

Seasonal and Diel Activity Patterns of Italian Wall Lizards, *Podarcis sicula campestris*, in New York

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Abstract - Lizard behavior can be influenced by ultimate forces such as adaptation and phylogeny, and proximate forces such as temperature and rainfall. Italian wall lizards (*Podarcis sicula campestris*) were successfully introduced into two locations in the USA, both at latitudes similar to their probable sources in Italy. Behavioral differences between native and introduced populations are likely due to proximate forces. From 1999–2000, we documented the seasonal and diel behavior of wall lizards in New York. We observed a bimodal activity pattern during the summer and a unimodal activity pattern in spring and fall, which has been reported for native populations in Italy. Unlike Italian populations, New York lizards were completely inactive during winter months, which is probably due to the much lower minimum winter temperatures in New York.

Introduction

Studies on lizards show that life history and behavior are quite variable. This variation is due to evolutionary forces, such as adaptation and phylogenetics, and proximate forces, such as climatic interactions with physiology (Adolph and Porter 1993). Few known studies have investigated the relative importance of these evolutionary forces. Dispersal events provide opportunities to investigate the relative importance of these forces, especially when new populations experience novel climatic conditions and investigations are carried out before enough time has passed for considerable genetic change. However, although observations of dispersal are important to our understanding of animal and plant distributions, natural events are rarely seen (e.g., Censky et al. 1998). In contrast, introductions of non-native species occur commonly. Notwithstanding their potential negative impacts on their new environments, introductions of non-native species can provide useful models of natural dispersal and colonization (Sheldon 2002) and examples for conservation-related reintroductions (Burke 1991). For example, concerns about the rare lacertid lizard, *Podarcis raffonei* (Mertens, 1952), have led to the suggestion that reintroductions may be appropriate in the future (Capula et al. 2002), and information about successes and failures of *Podarcis* sp. introductions elsewhere may prove relevant.

Italian wall lizards or ruin lizards, *Podarcis sicula campestris* (De Betta, 1857), are small (ca. 60 mm adult snout-vent length), mostly invertivorous (Burke and Mercurio 2002), and native to Italy and neighboring coasts. Because of their generalized habitat requirements (see Corti and Lo Cascio

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2002), they have been successfully introduced to many other locations in Europe (Arnold et al. 1978, Henle and Klaver 1986) and at least three locations in the United States, including Garden City, NY (40.4°N, 73.4°W; Gossweiler 1975), Topeka, KS, (39.0°N, 95.4°W; Collins 1982), and Philadelphia, PA (40.0°N, 75.0°W; Kauffeld 1931). However, this latter population is now extirpated (Smith and Kohler 1977; R.L. Burke, pers. observ.). Genetic analysis suggests that the origin of both extant US populations is the vicinity of Rome, Italy (41.9°N, 12.5°E; Oliverio et al. 2001). Further evidence of Roman origin is based on the observation that these populations started with pet trade animals, and collectors and exporters of reptiles for the pet trade were concentrated near Rome in the 1960–1970s (C. Bertolucci, University of Ferrara, Italy, pers. comm.; G. Deichsel, Boehringer Ingelheim, Germany, pers. comm.).

Podarcis sicula campestris was accidentally released from a pet shop in New York around 1967 (Gossweiler 1975). Although winters are frequently much colder in New York than in its native range in Italy (see below) and *P. sicula* is not freeze-tolerant (Burke et al. 2002), this species has clearly increased its range and numbers, and its populations in New York now consist of thousands of individuals (R.L. Burke, pers. observ.). Through both natural dispersal and additional illegal releases by people, *P. sicula campestris* has spread as much as 130 km from the original release site in Garden City (R.L. Burke, pers. observ.) and is now found in Nassau, Suffolk, Kings, Queens, and Bronx counties.

Podarcis sicula campestris lives mostly in urban and suburban environments in New York, and Northern Mockingbirds (*Mimus polyglottos* (Linnaeus, 1758)), Blue Jays (*Cyanocitta cristata* (Linnaeus, 1758)), and American Crows (*Corvus brachyrhynchos* Brehm, 1822), are probably the only possible native predators on these lizards. Non-native house cats (*Felis silvestris* Schreber, 1777) sometimes prey on *P. sicula campestris* in New York (R.L. Burke, pers. observ.). There are no other lizard species on Long Island, and few native non-lizard species that might be in direct competition.

Seasonal activity (here activity means not in a refuge, i.e., potentially visible) patterns of native *Podarcis sicula campestris* has been studied by Foà et al. (1992b) and Tosini et al. (1992) in Italy at about the same latitude (43.5°N, 10.2°E) as the introduced American populations, and therefore experience approximately the same photoperiod. Avery (1993) and Foà et al. (1992b) found that the daily pattern of activity in Italy changes from unimodal (one daily activity peak) in spring and fall to bimodal (two well-separated peaks) in summer. Seasonal shifts in diel activity observed in Italian *P. sicula* may be proximately cued by both endogenous and exogenous factors (Foà et al. 1994). Although the roles of endogenous cues have been investigated by Foà et al. (1992a) and Innocenti et al. (1994, 1996), exogenous cues have not been similarly examined.

We sought to discover whether thermoperiods or photoperiods, as exogenous cues, played important roles in determining activity patterns in this

species in New York. Adolph and Porter (1993) predicted that on the basis of physiology alone, when two genetically similar populations of ectotherms are compared, the population in the colder climate will be less active. The mean temperatures of New York summers are similar to those of central Italian summers, and New York winters are much colder than central Italian winters (see below). Therefore, we hypothesize that in the summer New York *Podarcis sicula campestris* will exhibit behavioral patterns similar to that reported for Italian *P. sicula*, and in the winter New York *P. sicula campestris* will be much less active than their Italian counterparts.

Methods

We surveyed *Podarcis sicula campestris* at a private residence in Garden City, Long Island, NY. The study site was located near a brick house; the vegetation was mostly lawn grass, garden plants, and flowers. The activities of many individual lizards observed in this study were centered around a wooden deck, which also provided multiple refugia. The entire study area was fully exposed to the sun except for shade caused by the house, the deck, and a few trees and shrubs.

Before starting censuses, we hand captured, noosed, marked, and released lizards on the sites. We marked each lizard by sewing unique combinations of colored beads flat to the skin near the base of the tail (see Fisher and Muth 1989), which permitted identification of individual lizards without recapture.

Our survey methodology was similar to that utilized by Foà et al. (1992b) and Rugiero (1995) in Italy, except they only surveyed three days/month, and Foà et al. (1992b) did not identify individual lizards. We conducted censuses (each 5–20 minutes long) along a 50-m transect each hour from 08:00–17:00 EDT one day/week March–October 1999, July–October 2000, and during any unusually warm days over the winter months, especially November 1999–March 2000, whenever it appeared lizards might be outside their winter refugia. We also conducted censuses for lizards later in the day whenever lizards were still present at the last regular census at 17:00. Each lizard was counted only once per survey. During each census, we noted which lizards were visible, therefore we consider active to mean not hidden in a refuge. We are not referring here to what each lizard was doing, only whether it was visible.

We summarized data in two ways. First, in order to examine seasonal patterns, we calculated the mean number of lizards observed in transects conducted in each month. Second, we calculated the mean number of hours lizards were observed each day for each month, and therefore determined a monthly mean for number of hours lizards were observable. For this analysis, we combined overlapping data from 1999 and 2000 for the months of July and August. Finally, in order to examine diel patterns, for each month's data we calculated the mean number of different lizards observed during each hour of the day that surveys were made. There are

no known statistical tests available to test whether a given data distribution is bimodal. We assessed bimodality on the basis of visual inspection only (see Foà et al. 1992b).

We averaged monthly mean and extreme climate data obtained from the National Weather Service Station 305377 (Mineola, NY, 3 km from the study site) for 1948–2001. We obtained monthly mean and extreme climate data for the region in Italy where Foà et al. (1992b) and Tosini et al. (1992) worked from Cantù (1977) for 1901–1930.

Results

During 300 censuses, we identified 58 different adults and 85 different subadults. The number of different individuals present per survey was 0 to 6 (mean = 1.15). Sample sizes were inadequate to examine differences between genders. Lizards were present from April–October, with maximum numbers seen in May–August (Fig. 1). During months when lizards were observed, the number of hours present per day varied from two to ten (Fig. 2). We never saw lizards during our irregular surveys in January–March and November–December.

In spring and fall months (April–May, September–October), daily presence pattern was unimodal (Fig. 3). Daily presence patterns varied in the summer (June–August). For example, in summer 1999 diel patterns were irregular (Fig. 4), while in summer 2000 diel pattern was bimodal with one peak in the morning and one in the afternoon (Fig. 5). To investigate the

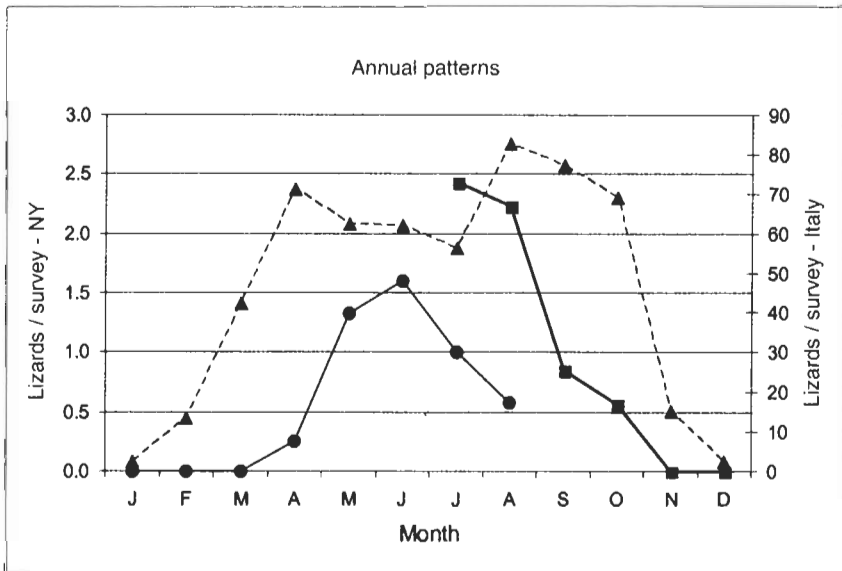


Figure 1. Mean number of *Podarcis sicula campestris* observed in surveys by month. Triangles represent data from Italy in 1988 (Foà et al. 1992b), circles and squares represent data from New York in 1999 and 2000, respectively (this study).

differences between these two summers more thoroughly, we also specifically compared the temperature profiles for the New York weather station for those months (Table 1). New York experiences mean summer temperatures 1–2 °C colder than Italy, and winter minimums 10–12 °C colder than Italy (Fig. 6).

Discussion

Foà et al. (1992b) did not report the lengths of their transects nor survey times, thus we cannot determine whether their finding of higher numbers of lizards observed each month was the result of longer transects and/or higher lizard densities. Foà et al. (1992b) also did not report actual lizard count data along with time of day, so we cannot directly compare diel data. Instead, they reported diel presence as either high activity, intermediate activity, low activity, and no activity (see Figs. 3 and 5).

Table 1. Temperature profiles for July and August 1999 and 2000 at Mineola, NY, weather station (°C). Tmean indicates the mean hourly temperature for the entire month, MeanTmax indicates the mean of the daily maximums for the entire month, and HighTmax indicates the highest temperature recorded for that month.

	Tmean	MeanTmax	HighTmax
July 1999	27.2	32.2	39.4
July 2000	21.7	26.2	33.3
Aug 1999	20.6	28.8	37.2
Aug 2000	25.0	26.3	32.2

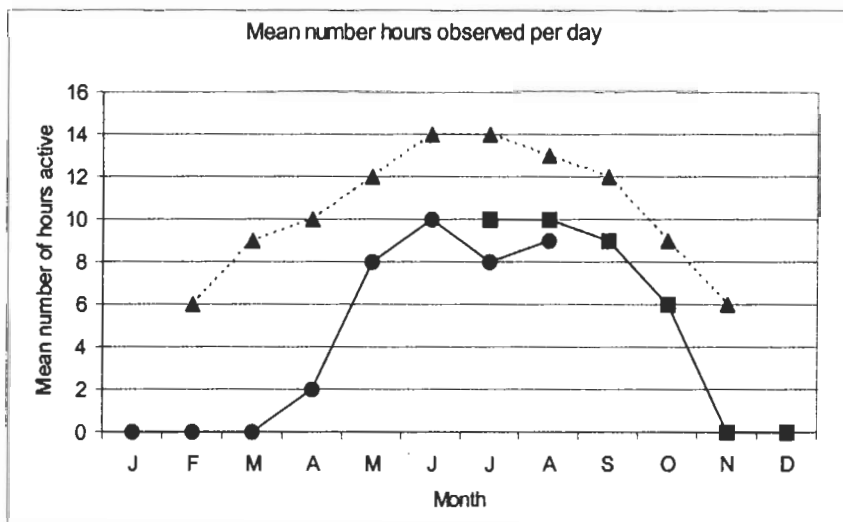


Figure 2. Mean number of hours *Podarcis sicula campestris* was observed in surveys per day in each month. Triangles represent data from Italy in 1988 (Foà et al. 1992b), circles and squares represent data from New York in 1999 and 2000, respectively (this study). Foà et al. did not report these data for January and December.

Based on empirical data and modeling results, Adolph and Porter (1993) predicted that differences in climate, particularly temperature, could cause dramatic differences in lizard behavior, even in the absence of important genetic differences between populations. We found strong evidence that a recently introduced (ca. 33 years old) population of *Podarcis sicula campestris* was active in New York only from April–October. This pattern of activity differs from that reported by Rugiero (1995), Tosini et al. (1992), and Foà et al. (1992b) for native *P. sicula campestris* populations near

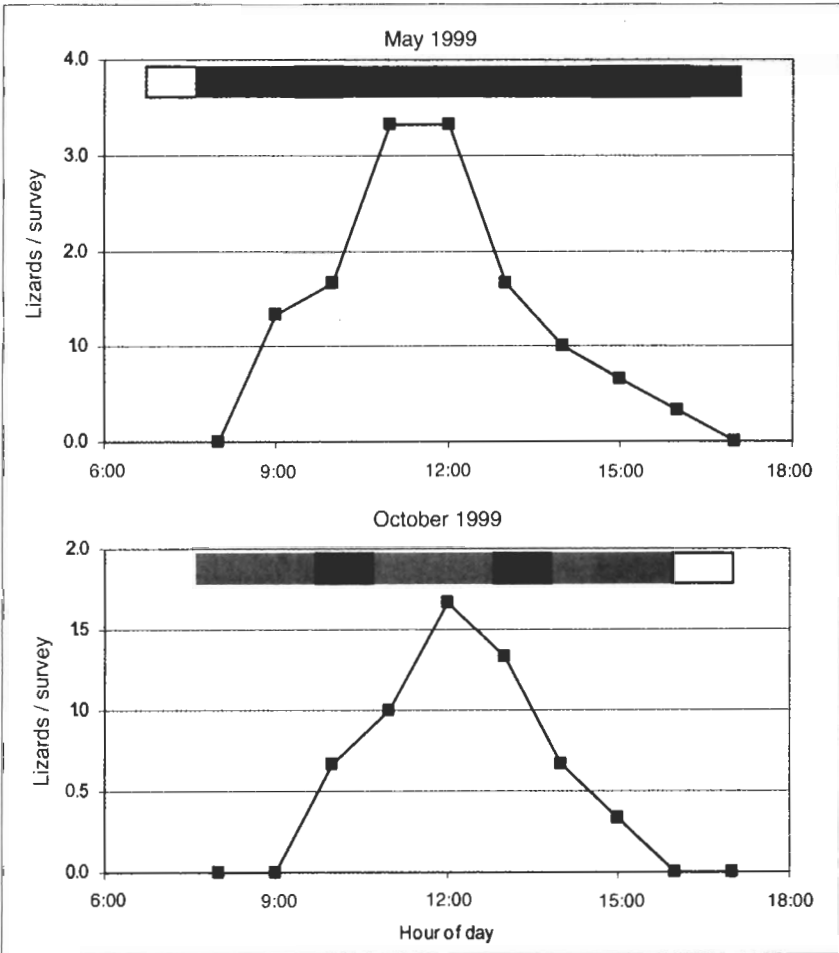


Figure 3. Representative New York *Podarcis sicula campestris* diel activity patterns in May (spring) and October (fall) (this study). Symbols indicate mean number of lizards observed in hourly transects conducted that month. The bars above each graph indicate qualitative levels of activity for the same months (in 1988) reported by Foà et al. (1992b) for Italy. Empty boxes represent periods of low activity, gray shaded boxes represent periods of intermediate activity, and black boxes represent periods of high activity, as defined by Foà et al. (1992b).

Rome, Italy, where the population was active year round, although considerably less active in winter (Rugiero 1995). We suggest that the colder mean temperatures in New York (Fig. 6) limit lizard behavior directly, because in New York there is less time in the year during which temperatures are high enough for normal activities. In addition, we suggest that extreme minimum temperatures reduce lizard movements indirectly. The colder New York temperatures mean that the risk of death from freezing is much greater for *P. sicula campestris* in New York than those in central Italy. While *P. sicula campestris* might overwinter in or near buildings, it is often found far from buildings (R.L. Burke, pers. observ.) and thus probably overwinters underground. This species is not freeze tolerant (Burke et al. 2002) and so it must overwinter below soil freezing depth, which is 25 cm in New York (Burke et al. 2002). In New York, it is unlikely that *P. sicula campestris* is able to take advantage of occasional warm periods during winter months, as it does in

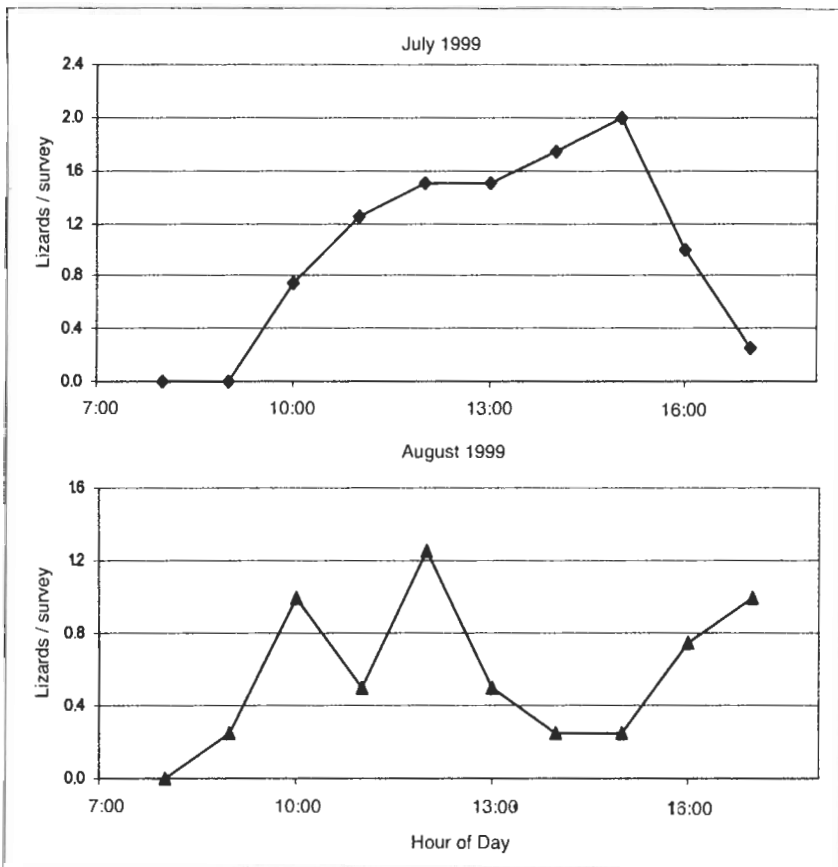


Figure 4. *Podarcis sicula campestris* New York diel activity patterns in July and August (summer) 1999 that do not show clear bimodal activity patterns. Symbols indicate mean number of lizards observed in hourly transects conducted that month.

Italy, because in New York it must hibernate much deeper. Hibernating deeper results in both a greater distance into and out of hibernacula, and greater insulation from warmer surface temperatures. The risk of freezing may account for the fact that New York *P. sicula* is inactive during all months during which extreme temperatures sometimes reach -14°C . Minimum temperatures around Rome never drop below 6°C (Fig. 6).

Not only was *Podarcis sicula campestris* active for fewer months of the year in New York than in Italy, in New York it was also active for fewer hours/day in every month when active. The difference between the number of active hours/day was three (August) to eight (April), and is likely attributable to the generally lower temperatures of New York throughout the year (Fig. 6).

Bimodal activity patterns have been reported in other lizard species (see Grant 1990, Porter et al. 1973). At one locality in Brazil, *Tropidurus torquatus*

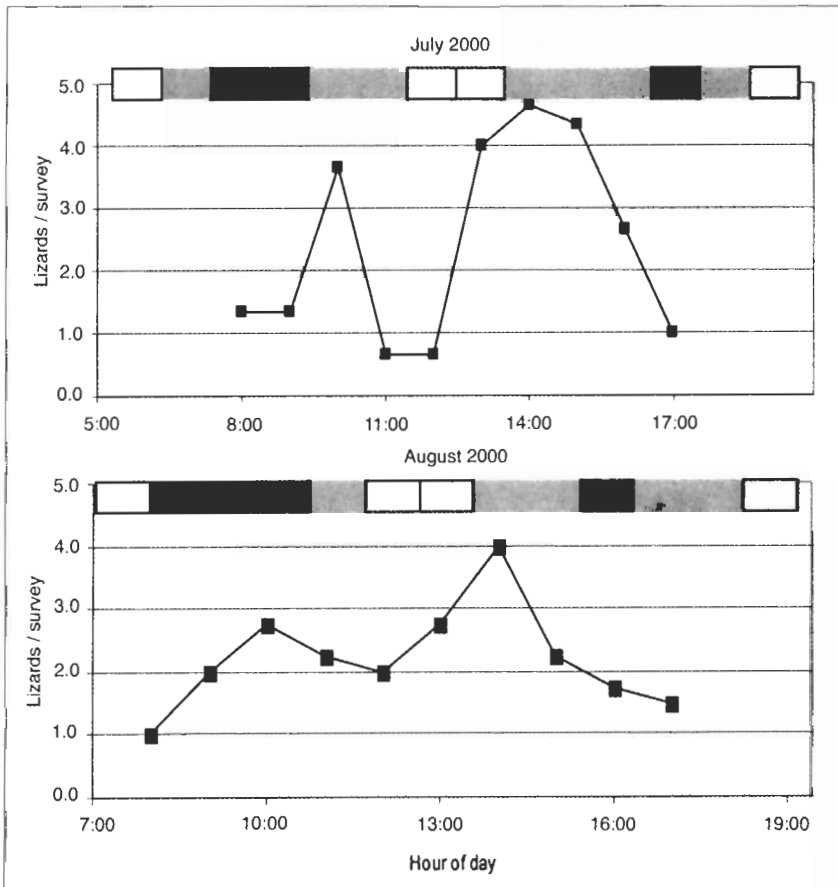


Figure 5. *Podarcis sicula campestris* diel New York activity patterns in July and August (summer) 2000 show bimodal activity patterns. Bar charts as described for Figure 3. Symbols indicate mean number of lizards observed in hourly transects conducted that month.

(Wied-Neuwied, 1820) had a bimodal pattern whereas others (*Cnemidophorus littoralis* (Rocha et al., 2000) and *Mabuya macrorhyncha* (Hoge, 1946)) were unimodal (Hatano et al. 2001), indicating that the same thermal environment does not affect all species the same way. Tosini et al. (1992) extended Avery's (1993) and Foà et al.'s (1992b) reporting of seasonal changes in Italian *Podarcis sicula campestris* by detailing lizard activities during active periods, showing that lizards shuttled between sun and shade, thermoregulating their body temperatures with precision when sufficient solar radiation was available. Tosini et al. (1992) found that in the summer, lizards tended to spend morning and late afternoon activity periods exposed to the sun, while avoiding the sun at midday (also see Avery 1978). Tosini et al. (1992) speculated that this avoidance of midday sun in the summer gives the appearance of inactivity. In the cooler weather of spring and fall, lizard body temperatures were constrained by a shortage of available warm microhabitats (Foà et al. 1992b; also see Grbac and Bauwens 2001).

Foà et al. (1994) and Innocenti et al. (1994) documented the switch in Italian *Podarcis sicula campestris* seasonal activity from unimodal to bimodal and back to unimodal, both in the field and in the laboratory. Foà et al. (1994) and Innocenti et al. (1994) further demonstrated that all of these changes can take place in the absence of exogenous cues (i.e., constant temperature and darkness). Therefore, seasonal shifts are not merely simple proximate responses to changes in temperature, solar radiation, or photoperiod, but instead have a considerable endogenous component. The endogenous responses are most likely mediated by the pineal gland (see

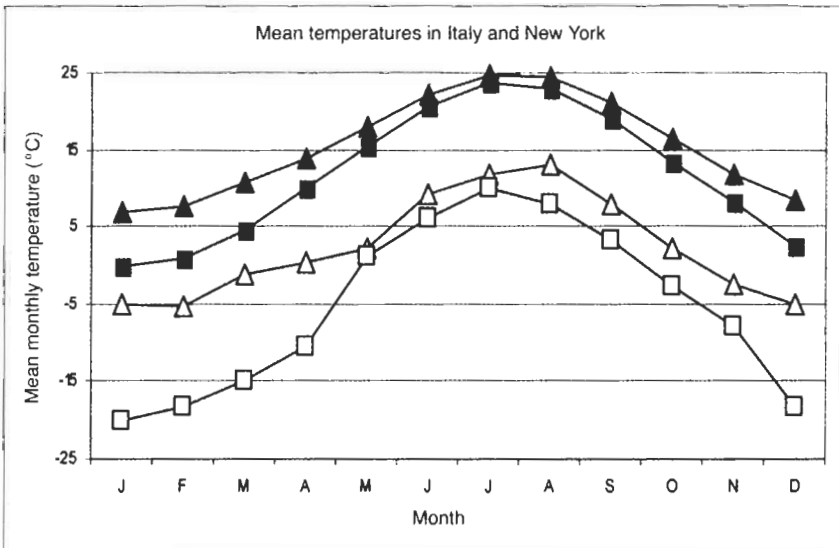


Figure 6. Mean monthly temperatures (°C): Rome, Italy from 1901–1930 (solid triangles); Mineola, NY, from 1948–2001 (solid squares). Extreme minimum monthly temperatures (°C): Rome, Italy from 1901–1930 (open triangles); Mineola, NY, from 1948–2001 (open squares).

Innocenti et al. 1994) and pineal secretion melatonin (Foà et al. 1992a). Our study population descended from a population near Rome and although it persisted under a photoperiod regime similar to that of Rome, it appears to have responded to the different temperature regime of New York. This adds to the understanding of the cues for behavioral activity patterns, demonstrating that New York lizards can switch their activity patterns seasonally as seen in the Italian populations. However, while Italian lizards have bimodal activity from April–October, New York populations are bimodal only in June–August (Fig. 4), at least in some years.

The summer 1999 diel pattern appears to show that the New York population did not always show the seasonal (summer) shift to bimodality, although by standard temperature measures, July and August 1999 were warmer than July and August 2000 (Table 1). We speculate that in some years, cloud cover may influence solar radiation to such an extent that even high air temperatures do not necessarily indicate high ground temperatures; the latter more directly influencing lizard thermoregulation (Avery 1978, also see Van Damme et al. 1990). Foà et al. (1992b) only reported data from a single year in Italy; thus we cannot speculate as to whether central Italian populations may also fail to show bimodal activity patterns in some years. Finally, Adolph and Porter (1993) predicted that when two populations of conspecific ectotherms are compared, the population in the colder climate will not only be less active, but also have higher survival and lower annual fecundity. It remains to be seen whether this is true of North American *Podarcis sicula campestris* in comparison to native Italian populations.

Acknowledgments

All procedures were in accordance with the principles of the Guidelines for the Use of Live Animals and Amphibians in Field Research (ASIH/HL/SSAR 2001). This work was authorized by the New York Department of Environmental Conservation permits LCP98-442, LCP-443, LCP99-434, LCP99-435, and LCP00-255. We are grateful to Barbara and August Ner, who graciously allowed use of the study site and provided both logistic and moral support; Katrina Broadwater for assistance with field work; G. Deichsel for essential translations; and B. Moon, M. Draud, P. Andreadis, and two anonymous reviewers for useful suggestions on previous versions of the manuscript.

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