Persistence of herpetofauna in the urbanized rouge river ecosystem

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ABSTRACT

Over 100 years, urbanization has taken place along the Rouge River watershed of southeast Michigan, USA. To determine the impact(s) of urbanization on herpetofauna, species richness and distribution in 122 wetlands along 13.0 km of the urbanized Rouge River watershed were monitored from early spring to late fall 2003. Data were mapped using Geographic Information Systems (GIS). Both amphibian and reptile species richness were associated with wetland size and hydroperiod. The invasive plants *Alliaria petiolata* and *Rhamnus cathartica* were coincident with lower than average amphibian species richness. In spite of the number of herpetofauna being relatively low, this study identified hydroperiod and wetland size as important features that may contribute to amphibian and reptile species sustainability in this highly disturbed and fragmented urban landscape.

Keywords: Amphibian; Hydroperiod; Invasive Plants; Reptiles; Wetland; Urban Herpetology

1. INTRODUCTION

Faced with increased urbanization and environmental disturbance to their native ecosystems, the future of resident amphibians and reptiles in SE Michigan (USA) is uncertain. Herpetofauna are also susceptible to a severe loss of genetic diversity because of life-history traits including genetics, breeding strategies, habitat fragmentation, and a low dispersal ability [1]. Habitat infringement from agriculture and urbanization contributes significantly to amphibian and reptile decline worldwide [2-6]. As human populations advance into undisturbed eco-systems, anthropogenic pollutants challenge resident herpetofauna [7-9]. Additional pressure on amphibians and reptiles arise from the human transportation infrastructure [10-12]. Some animals may adapt to a disrupted ecosystem by altering their behavior, habitat, or range [13,14].

Hydroperiod greatly influences amphibian population recruitment and composition [14,15]. The duration of water in a site plays a key role in amphibian reproduction and survival by influencing developmental rate, desiccation, and predation [16-19]. Wetland size and water duration are also important considerations in assuring diversity [20,21]. Some observations suggest a more complex relationship, where species diversity peaks at an intermediate hydroperiod, then drops in permanent wetlands [22]. Similarly, intermediate human exposure correlated with the highest species diversity [23].

This study was conducted in the Rouge River watershed in southeast Michigan, USA. During the 1980s, the Rouge River was classified as one of the most polluted rivers in the USA [24]. Historic and current challenges to this wetland community arise from human population growth: increased impermeable surfaces (e.g., roads, parking lots); the widespread use of combined sewer overflows in the urban design, municipal, industrial, and non-point discharges, contaminated sediments, habitat loss, and degradation [25-29]. According to the Southeast Michigan Council of Governments (SEMCOG), nearly 100% of the land is developed, and contains impervious surface cover of at least 32% [26,27,30]. The latter is of concern as 26% impervious surface cover (or higher) is considered "degraded" [31,32]. As low as 6% imperviousness can negatively impact aquatic macro invertebrate species abundance and diversity [33,34]. One major effect of impervious surfaces is enhanced flooding, even from minor rain events in the Rouge Rive watershed (<2.5 cm of rain) [28]. Flooding promotes erosion, alters stream bed and flow, increases pollutant load in receiving waters, de-

creases ground-water recharge and water-table declines, and generally impairs the resultant aquatic habitat [35].

Amongst the many possible stressors [1], increased urbanization could alter Rouge River wetland hydroperiods and coincidentally associated herpetofauna. To examine urbanization and anuran and reptile population size and species richness, characterization of 122 Rouge River wetlands was conducted. Wetland size, water quality, plant species richness, and the presence of invasive plant species were also examined.

2. MATERIALS AND METHODS

2.1. Wetland Classification

Wetlands were identified and delineated using the Michigan Department of Environmental Quality [36]. Wetlands were considered "land characterized by the presence of water at a frequency and duration sufficient to support, and that under normal circumstances does support, wetland vegetation or aquatic life" [36]. Wetlands within the Rouge River survey were classified as marsh, shrub-scrub, and forested, or complex (a mixture). A marsh was considered a frequently or continually inundated wetland, characterized by emergent herbaceous vegetation adapted to saturated soil conditions [37]. The shrub-scrub was dominated by dense, woody, low stature vegetation. Trees or shrubs dominated the forested wetlands, which lacked abundant herbaceous vegetation and dried up seasonally [37]. Wetlands that were a combination of two or more wetland types (within 20 m) were considered as complex.

2.2. Wetland Hydroperiod Assessment

Hydrology was recorded monthly at each site throughout the study period. Water depth was recorded up to 1 meter in marsh wetlands. For saturated wetlands, a soil probe was used to measure the level of the subsurface water within the top 30 cm of the soil profile. A lower maximum water level was generally associated with shorter periods of inundation. Watermarks, water-stained leaves, drift lines, and buttressing roots were also used to confirm wetlands from non-wetland locations.

2.3. Water Quality

Field measurements of conductivity, total dissolved solids, pH, and temperature employed a Hanna 1700 meter (Hanna Instruments, Woonsocket, RI, USA). Relative turbidity was estimated using a rating 0 - 3 (none to high, respectively). For nitrate and phosphate determination, sterile bottles were used for water collections. A Hatch Kit NI-14 (Hatch Company, Loveland, CO, USA) and EPA Method 365.3 were used to measure (in triplicate) nitrate and phosphate.

2.4. General Soil and Water Quality Assessment

The Wayne County Soil Survey map was used (Rouge Program Office Data CD Volume 9, Wayne County Rouge River National Wet Weather Demonstration Project, Detroit, MI, USA) and the soil types were classified as hydric soils (see [38]. Histosols form when drainage is limited, interrupting the decomposition of biomass [37]. Using the wetland delineation protocol from the US Army Corps of Engineers [39], histosols were determined visually. Reducing conditions were recorded as the presence/absence of reduced iron (rust) in the soil strata. Sulfidic odors were also recorded.

2.5. Herpetofauna Surveys

Historically, 14 amphibian species and 15 reptile species frequented the Rouge River study region [40]. Random surveys were conducted from March through October 2003, recording the number and species diversity of herpetofauna. Calling surveys, visual observations, and trapping were employed. All sites were surveyed bi-monthly with a minimum of 16 visits per site throughout the active season. Locations of all positively identified animals were recorded using Global Positioning Systems, (GPS), and a GIS database for analysis.

Amphibians that vocalize (anurans) to attract mates were surveyed using a point-count system [41,42]. Surveys were done bi-weekly at a fixed location and began one-half hour after sunset and ended before midnight throughout the active season. One of three call level codes was used to categorize the intensity of calling activity for each species. Call level 1 was assigned if calls did not overlap and calling individuals could be discretely counted. Call level 2 was assigned if calls of individuals sometimes overlapped, but the numbers of individuals could still be discriminated. Call level 3 was assigned if the calling of many individuals overlapped or the calling seemed nearly continuous. No calling was rated as 0. Visual observations (binoculars, log flipping) revealed animals in wetlands and forested areas that did not call. Only positively identified animals were incorporated into the database. Aquatic survey sites were divided into 2-meter blocks, each randomly surveyed bi-weekly. Aquatic funnel traps were used when appropriate. Un-baited funnel traps (3 - 4 L volume) were placed in the water with some headspace at the top of the trap. Traps were inspected after 24 h, and all trapped animals recoded, and released. Netting was used on several 10 - 12 m portions of the wetland (separate from the trapping sections). Generally, dip netting was concentrated in areas near submerged vegetation. Nets were swept in three replications of two meters through the wetland. Amphibians and reptiles were recorded using 1 - 3 m GPS.

2.6. Statistical Methods

Diversity measurements were based on the presence of species in each wetland. Using 14 species of amphibian and 15 species of reptile that frequent the region [40], if 7 amphibian species were observed in a site, the amphibian diversity value was considered 7 of 14 amphibian species, or 0.5 value. Diversity was estimated using the Shannon Diversity Index [43].

Water column maximum water levels throughout the season were used for hydrological analysis. Linear regression modeling was used throughout [44]. The dependent variable was generally species diversity whereas the explanatory variable was varied with each test (the wetland type, maximum water level, invasive plant species, pH, etc.). Mean values +/− SE are reported. Correlations between the explanatory and dependant variables were determined and the p-value and the R^2 recorded. One-way analysis of variance (ANOVA) was used to evaluate the median differences between species diversity and different environmental variables. The presence or absence of invasive plant species and any relationship to herpetofauna and plants diversity was analyzed using the non-parametric Mann-Whitney statistical test using JMP 5.01 software (SAS Institute Inc., Cary, NC).

2.7. Fieldwork Code Practice

During this study, efforts were made to reduce the risk of transmitting potentially harmful organisms (*i.e.*, bacteria, fungi, and invasive plant seed) and to minimize site disturbance. Guidelines of the Declining Amphibian Population Task Force [45] were used.

3. RESULTS

3.1. Rouge River Wetlands Location

The center of the study corresponded to 42 degrees 18' 42.82 "N 83 degrees 14' 08.82" W (**Figure 1**). Rather than classify land-use forms as residential, commercial, and industrial land [42] or urban, suburban, and rural [46], we chose to analyze potential habitats bordering the

river, surrounded by the diverse urban make-up of industrial and residential areas. Due to topography, the borders of the river are relatively free of buildings, where the river corridor creates a potential migratory path for the animals studied.

One hundred and twenty two wetlands, 90.40 hectares, were identified and delineated (**Table 1**). Most wetlands were "small," from 0.01 to 11.12 hectares2 and included four wetland habitat types: forested, marsh, complex, and scrub-shrub. In 122 wetlands, 62.3% were classified as forested. Marsh communities were 23.8% of the sites. The least common wetland was the scrub-shrub. Complex wetlands comprised 12.3% of the total wetlands considered during the study. From marsh and scrub shrub wetlands, 57% and 43% had detectable histosols. Some Forested (55%), Marsh (30%), and Scrub Shrub (15%) demonstrated reducing conditions.

3.2. Herpetofauna Observed

The herpetofauna observed included eight amphibian and eleven reptile species. The number of wetlands containing each animal is shown in **Figure 2**. Only a few of the total number of species were observed in most wetlands. The Eastern American Toad (*Bufo americanus*), Western Chorus Frog (*Pseudacris triseriata*), Eastern Garter Snake (*Thamnophis sirtalis*), Midland Painted Turtle (*Chrysemys picta marginata*), and Green Frog (*Rana cla-*
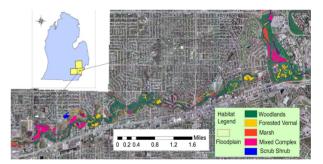

Figure 1. The study area along the Lower Rouge River, near Dearborn, MI (USA). Wetlands are coded according to the color legend shown above.

Table 1. Wetland size and herpetofauna observed in 122 wetlands along the Rouge River.

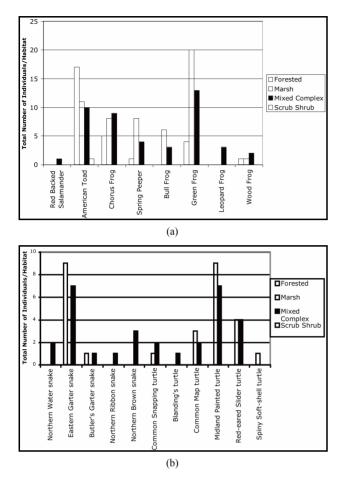| Type	Hectare^2	Total Wetlands	Total Amphibans	Amphibians/Hectare^2	Amphibians/Wetland
Forested	10.4	76	28	2.7	0.4
Marsh	19.6	29	54	2.8	1.9
Complex	39.8	15	45	1.1	3.0
Scrub Shrub	2.5	2	1	0.4	0.5
Type	**Hectare^2**	**Total Wetlands**	**Total Reptiles**	**Reptiles/Hectare^2**	**Reptiles/Wetland**
Forested	10.4	76	10	1.0	0.4
Marsh	19.6	29	22	1.1	0.8
Complex	39.8	15	30	0.8	2.0
Scrub Shrub	2.5	2	0	0	0

(a)

(b)

Figure 2. (a) Distribution of amphibians (**Figure 2(a)**) in the wetland habitats; (b) Distribution of reptiles (**Figure 2(b)**) within the wetland habitats.

mitans melanota) were the most often observed. Examining the species found in each wetland habitat, more reptiles and amphibians were found in marsh and complex wetlands compared to the other habitats surveyed (**Table 2**).

3.3. Diversity, Wetland Area, Hydrology, and Habitat Classes

Three surveyed wetlands contained the maximum species richness seen (5 amphibian species per wetland). Reptile species richness (overall) averaged 0.51 species (SE of 0.12) per wetland with the maximum of 10 species in one wetland. Shannon Diversity determinations were highest in Complex and Mash wetlands (**Table 2**).

3.4. Wetland Area, Hydroperiod, and Herpetofaunal Species Richness

Hydroperiod data (maximum water level) were examined with respect to species richness. ANOVA analysis showed an association between amphibian and reptile species richness and hydroperiod (**Table 3**). Amphibian and reptile species richness were also associated with

Table 2. Diversity determination using the Shannon index [43]. Symbol key, species richness (H), and evenness (Shannon's Equitability).

Habitat	Amphibians + Reptiles	Shannon Diversity Index (H)	Shannon's Equitability EH
Forested	38	1.49	0.80
Marsh	76	2.17	0.94
Complex	71	2.52	0.89
Scrub Shrub	1	0	0

plant species richness (**Table 3**). Distance (153 m) from the river system, water temperature, pH, conductivity, total dissolved solids, nitrate and phosphate did not show significant effects on herpetofauna species richness (not shown).

3.5. Plant Diversity and Wetland Area

The extent of wetland area was the most significant determinant in contributing to plant species richness, where the R^2 is 0.90 (**Table 4**). Some effects correlated with phosphate, and total dissolved solids were also observed (**Table 4**). Variables such as distance (153 m) from the river, water temperature, pH, conductivity, turbidity, and nitrogen levels did not significantly influenced plant community composition. In plants, the mean species richness per wetland (overall) was 16.02 species (SE of 0.75). Plant species richness was greatest in forested wetlands (**Figure 3**).

3.6. Invasive Plant Species and Diversity

Initial regression analysis between amphibian and reptile species richness versus invasive plant species revealed some potential interactions. Spatial Analyses were done using ESRI ArcMap 8.3 with prevalence of garlic mustard (*Alliaria petiolata*) compared to overall herpetofaunal species richness. For wetlands where garlic mustard was abundant or dominant (n = 9), herpetofauna never exceeded two species. In comparison, in wetlands with little or no garlic mustard, as high as 8 species of herpetofauna were observed (n = 82). Using the Mann-Whitney test to compare the two sets of unpaired data, amphibian species richness significantly declined with the co-presence of Garlic Mustard (*Alliaria petiolata*) or Buckthorn (*Rhamnus cathartica*) in wetlands (nearly 2 fold using a 2-tailed test, P value of 0.001).

4. DISCUSSION

Until the early 20th century and the emergence of the auto industry, Southeast Michigan was largely forested or used as farmland. Today urbanization has created many paved roads that bisect the study site. Average daily traffic along selected principal highways (Michigan Avenue, Ford Road, and Telegraph Road) ranged from 39,000

Table 3. ANOVA of amphibian and reptile species richness compared to several environmental variables. *Indicates a significant difference.

Amphibians	Dftotal	R2	F Ratio	P-value
Wetland Area	121	0.17	4.93	0.0005*
Hydroperiod	121	0.44	6.46	<0.0001*
Plant Species Richness	121	0.20	5.81	<0.0001*
Reptiles	Dftotal	R2	F Ratio	P-value
Wetland Area	121	0.44	14.96	<0.0001*
Hydroperiod	121	0.27	3.20	<0.0006*
Plant Species Richness	121	0.26	6.78	<0.0001*

Table 4. ANOVA of plant species richness compared to several environmental factors. *Indicates a significant difference between diversity and the variable considered.

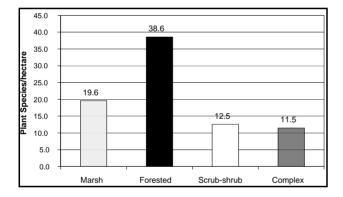| Factors	Dftotal	R2	F Ratio	P-value
Wetland Area	121	0.90	26.11	<0.0001*
Hydroperiod	121	0.23	2.43	0.0064
Dissolved Solids	121	0.62	2.23	0.008*
Phosphate	121	0.79	2.94	0.008*

Figure 3. Density of plant species, density/hectare 2. Values above bars indicate the actual value.

to 58,000 vehicles per day [47]. This single impediment likely contributes to the paucity of herpetofauna in this area [12]. A survey of the amphibian and reptile community (including the Henry Ford mansion) in this fragmented ecosystem was done to determine animal populations and investigate species richness and distribution.

Hydroperiod and wetland size were both associated with amphibian and reptile species richness (**Table 3**) [17, 18,21,22]. Altered hydroperiod and habitat fragmentation resulting from intense agricultural land-use are known to significantly lower amphibian diversity [48-50]. Under fragmentation, "small" wetlands, such as those described here, likely provide significant habitat and refuge opportunities for herpetofauna [22,28,49].

Plant species richness was also positively linked to amphibian and reptile species richness. Wetland area was the greatest determinant in plant species richness (**Table 4**). Invasive species garlic mustard and Buckthorn restricted herpetofaunal species richness by a factor of 2. This data is important, as the ecological plant community greatly influences the nature of the wetland (Marsh, Scrub Shrub, etc.) and amphibian and reptile populations. For example, particular plant species are known to promote or inhibit herpetofauna diversity [23,51].

The observed herpetofaunal diversity (**Table 2**) provided a reflection of the historic species coverage in this urban landscape [40,52]. Diversity of over 2.0 on the Shannon Diversity Index was found in Marsh and Complex habitats (**Table 2**). While encouraging, the total number of individual species/site was quite small (**Figure 2**, **Table 1**), compared to a protected non-urban wetland containing more than 360,000 individuals counted per year [31,53]. Given the low numbers of total individuals per species recorded, it is surprising that moderate species richness was observed. Several reasons for this could include; the reproductive prowess of the herpetofauna studied here, the presence of Golf Course refugia [28], upstream emigration, resilience, the adaptive nature of these species, and perhaps even human re-introduction. The presence of Marsh and Complex vegetation and the general lack of fish (seen in only 3 marsh wetlands) in most small wetlands also likely contributed to the remaining amphibian and reptile survival. Should road-crossing impediments and other "stressors" [1] become minimized, herpetofaunal abundance could increase in this region. One caveat is that this single season survey fails to account for innate dynamic population turnover sometimes observed in these animals [54].

5. CONCLUSION

Assuming a large mortality of herpetofauna likely due to the extensive road networks [10,12], this study found that wetland hydroperiod and size were linked to herpetofaunal species richness in relatively small Marsh and Scrub Shrub wetlands along the Rouge River. Plant species richness also had a positive effect on herpetofaunal species richness. Thinking forward, designed corridors and wetland connectivity could create accessible and larger habitat areas in this urban setting, supporting greater amphibian and reptile populations and maintain species diversity. Knowledge of wetland size and hydrology, together with a better understanding of the role of invasive plant species, herpetofaunal migratory patterns, and the use of buffer zones could greatly contribute to maintaining amphibian and reptile abundance and diversity in the urban Rouge River ecosystem [55]. This information could also aid in environmental planning and management to provide conservation-minded approaches to reduce the risks caused by human infringement to herpetofauna.

6. ACKNOWLEDGEMENTS

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