estimated to be random. Thus, where relatively thin trees with trunks of over 2 cm in diameter are dominant, a large proportion of lizards are expected to be distributed on them; whereas where thick trees predominate, a large proportion of lizards are expected to be distributed on thick trees. In addition, trunks with a diameter of 1 cm or less tended to be avoided, but not entirely. Therefore, the trunk diameter suitable for setting traps should reflect the distribution of diameter classes of forest trees at the site.

The diameter of perch frequently used by *A. carolinensis* in habitats varied among regions. The diameters of the various regions described below were measurements of the perches, including branches as well as trunk. In the Bahamas, they ranged from 1–4 cm (Losos et al., 1994) depending on the population. In two populations in Louisiana, they were less than

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2 cm to approximately 10 cm (Irschick et al., 2005a, b). In Ogasawara, it has been reported that the mean diameter of the perches measured in several areas of Chichijima Island and Hahajima Island, combined and tabulated by sex, is approximately 4–8 cm (Anzai et al., 2017). Regional differences in the diameters of frequently used perches within Ogasawara will require further study.

When the goal of control is a significant reduction or eradication of a population, it is necessary to remove a certain percentage of individuals from the population. For example, the adhesive traps currently in use have an opening width of 8.0 cm, which makes them unsuitable for setting on thin perches. In the Ogamiyama area (the study site), the proportion of the lizards on trunks with a diameter of 8 cm or more was relatively low, at 19.2%. The range of diameters of the most common tree trunks varies by region and by forest. Because lizards use the tree trunks that are available to them, the range of tree trunk diameters commonly used by lizards is likely to vary by location. Capture techniques need to be developed that are effective for trunks and branches of various diameters. However, targeting trunks smaller than 1 cm may be a low priority.

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