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Cover Photograph: Still image from video of adult common wall lizard (*Podarcis muralis*) eating conspecific, Prospect Lake, Vancouver Island, British Columbia, 2018. Photo by Deb Thiessen.

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Dietary Observations of Introduced Common Wall Lizards (*Podarcis muralis*) in a Suburban Environment, Victoria, British Columbia, Canada

Julien Gullo[1*], Gavin Hanke[2], Leigh Anne Isaac[3], Rob Higgins[4], and Karl Larsen[1]

Abstract - Introduced Common Wall Lizards (*Podarcis muralis*) have steadily increased their range on Vancouver Island and other parts of coastal British Columbia, Canada since the 1970s. Without substantial observations of their feeding habits in this introduced range, a full assessment of the ecological impact of this species introduction is not possible. In this study, we provide qualitative observations on the diets of a large sample of urban dwelling Common Wall Lizards collected from a residential neighborhood in Victoria, British Columbia. Specimens were euthanized, dissected, and had their entire digestive tracts examined. Our observations showed a rich diet of invertebrates typical of wall lizards, with ants (Family Formicidae) as the most detected prey followed by beetles (Order Coleoptera), and earwigs (Order Dermaptera). Adults consumed approximately 30% more prey taxa than juveniles. We also found the remains of other wall lizards within ~5 % of adult guts, suggesting cannibalism or carcass scavenging. The results of this study provide additional information for assessing the potential impacts of wall lizard trophic interactions in their British Columbian range and can help orient future investigations focused on this introduced species.

Introduction

Originally native to continental Europe, Common Wall Lizards Laurenti 1768 (*Podarcis muralis*; hereafter "wall lizards"), are a temperate-adapted, omnivorous lizard species that have established introduced populations in multiple regions throughout Europe, England, the United States, and Canada (Arnold and Burton, 1978, Burke and Deichsel 2008, Engelstoft et al. 2020, Heym et al. 2013, Michaelides et al. 2015). As a member of the genus *Podarcis,* this species is known for its diverse and flexible feeding habits which focus heavily on invertebrate prey such as beetles, ants, and other insects, but can also include vegetation and some carnivory (Capula and Aloise 2011, Mamou et al. 2019, Pérez-Mellado and Corti 1993, Simović and Marković 2013). Despite a history of known introductions throughout Europe and the United States dating back to 1874 (Burke and Deichsel 2008, Kraus 2009) the ecological impacts of *Podarcis spp.* are still poorly understood.

Since their release into the Saanich peninsula on British Columbia's (BC) Vancouver Island circa 1967 (Engelstoft et al. 2020), wall lizards have established populations that continue to expand throughout the region. Wall lizard populations have been documented on Saltspring, Hornby, and Thetis islands in 2021, 2022, and 2023 respectively, and four locations on the BC mainland (Chilliwack in 2020, Powell River and Delta in 2021, and Surrey in 2023). Although they have been listed as an exotic species in BC since 2005, study of their feeding habits in this range have been described only twice (Allan et al. 1993, Williams 2019).

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The implications of growing wall lizard populations in the region raise important questions regarding their status as a predator of and competitor with native species. Developing insight into the range of the top-down effects on prey species is an important step in answering these questions. In this study, we provide our observations of wall lizard diets from a large sample collected within a suburban portion of its Canadian range.

Methods

Juvenile and adult wall lizards were collected by GH from the Fairfield neighbourhood in the city of Victoria, BC, Canada (48.412° N, 123.347° E). This urban location lies within the moist maritime coastal Douglas-fir biogeoclimatic zone, more specifically in a highly modified portion of the Garry Oak ecosystem, and is characterized by its warm and dry summers and wet winters (Nuszdorfer et al. 1991). The collection sites were typically roadsides and urban parks with habitat features ranging from construction sites, leaf litter accumulations, rocky outcrops, and ornamental retaining walls made from cement, rock, and driftwood. Collections took place over six days between 18 August and 1 September 2022.

Specimens were humanely euthanized shortly after capture using guidelines published by the Canadian Council on Animal Care (Caulkett et al. 2023). Euthanized lizards then were stored frozen in water to prevent desiccation. No collection permit was required given that the Common Wall Lizard is an invasive species listed under Schedule C of the British Columbia Wildlife Act.

We measured the snout-vent-length (SVL, mm) of individual lizards in addition to sex. For sex determination, we used the presence of enlarged femoral pores and hemipenal sulci (pockets) to indicate male individuals as in Nevarez (2009) and O'Rourke and Lertpiriyapong (2015). As sexual differences in morphology can be difficult to distinguish in juvenile lizards (Eplanova and Roitberg 2015), we focused on identifying the sex of adults only. In some instances, sex could not be clearly identified. In these cases, data for individuals was included, but their sex was noted as "unidentified".

The sampled gut contents had been subject to substantial digestion by the time of our analysis. Most arthropod prey observed were in a highly fragmented state and were infrequently intact enough to identify individuals. Because of this, a quantitative assessment of diet (i.e., measuring prey abundance or mass) was not possible. In an effort to maximize prey identification in our sample, we chose to account for their presence (richness) in each gut sample and surveyed the entire digestive tract (from mouth to vent). Using a 4-20 power dissection microscope, we identified most prey items based on diagnostic morphological features (Marshall 2006, Ruppert et al. 2004). Prey were identified to the lowest taxonomic level possible. Given the state of degradation of our samples however, we suspect that our results may have underrepresented soft-bodied prey items (Pincheira-Donoso 2008).

We divided lizards into two size categories based on the bimodal distribution of SVL: hereafter we refer to these categories as 'juvenile' (i.e., hatchlings; 22.0–29.0 mm SVL), and 'adults' (i.e., adult and immature individuals; 44.0–72.0 mm SVL). Adults were further categorized by sex (male, female, and sex undetermined). We tested for similarity between male and female, juvenile and adult lengths using a Mann-Whitney U test.

Observations

A total of 106 wall lizards were collected and their guts sampled. SVL data for all specimens are included, save for one juvenile, which was incidentally not recorded. Of the 85 adult

lizards sampled, sex for 11 individuals was not determined (Table 1). Males were, on average, identical in length (n = 44, $\bar{x}$ = 63.1 mm, SD = 4.0 mm) to females (n = 30, $\bar{x}$ = 61.2 mm, SD = 5.4 mm; $U_{.05,\,44,\,30}$ = 550, P = 0.228). Juveniles were much smaller (n = 20, $\bar{x}$ = 26.0 mm, SD = 1.4 mm) and averaged less than half the size of the adult group ($U_{.05,\,85,\,20}$, $P < 0.01$).

In total, 97 of 106 lizards (~92 %) were observed with gut contents. Of lizards found with empty guts, 4 were juveniles (~19 % of juveniles) and 5 were adults (~6 % of adults). Gut contents of lizards included mostly invertebrate prey, with arthropods being the most common prey items. Arthropod prey was represented by at least nine different orders and eleven different families, and additional prey included the remains of wall lizards in 4 (~5 %) of adult individuals, suggesting cannibalism or carcass scavenging (Table 2). These remains consisted of body parts in various stages of digestion and included a small rear hindquarter and a tail (Fig. 1). Of the 4 separate wall lizard remains observed, one was identified as a juvenile lizard from the size of intact appendages (tail, hindquarter). Three other remains consisted of unidentifiable parts, but with clear features of wall lizard colouration and patterning. Of the adults found to have consumed lizards, two were males, one was female, and one was sex indeterminate. The average richness of ingested taxa in adult guts was ~30 % more than that of juveniles, and similar between males and females (Table 1).

The following detailed summaries of adult gut contents are inclusive of male, female, and sex-indeterminate individuals. Winged ants (Order Hymenoptera, Family Formicidae) were the most common prey item and made up the bulk of hymenopteran occurrences. Ants

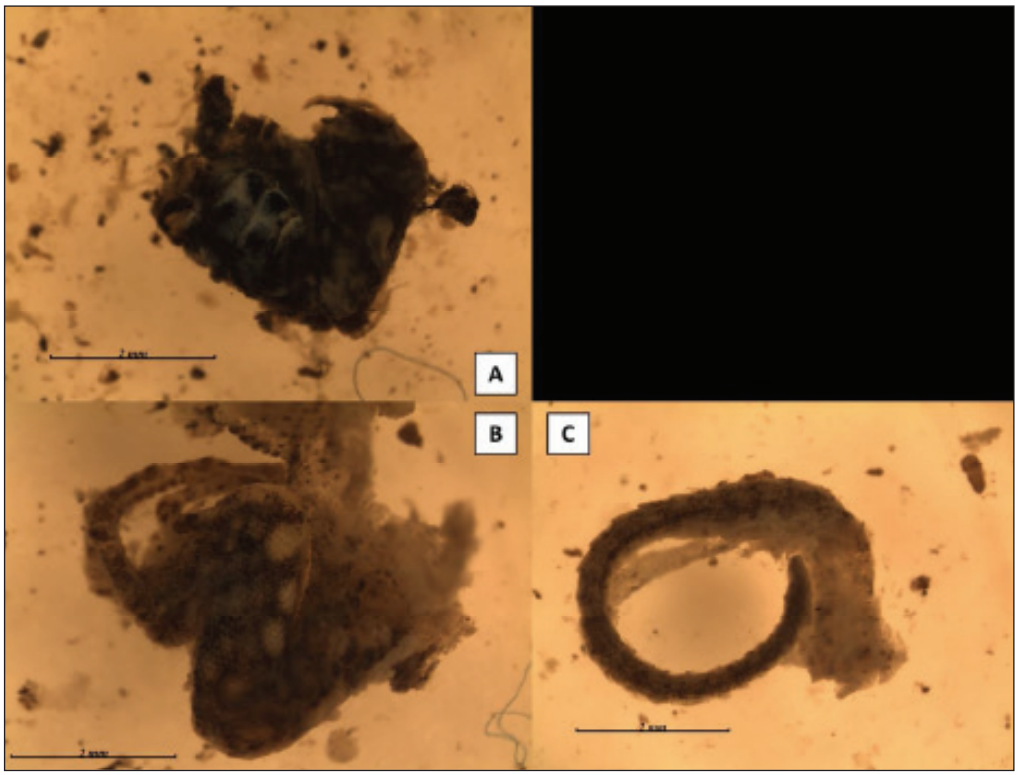

Figure 1. Remains of conspecifics ingested by two adult *Podarcis muralis* collected from suburban Victoria, British Columbia, Canada, 2022: (A), an undetermined body part, (B), a hindquarter, and (C), a portion of tail. 2 mm scale bars included for reference.

Table 1. Summary of biometric and diet statistics of a sample of introduced *Podarcis muralis* collected in Victoria, BC, 2022, including snout-vent length (SVL mm), mean number of ingested taxa (Order), maximum individual number of ingested taxa, and pooled (sample wide) number of ingested taxa.

Age class and sex	**Sample size (*n*)**	**Mean SVL (mm)**	**Max/min SVL (mm)**	**SVL SD**	**$\bar{X}$ No. ingested taxa**	**Max. No. ingested taxa**	**Pooled No. ingested taxa**
Juvenile	21	26.0	28.1/ 22.5	1.4	1.5	3	9
Adult	85	61.5	71.2/ 44.7	5.4	2.4	5	15
Male	44	63.1	71.2/56.1	4.0	2.4	5	12
Female	30	61.2	69.9/44.7	4.7	2.6	5	13
Sex undetermined	11	55.0	68.4/44.7	6.4	2	4	8

Table 2. Number of *Podarcis muralis* found to have consumed at least one individual of various representative animal and plant taxa (Total *n* =106: juveniles *n*= 21, adult males *n* = 44, adult females *n* = 30, adult sex- undetermined *n* = 11) collected in Victoria, BC, 2022.

	Age class and sex of wall lizards			
Prey type	**Juveniles**	**Adult males**	**Adult females**	**Adult- sex undetermined**
KINGDOM: ANIMALIA				
Order: Hymenoptera	**4**	**38**	**26**	**9**
Family Formicidae	4	34	23	8
Family Vespidae		3	3	1
Undetermined		1		
Order: Coleoptera	**1**	**14**	**12**	**2**
Family Curculionidae		6	5	1
Undetermined	1	8	7	1
Order: Dermaptera		**9**	**10**	**2**
Order: Lepidoptera		**3**		
Order: Diptera	**3**	**4**	**6**	**1**
Order: Hemiptera	**8**	**4**	**3**	
Order: Zygentoma	**2**		**1**	
Order: Undetermined	**7**	**19**	**10**	**4**
Order: Isopoda	**2**	**8**	**6**	**1**
Order: Araneae	**4**	**3**	**3**	**1**
Order: Opisthopora				**1**
Order: Gastropoda		**4**	**1**	
Order: Squamata		**2**	**1**	**1**
Podarcis muralis		2	1	1
KINGDOM: PLANTAE				
Order: Cupressales			**1**	
Cedar			1	
Order: Undetermined	**1**	**2**	**3**	

occurred in 65 (~76 %) of adult lizard guts but only in 4 (~19 %) of juveniles (Table 2). Coleopterans and dermapterans were also found in many adult lizard guts but were near absent in those of juveniles (only coleopterans found in ~5% of juveniles; Table 2). Spiders (Order Araneae) and true bugs (Order Hemiptera) were found in approximately 2 and 4 times more juveniles than adults, respectively (Table 2).

Terrestrial arthropods (insects that spend the majority of their time on the ground) were the most common category of wall lizard prey (found in 92 of 106 lizards). However, 21 (~20 %) lizards in the sample had consumed at least one flying insect (winged; excluding winged ants, beetles, and earwigs). Of these, dipterans occurred the most frequently (in ~13 % of adult guts and ~14 % of juvenile guts). Wasps (Order Hymenoptera, Family Vespidae) ranked second in frequency among flying insects, occurring in 7 (~8 %) of adult lizard guts. Lepidopterans were found infrequently in only 3 (~4 %) adult samples. Finally, trace amounts of vegetation occurred in ~5 % of the total sample, including a small, ~3 mm long piece of cedar foliage, a small < 5 mm long needle from an undetermined conifer, a small, ~4 mm long piece of moss-like organic material, and some small seed-like objects found in 5 adults and 1 juvenile.

Discussion of Observations

The suite of prey items we observed within the guts of wall lizards in this study confirm that a euryphagous feeding strategy is utilized by this generalist species at this location in Victoria, BC. Diverse prey consumption observed in this study appears to be congruent with typical wall lizard feeding ecology and bears similarities, in terms of diverse prey use (i.e, widespread use of 10 or more orders of prey), to the results obtained from other studies of wall lizards in this location and in other parts of its native range in Europe (Pérez-Mellado and Corti 1993, Williams 2019). Further, our observations suggest the possibility of an ontogenetic shift or a size-based constraint in the prey-use of adult and juvenile wall lizards, with some evidence of mature individuals including more taxa in their diets. In contrast, we noted that male and female wall lizards in this sample appeared to consume similar prey types, specifically with ants and beetles being dominant in occurrence. Finally, our observations suggest that cannibalism or scavenging of carcasses of conspecifics occurs in this population of wall lizards.

Wall lizards and their congeners are commonly observed to have regionally and seasonally variable diets (Mamou et al. 2019, Pérez-Mellado and Corti 1993, Taverne et al. 2019). Because phenological variation in invertebrate prey availability is common, our observations are likely to be biased by the short time-period and season in which our samples were collected. For example, the widespread consumption of winged ants by lizards in our sample may simply reflect the seasonal availability of this prey (i.e., ant dispersal and mating events occurring during the time of our sample collection).

While our results showed that wall lizards in all size and sex categories frequently ate ground-dwelling arthropods, predation on flying insects was not uncommon. Flying insects, especially Diptera, have been previously reported as a recurrent prey item in the diet of wall lizards (Capula et al. 1993, Pérez-Mellado and Corti 1993, Williams 2019). Considering that our sampling procedure and the condition of specimen guts would have biased our observations towards insects with hard parts (i.e., hard-bodied insects remained intact longer during protracted sample transportation and were more likely to be observed in lower gut tracts than softer-bodied insects), we suspect that softer bodied dipterans and lepidopterans were underrepresented in our results. Future research on the diet of these animals should include a reference prey collection and DNA metabarcoding techniques, such as those used in Pincho et al. (2023), to reduce this bias and facilitate successful prey identification.

Several field observations of cannibalism in the wall lizard have been made in both its native and invasive ranges. These accounts typically feature adult males consuming juveniles, however, one case of cannibalistic oophagy by an adult female has been reported (Lam 2022, Simović and Marković 2013, Zagar and Carretero 2012, Zagar et al. 2016). At least two accounts of saurophagy observed in wall lizards in Greece and the United Kingdom (Andriopoulos and Pafilis 2019, Thomas et al. 2020), and one field observation (G. Hanke, Royal BC Museum) near Prospect Lake, Vancouver Island, featured larger adults capturing and consuming smaller animals, suggesting that cannibalism is common in wall lizards. However, it is not possible to fully verify our observations of saurophagy as cannibalistic as wall lizards have also been observed consuming dead lizards (Andriopoulos and Pafilis 2019).

Our observations add to our understanding of the trophic ecology of introduced Common Wall Lizards in suburban areas of BC, Canada. However, given the quantitative limits on our observations, the narrow temporal focus of our sampling period, our lack of a prey reference sample, and the confinement of our sampling to a suburban population of lizards, more research is needed to make stronger conclusions about the diet of wall lizards in their novel ranges in BC and to gain a better understanding of the potential impacts they might have on native species. Despite these limitations, our observations successfully reveal patterns of euryphagy in the wall lizards in our study area and confirm some of their feeding habits.

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