

Food Habits of a New York Population of Italian Wall Lizards, *Podarcis sicula* (Reptilia, Lacertidae)

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ABSTRACT.—We studied the food habits of the Italian wall lizard, *Podarcis sicula*, that was introduced to Long Island, New York in 1966. We recovered 436 prey items from 96 lizards. There was no significant relationship between the percentage of lizards without prey items and date of capture. On average, females had significantly more prey items per lizard, lower overall prey diversity and lower prey evenness, than did males. This suggests important differences in foraging habits between the sexes. We found remarkably high similarity between prey species diversity for the Long Island and two of four European populations. There was no correlation between prey size and either head width or snout-vent length of the lizards.

INTRODUCTION

Italian wall lizards (*Podarcis sicula campestris*) were introduced to Long Island, New York, in 1966 (Gossweiler, 1975). On Long Island they live only in urban, suburban and light industrial environments, and although the lizards are clearly increasing in range and numbers, they have not spread into any environments not severely disturbed by humans. Therefore the environments they inhabit contain many other introduced species, mostly plants and invertebrates. Nothing has been reported regarding their food habits in this new environment. Diet studies have been published for *P. sicula salfilii* populations on a small island near Naples, Italy (Ouboter, 1981), six small islands off the west coast of northern Italy (*P. sicula campestris*; Pérez-Mellado and Corti, 1993), *P. sicula campestris* introduced to Menorca, a large island off the east coast of Spain (Pérez-Mellado and Corti, 1993) and *P. sicula campestris* in their native habitat in central Italy (Rugiero, 1994). None of these habitats is urbanized, as is *Podarcis* habitat in the United States.

We compared prey species diversity of males and females in the Long Island population, and the aggregate Long Island prey species diversity with each of the European populations, primarily using Simpson's D, a commonly used measure for diet studies. Simpson's D is an index of the likelihood that two individual prey items, chosen at random from all the prey items in the entire sample, are of the same taxon. Simpson's D has strengths and weaknesses compared to other potential measures; its results are highly sensitive to sample size, yet it is very good at detecting differences between samples (Magurran, 1988). D values are a function of the number of taxon categories (s) and taxon evenness, (E), and they measure the distribution of prey individuals among taxon categories. Food habit studies typically deal with prey specimens that are difficult to identify to species, and so prey items are grouped into taxon categories. Unfortunately this may invalidate dietary comparisons unless categorization methods are standardized.

Studies of the food habits of other lizards have demonstrated that prey size often increases

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TABLE 1.—Percentage of lizards with no prey items in their guts in different sampling periods

Sampling period	N captured	% (N)	With no prey
April–May	32	15.6%	(3F, 2M)
June–July	23	13.0%	(1F, 2M)
Aug–Sept	46	26.1%	(5F, 7M)
October	17	11.8%	(1F, 1M)
Total	118		10F 12M

with lizard body size and head size (*e.g.*, Herrel *et al.*, 2001; Schoener, 1967; Vitt and Zani, 1996, 1997), suggesting an improved ability to handle larger prey as the animal grows. However, this relationship is not found in all lizards (*e.g.*, Vitt *et al.*, 1997a, b). We sought to examine this relationship in the New York population of *Podarcis*. We hypothesized that size variation would be associated with significant variation in consumed prey size.

METHODS

Lizards were collected from April through October 1997 from three neighboring sites in Garden City and Carle Place, on Long Island, New York. These sparsely vegetated sites are mostly industrial areas, where most plant life is nonnative grasses and low bushes. Lizards were caught in sticky traps placed flat on the ground early in the morning and collected in late afternoon the same day. After removal from traps, lizards were euthanized, fixed in formalin, and permanently preserved in alcohol. Snout-vent length (SVL), maximum head width, maximum head length, forelimb length and hind-limb length measurements were taken, and the contents of the stomach and small intestine were examined. Morphometric differences between males and females were measured by calculating the linear regressions of maximum head width, maximum head length, fore-limb length and hind-limb length measurements against SVL separately for males and females. The slopes of the regression lines for males were compared to those of females for each of the four characteristics using two-tailed *t*-tests.

All prey items were identified as completely as possible. The maximum width of each beetle found was measured. We calculated species diversity using the Simpson's index of diversity (D) and evenness (E) using relevant equations from Brower *et al.* (1997).

Because calculations of D can be sensitive to the classification scheme used, the D value for the New York population had to be recalculated for each comparison. To compare the New York data with each of the four European *Podarcis sicula* populations, we reorganized our data in four different ways to match the different classification systems used by each of the four European data sets. Because of Ouboter's (1981) small sample size, we summed his data from four vegetational zones on one small island. The calculated D values of Long Island males were compared statistically to those of Long Island females, and the combined data for all Long Island lizards were statistically compared to those reported by other researchers using the modified *t* test presented by Brower *et al.* (1997).

RESULTS

Twenty-two lizards (19%) had no prey items in their stomachs or intestines (Table 1). Seasonal differences in the frequency of empty guts were not significant ($\chi^2 = 0.59$, two-tailed $P > 0.10$). Ninety-six lizards had at least one prey item in their stomachs, and/or intestines, with a total of 436 prey items from these lizards. No significant amount of plant material was found. Female lizards had significantly more prey items in their stomachs than

TABLE 2.—Gut contents of 96 *Podarcis sicula* captured on Long Island, New York. N refers to number of lizards sampled. Females had significantly higher D ($t = 4.91$, $P < 0.01$)

Prey category	Order or Class	Male lizards (N = 38) % of total	Female lizards (N = 58) % of total	Combined (N = 96) prey N (%)
Aphids	Homoptera	8.6	52.8	189 (43.3%)
Plant hoppers	Homoptera	0	2.6	9 (2.1%)
Adult beetles	Coleoptera	25.8	14.6	74 (17.0%)
Larval beetles	Coleoptera	2.2	0.9	5 (1.1%)
Ants	Hymenoptera	6.5	2.3	14 (3.2%)
Wasps	Hymenoptera	2.2	1.8	8 (1.8%)
Bees	Hymenoptera	1.1	0.3	2 (0.5%)
Earwigs	Dermaptera	1.1	1.8	7 (1.6%)
Crickets	Orthoptera	0	0.6	2 (0.5%)
Caterpillars	Lepidoptera	0	0.9	3 (0.7%)
Moths	Lepidoptera	1.1	0.3	2 (0.5%)
Stinkbugs	Hemiptera	0	1.1	4 (0.9%)
Flies	Diptera	8.6	0.6	10 (2.3%)
Lacewings	Neuroptera	1.1	0	1 (0.2%)
Centipedes	class Chilopoda	0	1.1	4 (0.9%)
Spiders	class Arachnida	3.2	4.1	17 (3.9%)
Harvestman	Opiliones	2.2	4.1	16 (3.7%)
Pill bugs	Isopoda	25.8	9.0	55 (12.6%)
Snails	superorder			
	Stylommatophora	2.2	0.6	4 (0.9%)
Earthworms	class Oligochaeta	3.2	0.3	4 (0.9%)
Unidentified		5.4	0.3	6 (1.4%)
	Total number prey items	93	343	436
	Prey items/lizard	2.4	5.9	4.5
	Evenness (E)	0.95	0.72	0.80
	Diversity index (D)	0.84	0.69	0.76

did males with all 118 lizards considered ($t = 3.27$, $P = 0.002$) and with lizards with empty guts excluded ($t = 3.21$, $P = 0.002$). A wide variety of prey taxa was found (Table 2). The most common prey type was aphids, largely because a few lizards had eaten a large number of aphids. For example, one lizard had eaten 50 aphids, another 24 and a third 15. No other prey item was present in high numbers in any single lizard. Female lizards had significantly more prey items in their stomachs than did males when aphids were excluded ($t = 1.95$, $P = 0.05$). Twenty-nine lizards (15 males), ranging in size from 43–70 mm SVL, had eaten beetles. Beetle width varied from 4.5 mm to 11.9 mm ($\bar{x} = 7.9$ mm). There was no significant correlation between either lizard snout-vent length and beetle size or lizard head width and beetle size (both $P > 0.10$).

Male body size (SVL $\bar{x} = 62.9$ mm, range = 39.3–79.5 mm) was significantly larger than female SVL ($\bar{x} = 58.4$ mm, range 41.7–75.8 mm) ($t = 2.3$, $P = 0.024$). The slopes of linear regression lines of male head width, head length, front limb length and hind limb length on SVL were each greater than the corresponding slopes for females ($t = 11.36, 5.70, 2.24$ and 2.90 , respectively, all $P < 0.01$).

Female lizards from Long Island had significantly lower prey taxon diversity (Simpson's $D = 0.69$) than males ($D = 0.84$, $t = 4.91$, $P < 0.01$, Table 2). The D value for all Long

Island lizards combined was significantly smaller than those reported for stomach contents from lizards collected on the Tuscan Archipelago ($D = 0.89$) and those collected on Menorca ($D = 0.88$) (Pérez-Mellado and Corti, 1993) (Table 3). There were no significant differences in Simpson's D between combined Long Island data and D as determined by gut content analysis from an Italian island by Ouboter (1981, $D = 0.71$, Table 3), or between combined Long Island data and fecal pellet data from Rugiero (1994, $D = 0.73$) collected in central Italy (Table 3).

DISCUSSION

We sampled lizards throughout their active season and, although as many as 18.6% of the Long Island lizards had no prey items in either their stomachs or intestines in any one sampling period, there was no significant variation in the percentage of empty guts between sampling periods. This contrasts with Avery (1978), who reported that *Podarcis sicula campestris* captured in Italy had significantly lower rates of food consumption in early April than in either late April or August. Further, Avery presented evidence that daily food consumption rates were in part determined by cloud cover, in that lower amounts of solar radiation reduced foraging behavior.

The proportion of NY lizards "running on empty" is somewhat higher than the 13.2% reported for an enormous sample of lizards of numerous species (Huey *et al.*, 2001). The levels we observed for the April–May, June–July, and October periods are much lower, and very similar to the typical value for lizards reported by Huey *et al.* (2001), with only the August–September level (26.1%) being considerably higher. Unfortunately, Huey *et al.* (2001) did not include any nondesert temperate lizards or Lacertids other than desert species in their analysis, so it is not possible to make a more specific comparison.

Feeding rates and the length of time lizards are "empty" are important because lizards with empty guts must rely on energy stores for maintenance and foraging needs (Huey *et al.*, 2001), and feeding rate also affects basking and other thermoregulatory behavior (Tosini *et al.*, 1994). We are unaware of any reports of passage times for invertebrate prey through these lizards, but it seems reasonable to assume that commonly eaten hard-bodied items, such as beetles, take at least a day to pass through the gut. Since our captures were made primarily in the afternoon, they probably had not eaten earlier that day nor at least past midday of the previous day. If true, that would indicate that lizards with empty guts had not eaten in at least a day.

Males in the Long Island population on average contained significantly fewer prey items than females, and males had higher prey species diversity values (D) and evenness values (E). This suggests that females successfully specialize on a smaller number of prey types, and examination of Table 2 shows that this specialization is primarily on aphids. However, the high levels of aphid consumption were weighted by a small number of females that ate large numbers of aphids. When we recalculated the values of Table 2 after removing aphids from the list of prey types, not surprisingly the new number of prey items per lizards for males (2.2) became much more similar to that of females (2.7), and the D value for males (0.82) was now smaller, and quite similar to, that of females (0.84). Thus in the absence of this single prey type gender differences were minor. However, even with aphids removed from the analysis females still ate significantly more items/individual than did males, so aphids did not account for all of the observed differences.

We also compared the dietary habits of *Podarcis sicula* captured on Long Island with similar data from four populations in Europe. The D values in all these populations are fairly similar, ranging only from 0.71 to 0.89. No prey item categories are conspicuously important in any one population but absent in another. In two populations, Ouboter (1981)

TABLE 3.—Comparison of Simpson's D values and other study parameters for five reports of prey diversity in *Potamis sicula*

	D: Species diversity	D compared to Long Island population	E Evenness	Source of data	Population origin	Habitat	# lizards examined
Long Island, NY (LI)	0.74-0.76		0.80	stomach and intestines	non-native	large island, mostly non-native	96
Vivaro di Nerano (VN)	0.71	NS $t = 1.04, P > 0.10$	0.77	stomach and intestines	native	small island, mostly native Mediterranean grasses and shrubs	8
Tuscan Archipelago (TA)	0.89	sig different $t = 7.39, P < 0.01$	0.95	stomach only	native and non-native	small island, mostly native Mediterranean grasses and trees	42
Menorca (MN)	0.88	sig different $t = 4.38, P < 0.01$	0.95	stomach only	non-native	large island, mostly native Mediterranean grasses and trees	12
Central Italy (CI)	0.73	NS $t = 0.30, P > 0.10$	0.79	fecal material	native	Mainland, coastal sand dunes with native shrubs	31

Long Island, NY: combined male and female data from this report, D varies slightly depending on which prey classification scheme is used (see text); Vivaro di Nerano, Italy: Ouboter, 1981; Tuscan Archipelago Islands, Italy: Pérez-Mellado and Corti, 1993; Menorca, Spain: Pérez-Mellado and Corti, 1993; central Italy: Rugiero, 1994.

and Rugiero (1994) reported finding lizard skin, suggestive of cannibalism. Although we found no evidence of this in our examination of lizard gut contents, we once observed an adult *P. sicula* catch and eat a juvenile.

There were some significant differences in prey species diversity among the four European populations and the New York population. Neither population origin (native or nonnative), habitat (island or mainland), general vegetation description (native or nonnative), nor differences in number of lizards sampled explains why Long Island prey species diversity was not significantly different compared to either Vivaro di Nerano (VN) or Central Italy (CI), but prey species diversity recorded from the Tuscan Archipelago (TA) and Menorca (MN) were significantly larger than Long Island (LI) (Table 3). Unfortunately, there are no prey availability data for any of these sites, so this cannot be analyzed as a possible source for these patterns. It is also difficult to compare the habitats of these different study sites meaningfully, because of limited descriptions in the original reports. The Long Island site where *P. sicula* were collected for this study was mostly dominated by nonnative grasses and shrubs interspersed among industrial buildings, a railroad track and a parking lot. Vegetation cover varied between 0% and 100% within only a few meters. Vegetation cover at the VN site varied between 25%–75%, and was dominated by native Mediterranean grasses and shrubs (Oubotor, 1981). Vegetation at the TA and MN sites was described as “typically Mediterranean” (Pérez-Mellado and Corti, 1993). No further details are reported for TA, but plant cover at MN varied from “extremely poor plant cover” on the north coast of MN to “oak and pine forests” to “cultivated areas” (Pérez-Mellado and Corti, 1993). CI was described as a “woody zone” within a coastal sandy dune, with native Mediterranean shrubs (Rugiero, 1994). Better characterization of study sites, including vegetation types, plant cover and prey species availability would greatly facilitate comparison of these populations.

The relatively high *D* values for TA (0.89) and MN (0.88) are particularly striking not only because they are high compared to LI, VN and CI, but also because TA and MN used only stomach contents, whereas LI ($D = 0.74\text{--}0.76$) and VN ($D = 0.71$) used both stomach and intestines. CI used only fecal material, which probably results in the poorest sampling of true dietary habits, yet CI's *D* (0.73) is not statistically different from those of LI and VN. Food habits studies based on stomach contents alone probably result in lower estimates of taxon diversity than do studies of stomach contents and hindguts combined (Floyd and Jenssen, 1984; Schoener, 1989). Floyd and Jenssen (1984) found that omitting the hindgut from analyses of lizard gut contents decreased prey taxa diversity by about 32%, and that this decrease was mostly due to the absence of soft-bodied prey. Schoener (1989) found that including the hindgut contents in dietary compilations slightly increased both prey species diversity and prey size diversity. *D* was estimated for CI using only fecal material, yet the result is similar to that of LI and VN, which used the most thorough method of recovering prey items. Very likely prey diversity estimates for CI would be higher than those of LI and VN if similar methodology was used in all three studies. Similarly, *D* values for TA and MN, which were estimated using only stomach contents, probably resulted in lower prey species diversity estimates than would have been obtained using both stomach and hindgut contents.

D is a function of both number of species (*s*)—in this case prey categories—and the evenness of prey distribution among those categories (*E*). We calculated *E* (Table 3), and noted that *E* of the Long Island, VN, and CI populations are much lower than *E* of the TA and MN populations. Unfortunately no tests are available to determine if the observed differences in *E* are significant. *E* can be artificially high (and usually is artificially low) if the sampling technique used does not allow recovery of many rare species, as may be the case when only stomach contents are recovered. In this context it is interesting to note that

analysis of fecal material alone, as in the CI study, resulted in D and E values more like those of combined stomach and intestine analyses than did the studies of stomach content alone. Future studies should include stomach and intestine contents to make the results more thorough and comparable to other studies.

We found no relationship between prey size, as measured by beetle size, and either lizard head size or lizard body size. Long Island *Podarcis* exhibit significant size variation; they hatch out at about 20.5 mm snout-vent (SVL), and may grow to 81 mm SVL. The lack of a relationship between lizard size and prey size is surprising because beetles are probably difficult to handle, and larger beetles are more difficult than smaller (Herrel *et al.*, 2001). Thus it is reasonable to expect that small lizards have a particularly difficult time subduing large prey. However, it could be that in the urban environment where these lizards were collected, large beetles are unusual and thus rarely encountered by lizards, or that even the largest beetles encountered were within a manageable size range and did not present a significant challenge for these lizards.

Contrasting evidence that lizard body size is important to prey choice was found by comparing male morphometrics and diet to that of females. Male lizards in this population have relatively longer and wider heads, and relatively longer front and hind limbs, than do females, though males have only slightly larger SVLs on average, than do females. One explanation for these sexual dimorphisms is that they reflect a type of feeding niche separation, and thus reduce competition between members of the sexes. These dimorphisms may help males capture and handle larger and more elusive prey. The data presented here lend two types of support to this hypothesis. First, three types of hard-bodied prey, adult beetles, pill bugs, and snails, together make up a much larger percentage of male diets (53.8%) than of female diets (24.2%). Furthermore, the most dramatic difference between the diets of each gender is the large number of aphids found in some females, making up 53% of the items taken by female lizards, compared to 9% of males' diets. Aphids are small, slow moving, soft-bodied, and without chemical or physical defenses, exactly what would be expected for lizards that specialize in slower moving, relatively defenseless prey. Further studies are underway to determine whether the observed sexual dimorphisms actually are associated with differences in prey capture and handling capabilities. These studies should be duplicated in populations of *Podarcis sicula* within its natural range.

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