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CHAPTER 24

LACERTID LIZARDS INTRODUCED INTO NORTH AMERICA: HISTORY AND FUTURE

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Abstract — Two species of lacertid lizards, Italian Wall Lizards (= "Ruin" Lizards), *Podarcis sicula*, and Common Wall Lizards, *P. muralis*, have been successfully introduced into at least 7 urban and suburban locations in North America, all close to the same general latitudes as their native ranges. The Pennsylvania *Podarcis* population is apparently extinct but the other *Podarcis* are expanding their new ranges. Extant *Podarcis* populations have been studied to a limited extent, and their date of origin, number of released individuals, and source population can be reliably estimated. A third species, Western Green Lacertas, *Lacerta bilineata*, has been introduced to Kansas, USA but is apparently not spreading.

Whereas other lizard species have been successfully introduced in the southern United States, these lacertid populations are the only successful introductions of lizards into temperate North America. It is not coincidental that they are restricted to urban and suburban areas. Few native North American lizards exploit urban habitats above 35o latitude, so lacertids encounter few native competitors. These lacertid species thrive in urban/suburban areas in southern Europe, and are common commensals with humans there because they are diet and habitat generalists that quickly habituate to new environmental conditions, including the presence of humans. They are also apparently well adapted to the specialized guild of potential predators that inhabit urban areas in both their native and new habitats.

Key Words — Introduced species, Introduction, Invasive, Ruin Lizard, Wall Lizard

Introduced and invasive species have caused massive ecological upheavals and millions of dollars of damage (US Congress Office of Technology Assessment 1993; Williamson 1996; Mack et al. 2000; Pimental et al. 2000). They have recently been declared the second greatest cause of species endangerment worldwide (Schmitz and Simberloff 1997; Wilcove et al. 1998; Mack et al. 2000). It is unlikely that any knowledgeable ecologist would currently advocate the release of a potentially invasive species, except perhaps for an extremely well-planned biological control effort. Only a few decades ago however, prominent herpetologists were advocating the release of exotic species, which might increase "harmonious resource-partitioning" and lead to a "very satisfying enrichment" (Smith and Kohler 1977). At least 75 introductions of exotic amphibians and reptiles into North America had already occurred by then (Smith and Kohler 1977), and it is unclear whether such advocacy led to more releases of exotic species.

Although numerous negative effects can be clearly attributed to introduced and invasive species, and there can be no justification for making additional introductions of exotic species except perhaps in extremely limited examples involving biological control, existing populations of exotic species can have scientific value. First, they can provide extremely useful data for evolutionary and ecological model testing, especially regarding theories that make predictions about how species will respond to novel environments (e.g., Adolph and Porter 1993; Crozier 2004). Particularly revealing is when the novel environment differs from the original or native environments in only a few factors, such as day length or minimum temperature. Secondly, introductions of exotic species can provide lessons with conservation value (Hierro et al. 2005). For example, concerns about the rare lacertid lizard *Podarcis raffonei* have led to the suggestion that reintroductions may be appropriate in the future (Capula et al. 2002), and information about successful

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introductions of similar species may be relevant. Finally, many introductions occur in urban or suburban areas (Smith and Kohler 1977; Enge et al. 2004; Smith et al. 2004) and remain restricted to those areas. Although native lizards do occur in some urban settings elsewhere (e.g., Koenig et al. 2001; Sullivan et al. 2004), urban and suburban areas of temperate North America north of 35° latitude have few species of native reptiles. Under these circumstances, introduced species may offer excellent opportunities for study by amateur herpetologists, because such species are often common, conspicuous, and subject to few legal restrictions. Thus introduced reptiles in urban and suburban areas can provide the herpetological equivalent of watching birds at feeders, introducing students and other non-professionals to the basics of scientific research. Examples of such work include Alvey (1993), Gossweiler (1974, 1975), Gubanyi (1996, 1999), Walker and Deichsel (2005), and B.J. Tucker and J.T. Collins (unpubl. data).

Wall Lizards (*Podarcis* spp.) provide examples of these three points. Podarcis comprises a genus of approximately 20 species of lacertid lizards from southern Europe and extreme North Africa (Oliverio et al. 2000). *Podarcis sicula* and *P. muralis* share the characteristics of having been introduced to many locations (Henle and Klaver 1986; Capula 1994; Arnold and Ovenden 2002; Corti and Lo Cascio 2002; Gleed-Owen 2004; Podnar et al. 2005) and being commonly found around human habitations, such as rock walls, parks, gardens, cemeteries and railyards (Hellmich 1962; Hvass 1972; Arnold and Ovenden 2002; Corti and Lo Cascio 2002; G. Deichsel pers. obs.). In addition to European introductions, *P. sicula* and *P. muralis* have been successfully introduced to at least seven locations in North America. Populations of *P. sicula* have been reported from Garden City, New York, USA (40.4° N, 73.4° W, Gossweiler 1975), Topeka, Kansas, USA (39.0° N, 95.4° W, Collins 1982; Gubanyi 1999; 2000), and Philadelphia, Pennsylvania, USA (40.0° N, 75.0° W, Kauffeld 1931; Conant 1959). Populations of *Podarcis muralis* have been reported from Cincinnati, Ohio, USA (39.8° N, 84.3° W, Vigle 1977), Ft. Thomas, Kentucky, USA (39.1° N, 84.3° W, Draud and Ferner 1994), Clarksville, Indiana, USA (38.3° N, 85.8° W, Walker and Deichsel 2005) and Victoria, British Columbia, Canada (48.3° N, 123.2° W, Allan et al. 1993). All of the known North American populations are within a fairly narrow latitudinal range except for the British Columbia population. Other lacertid introductions into North America have certainly occurred (e.g., Conant 1945; Deichsel 2004), but these have apparently not resulted in reproducing populations.

These widely dispersed North American introductions have numerous similarities. The New York, Kansas, Ohio, and British Columbia releases occurred 1950–1970 (Gossweiler 1975; Deichsel and Gist 2001; Deichsel and Schweiger 2004). The Pennsylvania introduction occurred in 1927 (Kauffeld 1931), and the Indiana and Kentucky populations probably resulted from more recent introductions and dispersals of individuals from the Ohio population. All except the Ohio population originated from the release of pet trade specimens, probably recently captured in their native habitats. Only the Ohio and British Columbia releases appear to have been deliberate. In those introductions where the number of released individuals is known (New York, Ohio, British Columbia, Pennsylvania), only a small number of lizards was released, and it appears that only a single release occurred in all cases except Kansas and British Columbia. All of the releases were into urban or suburban areas, and thus involve habitats similar to those that *Podarcis sicula* and *P. muralis* inhabit in their native ranges. However, G. Deichsel (pers. obs.) has observed that North American *Podarcis* inhabit "woody" microhabitats (wood walls, railroad ties as stabilization elements, piles of cut wood etc.), whereas European populations tend to inhabit "stony" habitats, such as unmortared stone walls or rocks in gardens, that mimic their primary natural habitats (Hellmich 1962; Hvass 1972; Arnold and Ovenden 2002; Corti and Lo Cascio 2002; G. Deichsel pers. obs.). This may be because wood is more commonly used as building material in North America than in Europe. Competition and predation involving native lizards at most of the release sites is likely to be minor (see below). Although a small number of studies have been carried out on nearly all North American populations, no comparative studies have been performed.

Podarcis sicula in New York

Podarcis sicula campestris was introduced to a suburban/light industrial area of Garden City, New York, in 1966 when an unidentified but probably small number of individuals escaped from an urban pet shop (Gossweiler 1974; 1975). Six yr later, juvenile lizards were abundant, and the population was growing and expanding geographically. Gossweiler (1974) reported that lizards had spread out in a semicircular pattern to about 0.4 km from the original release site. The population had spread over 1 km around the release site within ten yr (Garber 1985). Alvey (1993) documented lizard subpopulations 2.6 km from the release site. Currently, their range in New York is highly discontinuous but includes populations in the Bronx, over 23 km to the west and separated from the original release site by many significant barriers (Oliverio et al. 2001; R. Burke, pers. obs.), and Hampton Bays, 105 km to the east (R. Burke, pers. obs.). Alvey (1993) reported that the population continued to spread, primarily along powerline and railroad rights-of-way and through the assistance of individuals who collected lizards and released them elsewhere.

Research on this population has included genetic origin (Oliverio et al. 2001; but see Podnar et al. 2005), food habits (Burke and Mercurio 2002), freeze tolerance (Burke et al. 2002), and patterns of diel and annual activity (Burke and Ner 2005). R. Burke (unpubl. data) has also documented basic demography, including reproductive rates and survivorship. Most of this work was explicitly comparative, finding that *P. sicula* in New York have similarly diverse diets, much lower levels of activity, but higher reproductive levels, compared to their counterparts in Italy.

Podarcis sicula and *Lacerta bilineata* in Kansas

Podarcis sicula campestris and Western Green Lacertas (*Lacerta bilineata*) were introduced to a suburban/light industrial area of Topeka, Kansas, in the late 1950s to early 1960s, probably as multiple escapes from a pet wholesaler who went out of business in about 1964 (Collins 1982; Gubanyi 1999; B.J. Tucker and J.T. Collins unpubl. data). J. Gubanyi (pers. comm.) estimated that probably fewer than 100 *P. sicula* escaped originally, but that the feral population grew very rapidly. *Podarcis sicula* currently is spread out over a roughly rectangular range approximately 1.6 km long and 0.8 km wide (R. Burke pers. obs.); the population is still spreading (L. Miller pers. comm.). Additional, self-sustaining *P. sicula* populations now exist in Hays, Oxford, and Lawrence, Kansas, all presumably due to secondary releases of Topeka lizards (J. Collins pers. comm.).

Lacerta bilineata also persists in the same area, although its spread is much more restricted, and populations are much smaller than *P. sicula* (Gubanyi 1996; 1999; Gubanyi and Gubanyi 1997; R. Burke pers. obs). Although originally described as *L. viridis*, it was subsequently confirmed as *L. bilineata* (Deichsel and Miller 2000; Kalyabina-Hauf and Deichsel 2002).

Very little additional work has been carried out on either of these populations. B.J. Tucker and J.T. Collins (unpubl. data) conducted a brief study of annual activity patterns in *P. sicula* and Oliverio et al. (2001, but see Podnar et al. 2005) investigated their genetic origin.

Podarcis sicula in Pennsylvania

Podarcis sicula campestris was first identified in Philadelphia, Pennsylvania as *Lacerta melisellensis* (Kauffeld 1931). Kauffeld reported that a "number" of *Lacerta* had escaped from an animal wholesaler in 1927 and by 1931 they were "very numerous." They persisted at a nearby railroad property and lumber yard, but their numbers had apparently decreased by 1958 (Conant 1959). Conant (1959) identified them as *Lacerta* (*Podarcis*) *sicula campestris*. R. Conant (pers. comm. 1975, cited in Smith and Kohler 1977) reported that the Pennsylvania *P. sicula* population was extinct. Recent searches of the area have also failed to locate any lizards (R. Burke, N. Gilmore, and P. Warney pers. obs.), although amateur herpetologists continue to report sightings of *Podarcis* in the surrounding area (R. Burke, unpubl. field notes). No additional work has been carried out on this population.

Podarcis muralis in Ohio, Kentucky, and Indiana

Podarcis muralis muralis was deliberately introduced to suburban Cincinnati, Ohio, in 1951 or 1952 by a private individual who transported ten lizards from Italy (Deichsel and Gist 2001). The same individual released ten more lizards, apparently *P. pityusensis*, in about 1958, but these do not seem to have survived nor hybridized with the *P. muralis* (Deichsel and Gist 2001). Deichsel and Gist (2001) and Schweiger and Deichsel (2003) considered this explanation of the origin of Ohio *P. muralis* more plausible than that reported by Vigle (1977) and Hedeen (1984), both of which involved only two lizards.

By 1977, *Podarcis muralis* inhabited approximately 3 km^2 in Cincinnati (Vigle 1977); by 1984, they had spread over at least 6 km^2 (Hedeen 1984). The population is known to have spread by several means, including railroad rights-of-way (Hedeen and Hedeen 1999) and secondary escapes from captive populations (Hedeen 1988). It is uncertain how the species became established across the Ohio River from Cincinnati into suburban Kentucky, where large populations now exist (Draud and Ferner 1994), but deliberate releases from the Cincinnati population seem likely (Ferner and Ferner 2002). More details on the spread and habitats of this population are reported by Brown et al. (1995a) and Ferner (2004). The recent discovery of *P. muralis*, genetically identical to the Cincinnati form, at a flotsam deposit on the banks of the Ohio River in a state park in Clarksville, Indiana, could be the result of another deliberate release or lizards rafting on the Ohio River (Walker and Deichsel 2005).

Considerable research has been carried out on Ohio *Podarcis muralis*. For some of this work, the fact that the study organisms were not native was largely irrelevant (e.g., Claussen et al. 1990; Brown et al. 1995a; Gribbins and Gist 2003). Others explicitly compared their findings with similar work on Italian *P. muralis*. Brown et al. (1995b) found that Ohio *P. muralis* had much smaller home ranges than their European conspecifics, but Kwiat and Gist (1987) found that Ohio *P. muralis* had reproductive cycles remarkably similar to conspecifics in France.

Podarcis muralis in British Columbia

Twelve *Podarcis muralis maculiventris* were deliberately introduced to suburban West Saanich, Vancouver Island, British Columbia, in 1970 by the owner of a private zoo (Allan et al. 1993; Bertram 2004; Deichsel and Schweiger 2004). Three additional releases of 6 lizards each occurred later — in 1983 to 2 locations in Summerville, and in 1986 to nearby Triangle Mountain. The West Saanich population is currently expanding (Allan et al. 2000; Bertram 2004), and although the Summerville populations are extinct, the Triangle mountain population persists (Deichsel and Schweiger 2004). Spread of these remaining populations is occurring along powerline rights-of-way, roads, and via deliberate releases of captured lizards (Bertram 2004). Bertram (2004) reported some preliminary reproductive data in *P. muralis* in British Columbia. Allan et al. (2000) described an effective trapping method for these lizards. Allan et al. (2006) reported a variety of behavioral and life history data from the West Saanich population, including annual activity patterns, sexual dimorphism, tail loss rates, clutch size, growth rates, and tail autotomy rates.

Impact on their New Ecosystems

Given that some introduced species are known have detrimental effects on local ecosystems, it is reasonable to investigate the effects introduced *Podarcis* have in their new environments. Here we report on potential effects through competition, predation, and as prey.

There are numerous studies of *Podarcis* food habits in their native habitats (e.g., Strijbosch et al. 1980; Mou and Barbault 1986; Corti 1993; Pérez-Mellado and Rugiero 1994; Tosini et al. 1994; Bombi and Bologna 2002), but only one of the populations in North America has been studied (Burke and Mercurio 2002). Because New York *P. sicula* inhabit highly altered habitats, it is not surprising that over 50% of the prey species identified were non-native (Burke and Mercurio 2002, unpubl. data). Further investigations are needed on the potential impacts that introduced lacertids may have on native prey species.

In its native habitat, *Podarcis muralis* is reported to compete with other *Podarcis* (Steward 1965; Gruschwitz and Boehme 1986; Arnold and Ovenden 2002) and other larger lizards (Deichsel and Gist 2001). There is indirect evidence that introduced *P. muralis* may compete with Viviparous Lizards (*Zootoca vivipara*) and Sand Lizards (*Lacerta agilis*) in southern England (Gleed-Owen 2004). There are no potential lizard competitors where *P. sicula* currently occur in New York, but they will encounter competition as they expand westward. L. Miller (pers. comm.) suggested that young Great Plains Skinks (*Eumeces obsoletus*) may compete with Kansas *P. sicula*, with whom they are sympatric in some places. In some places in Ohio, *P. muralis* are sympatric with native Common Five-lined Skinks (*Eumeces fasciatus*), but there is no evidence of competition (J. Ferner pers. comm.). Allan et al. (1993) and Bertram (2004) concluded there was a weak possibility of competition between *P. muralis* in British Columbia and native Northern Alligator Lizards (*Elgaria coerulea*).

In their native habitats, *Podarcis* are prey for several species of snakes and occasionally for Common Buzzards (*Buteo buteo*), various corvids (*Corvus* sp., *Pica pica*), feral Cats (*Felis catus*), and Pine Martens (*Martes martes*) (Arnold & Ovenden 2002; Diego-Rasilla 2003; Amo et al. 2004). Gossweiler (1975) observed that New York *P. sicula* had no predators, but R. Burke and S. Ner (pers. obs.) and Alvey (1993) found that feral Cats prey on them in some locations. Also in New York, S. Ner (pers. comm.) observed a spider (species unknown) eating a hatchling *P. sicula*, and R. Alvey (pers. comm.) observed a Praying Mantis (probably *Tenodera aridifolia*) eating a hatchling *P. sicula*, and both have observed that many lizards are killed by lawnmowers. L. Miller (pers. comm.) has observed Great Plains Skinks (*Eumeces obsoletus*) chasing and eating Kansas *P. sicula*, especially juveniles, and has received reliable reports that Blue Jays (*Cyanocitta cristata*) and domestic Cats also predate *P. sicula* there. Conant (1975, cited in Smith and Kohler 1977) concluded that the Philadelphia *P. sicula* population went extinct through a combination of habitat destruction, predation by feral Cats, collection for pets, and pesticide exposure. Brown et al. (1995a, b) reported that Ohio *P. muralis* were heavily predated by feral Cats and observed many predation events.

Future Work

While there are many types of research for which these introduced lacertid populations might be useful, we present three examples. Kolbe et al. (2004) showed that due to multiple introductions over time, populations of Brown Anoles (*Anolis sagrei*) introduced into the southern United States had a high degree of genetic variability. They further suggested that this genetic variability might be responsible for rapid expansion of *Anolis* after introduction. *Podarcis introductions* in North America and elsewhere would provide excellent opportunities to test the general validity of this conclusion. There is a long history of genetic work on lacertid lizards, especially the genetics of island and introduced populations (e.g., Gorman et al. 1975; Capula 1994; Oliverio et al. 2000; Oliverio et al. 2001; Podnar et al. 2005), and genetic markers sufficiently sophisticated to test Kolbe et al.'s (2004) hypothesis have been reported recently for lacertids (Podnar et al. 2005).

Another interesting potential use for introduced lacertid populations is tests of the "enemy release hypothesis"— the hypothesis that invasive species often succeed in new environments because the typically small, introduced populations often contain only a small subset of the parasites that occur in their native habitats. If parasite loads in native habitats reduce host fitness, then lower parasite loads in the new environments may result in higher survivorship and reproduction (Mack et al. 2000). Recent work and reviews of this topic (Mitchell and Power 2003; Torchin et al. 2003) have found strong general support for this hypothesis. This hypothesis is poorly studied in lizards, although lacertids would be ideal subjects for such tests because of their multiple introductions into diverse locations both in North America and Europe. Lacertids in their native environments are known to host numerous parasites (e.g., Roca and Garcia-Adell 1988; Volf et al. 1999; Casanova et al. 2003; Oppliger et al. 2004); the introduced populations have not been similarly studied.

Finally, Adolph and Porter (1993) suggested that most of the variation in life history and behavior observed within and between lizard populations is a consequence of thermal environment. There are numerous studies documenting thermoregulation, daily and annual activity patterns, and demography of *Podarcis* in their native habitats (e.g., Avery 1978; Tosini et al. 1992; Avery 1993; Rugiero 1995; Uller and Olsson 2003), as well as an excellent series of studies investigating the endogenous hormonal mechanisms controlling these patterns (see review in Burke and Ner 2005). Because the United States *Podarcis* populations happen to occur at similar latitudes but different climates than those of their source populations, they can provide excellent opportunities for investigation of the relative importance of endogenous and exogenous cues for diel and

seasonal behaviors and demography (Adolph and Porter 1993). Burke and Ner (2005) and B. Tucker and J. Collins (unpubl. data) have reported useful preliminary data for such behavioral comparisons, and both Bertram (2004) and Kwiat and Gist (1987) reported demographic data for introduced lacertid populations that provide interesting comparisons with native populations. Studies of this type provide excellent opportunities for easy, inexpensive studies appropriate for amateur and professional urban herpetologists, who can make significant contributions to our knowledge of the evolution of life histories.

The Future of these Introductions

The Indiana *Podarcis muralis* and Kansas *Lacerta bilineata* populations are so small that they probably are vulnerable to extinction. They are particularly attractive as research topics because they may indicate the biotic and abiotic factors that influence changes in the size of small populations, a topic of significant concern in conservation biology. We encourage monitoring of these populations.

Given the population size and geographic area occupied by the New York, Ohio, Kentucky, and British Columbia *Podarcis* populations, it is unlikely they will be extirpated by climatic or biological factors. These populations are still spreading, both on their own through diffusion and by jump dispersal, facilitated by collectors who want to establish new populations. It would be extremely difficult to restrict either type of spread. One of us (RLB) regularly receives emails and phone calls from amateur herpetologists from many different states, asking for *P. sicula* that they can release them locally, although it is illegal in most cases. These requests are denied, but individuals can find many other sources. The spread of urban and suburban habitats (Kim 2000) in United States will facilitate dispersal of *Podarcis* populations and we assume that their ranges will eventually be limited by abiotic factors.

Allan et al. (2006) suggested that *P. muralis* in British Columbia would be restricted to urban/suburban habitats because the surrounding forests were unsuitable for dispersal. In contrast, one of us (RLB) recently encountered a large *P. sicula* population on the southern shore of Long Island in native beach grass (*Ammophila breviligulata*) habitat. This habitat and similar habitats are common along the entire eastern coast of the United States, and could present an opportunity for *P. sicula* to expand significantly outside urban/suburban habitats. Inevitably, as these populations spread beyond urban and suburban habitats, introduced lizards will interact more and more with native species. Given that these populations are here to stay, it makes sense to use them for research as outlined above.

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