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Assessing the health of the ground beetle assemblage and ecosystem at emerging Victoria Park

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Introduction

The conversion of the 65-acre site now known as Victoria Park from an oil tank farm to an urban green space created an important and rare opportunity to both study ecosystem changes and support urban green spaces. Development in the Twin Cities Metropolitan Area has resulted in a significant increase in land used for urban development accompanied by a decrease in forests and wetlands (1) as well as accompanying ecosystem fragmentation, isolation and simplification (2). The rarity of this land use change makes monitoring Victoria Park's development all the more important.

Ground beetles (Coleoptera: Carabidae) are considered to be an indicator species capable of providing information about habitat and ecosystem health (3, 4, 5) even to the extent of producing specific information about ecosystem changes, including successional changes (6).

This study attempted to characterize and track changes in the ground beetle assemblage at Victoria Park from 2016 – 2019 in order to understand ecosystem changes as the park evolved from industrial use to urban green space. Furthermore, effective protection and development of an ecosystem often involves measurement of ecological integrity (7); indicator species like ground beetles are excellent inputs into this measurement. It is the hope of this study that the data produced is useful to St. Paul Park and Recreation in their approach to this special piece of urban land.

Characterization of the ground beetle assemblage was measured through tracking assemblage activity density, measuring assemblage diversity, and investigating immigration by looking at population patterns of one species composing this assemblage (*Agonum cupripenne*).

Assemblage Activity Density

Pitfall traps by themselves (that is, not in conjunction with marking) produce activity density data, a parameter of population density and relative activity (8). While activity density is not necessarily a direct measure of population size, activity density data from the same habitat over the course of time correlates well with changes in overall population density (9). This stage of the study measured activity density to track changes in overall assemblage density and assumed that higher densities equate to healthier assemblages and thus to healthier ecosystems.

Methods

Forty-five pitfall traps (composed of 16 oz cups placed flush with the ground and Styrofoam covers suspended 10cm above using 3 bamboo skewers) were randomly placed in the study area (Fig. 1) from May 4 to May 26 in each year from 2016-2019. Traps were checked daily and the number of ground beetles in each trap was recorded before trap contents were released back into the study area a minimum of 50 cm from the trap.

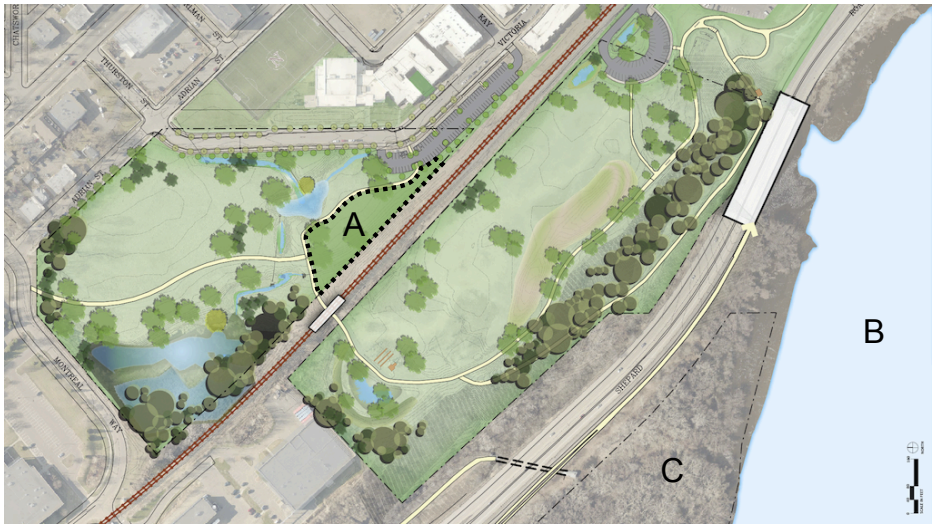


Fig. 1: Study Area: Victoria Park, St. Paul, Minnesota. The dotted line indicates the area of study (A), approximately 1.5 acres in total; no park restoration activity took place in this section of the park. Victoria Park is near the Mississippi River (B) and adjacent to Crosby Farm Park (C).

Results

During the four years of the study 2,322 ground beetles were trapped and released. Activity density, measured in number of ground beetles per trap per day, increased 28% from 2016-2019 (Fig. 2), though was clearly influenced by daily weather. In general, warmer temperatures and drier conditions resulted in higher activity density (Fig. 3).

The highest activity density was recorded in 2019, the final year of the study. This increased activity despite the suppressing effects of lower temperatures and higher precipitation in 2019 (Fig. 4) may be a good indication that activity density, and thus overall assemblage density were at their highest level. In addition, and according to the assumptions of this study, this could be an indication of improving ecological conditions within the study area.

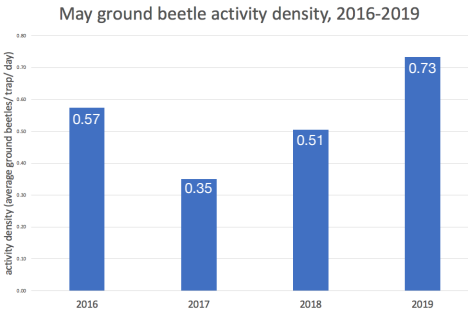


Fig. 2: May ground beetle activity density. Over the four year course of the study activity density, measured in ground beetles per trap per day, showed a 28% increase.

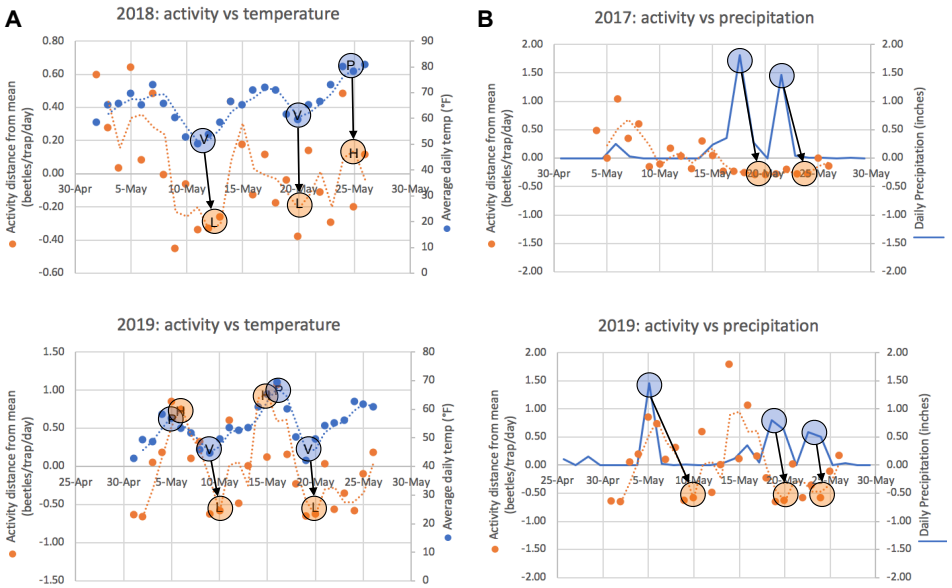
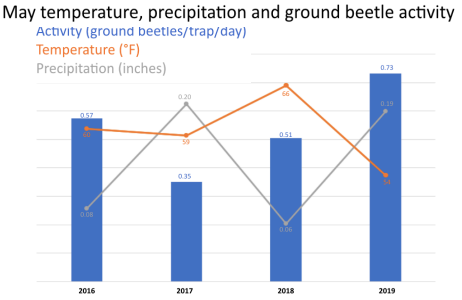


Fig. 3: Temperature and precipitation affect ground beetle activity density. (**A**) The moving average of the activity distance from the mean in each year of the study showed temperature peaks (P) and valleys (V) generally associated with activity highs (H) and lows (L) respectively; years 2018 and 2019 shown here. (**B**) Precipitation also affects activity as measurable rain is associated with a drop in activity, though with a lag time; years 2017 and 2019 shown here.

Fig. 4: 2019 was the most active year for ground beetles. Lower temps and higher precipitation tend to suppress ground beetle activity; 2019 was the most active year despite the cool, wet weather.



Assemblage Diversity

Species diversity has been linked to ecosystem productivity (10) and stability (11) and often serves as a general indicator of ecosystem health. Using the same principles, this study attempted to use assemblage diversity as a measurement of the overall health of the assemblage and thus the ecosystem.

Methods

The trap proceeds on the last day of the study (May 26) of each year were retained, preserved and identified to the genus level using Lindroth's excellent key (12). In addition, any ground beetle found dead in traps was retained during the study and the 2018 and 2019 study included an expanded collection in an attempt to verify diversity index measurements.

Genus numbers were used to calculate diversity using and Simpson's diversity index. Though the use of these indices at the genus level is recognized as being generally less informative (13), applied over time and in conjunction with activity density it is the hope of this study that genus level diversity provides an additional parameter with which to understand assemblage health.

Results

The intention of this study was to compare the diversity temporally using Simpson's diversity index, controlling trapping variables by comparing diversity on a single date. However, the size of the collection on May 26 was significantly variable, ranging from a low of 7 on May 26, 2016 to a high of 52 on May 26, 2018. This variation seemed to play an oversized role in the diversity calculations, thus collection was expanded in the final two years of the study in an attempt to verify the relationship between collection size and diversity calculations. Diversity results from this expanded capture indeed indicate that a single day's capture may not accurately reflect overall assemblage diversity (Fig. 5).

Fig. 5: Diversity index changes with the size of capture. This data suggests that diversity may be more accurately measured with larger samples.

Simpson's Diveristy Index Results 2016-2019

	May 2016	May 2017	May 2018	May 2019	
May 26 Only	0.83	0.67	0.75	0.74	total
total captures	18	7	52	35	112
All May Captures	0.83	0.80	0.78	0.81	total
total captures	18	19	104	288	429

	Genus	May 2016	May 2017	May 2018	May 2019
1	Acupalpus	0	0	0	0
2	Agonum	14	1	10	22
3	Amara	2	1	10	36
4	Anisodactylus	3	2	7	24
5	Badister	0	0	0	1
6	Bradycellus	0	0	0	1
7	Chlaenius	12	3	5	2
8	Dicaelus	0	1	16	2
9	Elaphrus	0	0	0	1
10	Harpalus	5	0	5	80
11	Loricera	1	0	0	0
12	Notiophilus	0	0	1	0
13	Poecilus	5	8	43	75
14	Pterostichus	0	0	6	60
15	Scarites	1	3	1	0
16	Stenolophus	6	0	0	2
	Total	49	19	104	306

Fig. 6 (left): The Victoria Park ground beetle assemblage contains at least 16 genera. Expanded capturing increased the number of genera from 12 to 16.

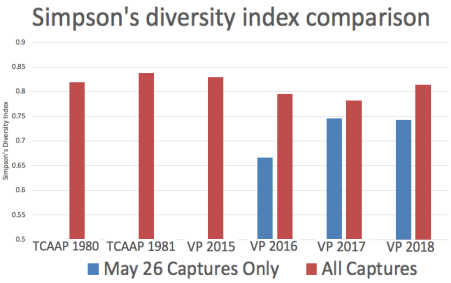


Fig. 7 (above): Diversity of Victoria Park is in line with assemblages from similar areas. Genera diversity calculations at Victoria Park with expanded captures (red) were similar to the diversity at the TCAAP measured by Eptstein in 1980 & 1981.

An expanded capture found ground beetles from 16 genera (Fig. 6) with a diversity that was in line with similar studies. For example, in 1980 and 1981 Epstein (14) sampled the ground beetle assemblage from fields on the property at the Twin Cities Army Ammunition Plant (TCAAP), a property that has a similar habitat and history as Victoria Park: both sites are closed industrial areas in need of environmental remediation. The data from the TCAAP shows a genus-level Simpson's diversity index of 0.82 (238 specimen) in 1980 and 0.84 (352 specimen) in 1981 (Fig. 7). With TCAAP data as a guide, the larger samples may be a more accurate reflection of the assemblage diversity. While this disrupts the ability to recognize temporal diversity patterns at Victoria Park, it does serve as an indication that the assemblage at Victoria Park is on par with similar sites. It may be a good sign for the health of the assemblage, but the disruption of the methods make this part of the study more of an exercise in protocol fine-tuning.

Population Analysis

Because non-synonymous single nucleotide polymorphisms (SNPs) can accumulate over time with no effect on individual fitness, they serve as an effective tool for accurate species identification (15) and can be an efficient indicator of species diversity (16). SNPs in slowly evolving genes such as the mitochondrial cytochrome oxidase I subunit (CO1) can occur in one population but not another and indicate separate populations, or at least indicate infrequent migration between populations. Thus these SNPs can also be used conversely: to confirm migration between geographically separate populations, an important process affecting assemblage composition in newly restored habitat.

Fig. 8: Primers (right) and PCR conditions (below) for mtCO1 amplification.

Primers	
Forward	Reverse
LCO1490	HCO2198

Primers are specific to arthropods, conditions were adjusted from Gilbert et al. (2007).

Initial Denature		Cyles	Denature		Anneal		Extension		Final Extention	
Time (min)	Temp (°C)	Number	Time (s)	Temp (°C)	Time (s)	Temp (°C)	Time (s)	Temp (°C)	Time (min)	Temp (°C)
5	94	38	45	94	45	49	80	72	7	72

Methods

The CO1 gene was extracted and amplified according to protocols laid out by Gilbert et al. (17) (Fig. 8). Genes from 13 specimen of the species *Agonum cupripenne* from Victoria Park and Coldwater Spring (on opposite sides of the Mississippi River) were compared and SNPs were identified.

SNP summary for 13 specimen of *Agonum cupripenne*

Position (bp)	Change	Specimen no.	Population
56	insert T	VP113	Victoria Park May 2018
97	T --> C	CW31	Coldwater Spring May 2015
131	T --> A	VP73	Coldwater Spring July 2016
143	T --> C	CW34	Coldwater Spring May 2015
229	A --> G	VP44	Victoria Park May 2016
		VP113	Victoria Park May 2018
		CW31	Coldwater Spring May 2015
		VP112	Victoria Park May 2018
		CW51	Coldwater Spring May 2015
278	T --> C	VP45	Victoria Park May 2016
		CW31	Coldwater Spring May 2015
		VP112	Victoria Park May 2018
337	A --> G	VP44	Victoria Park May 2016
362	T --> C	CW27	Coldwater Spring May 2015
436	A --> G	CW73	Coldwater Spring July 2016
551	T --> C	CW31	Coldwater Spring May 2015
619	insert T	VP44	Victoria Park May 2016
637	A --> G	VP113	Victoria Park May 2018
644	A --> G	CW51	Coldwater Spring May 2015
650	C --> T	VP113	Victoria Park May 2018
		CW27	Coldwater Spring May 2015
		VP33	Victoria Park May 2016
		VP106	Victoria Park May 2018

Fig. 9: SNPs in two populations of *Agonum cupripenne*. All alleles are present in both the Coldwater and Victoria Park populations, this is likely a result of migration across the river.

Results

Thirteen single nucleotide polymorphisms were identified between the 13 specimen (Fig. 9). In three locations on the gene these SNPs occurred in multiple specimen. No allele was particular to one location; all appeared in both locations. This clearly shows that the Coldwater Spring and Victoria Park populations of *Agonum cupripenne* are not distinct and a good indication that at least this species is capable of dispersal across the river. As Victoria Park is connected to the floodplain forest at Crosby Farm Park, certainly an easier migration than across the river, this may indicate that dispersal of ground beetles into Victoria Park is likely.

Final Conclusions

The ground beetle assemblage in the study area has shown an increase in activity density, has a diversity comparable to a similar area that had been "wild" longer, and is likely composed of species immigrating from nearby natural areas. All these indicators are positive for the health of the ground beetle assemblage at Victoria Park. As ground beetles are an established bioindicator, these results could be interpreted as a positive indication of the improving health of the park ecosystem.

The only potential, if unlikely, concern is in the state of the captured individuals: 7.1% of preserved specimen (a total of 41 individual ground beetles) had an oily residue on their elytra. This is likely a result of the ability of ground beetles to store energy as fat and thus a residue of the breakdown of these fats after death. However, it is within the realm of possibility that these individuals picked up this oil in their environment. If that is true it might be possible that some oil continues to exist in the park despite soil remediation efforts and the gravel cap.

Special Thanks

This project would not have been possible without the help from the following group and individuals. My genuine and heartfelt thanks for freely giving your time and attention.

- The 152 UMA students who participated in some form and almost always thought it was fun
- Alice Messer, St. Paul Parks and Recreation, who was always quick to answer questions
- Dr. Roger Blahnik, University of Minnesota, who taught me how to ID Carabids
- Dr. Matt Dean, University of Southern California, who guided me through the challenges of DNA sequencing in the dusty basement of a charter school

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Post Script

Tracking daily activity for an entire assemblage was, perhaps, a unique methodology (certainly engaging hundreds of ninth and tenth grade science students to do so is outside the norm). While some studies have tracked daily activity, it is nearly always focused on a specific species. Other studies that look at the entire assemblage tend to check and empty traps infrequently and cannot ascertain daily activity patterns. Thus, there does not appear to be a way to corroborate the assemblage activity pattern seen in Victoria Park during the course of the study (Fig. 10). But it is a pattern worth exploring, nonetheless. The distance from the yearly activity average (measured in ground beetles per trap per day) was calculated for each year and plotted by date, a moving average line was then inserted to smooth out random fluctuations. An apparent pattern emerges from this data: in each May of the study the highest activity (or second highest in the case of 2019) occurs between May 4-5 followed immediately by a six-day period that contains the lowest activity, excluding 2019. This is followed by a second activity peak for each year, all occurring within the three-day period May 14-16. The pattern ends with a leveling out of activity where 88% of all activity falls within 0.43 ground beetles per trap per day from the average. This is a complicated way of saying all years seem to have aligned peaks and troughs of ground beetle activity.

This is surprising because each species in the ground beetle assemblage likely has its own unique activity pattern that balances its needs of temperature regulation, reproduction, feeding, and predator avoidance. Indeed, activity with ground beetles is so particular that some species show activity differences between genders (18).

So why might this pattern emerge form daily activity data? It certainly could be stochastic; the sample size is only four Mays after all. But I suspect there is some general alignment of activity cycles between species in the early spring as the thawing of the ground and increased light level is likely a universal indicator for all arthorpods to activate. The first activity peaks and valleys line up (Fig. 10 A-C), then, because all species are activating at generally the same time. As spring progresses each species goes about its business with their own unique cycles and so the assemblage as a whole takes on a more consistent activity pattern (Fig. 10D). Whatever the reason it's been fun to watch.

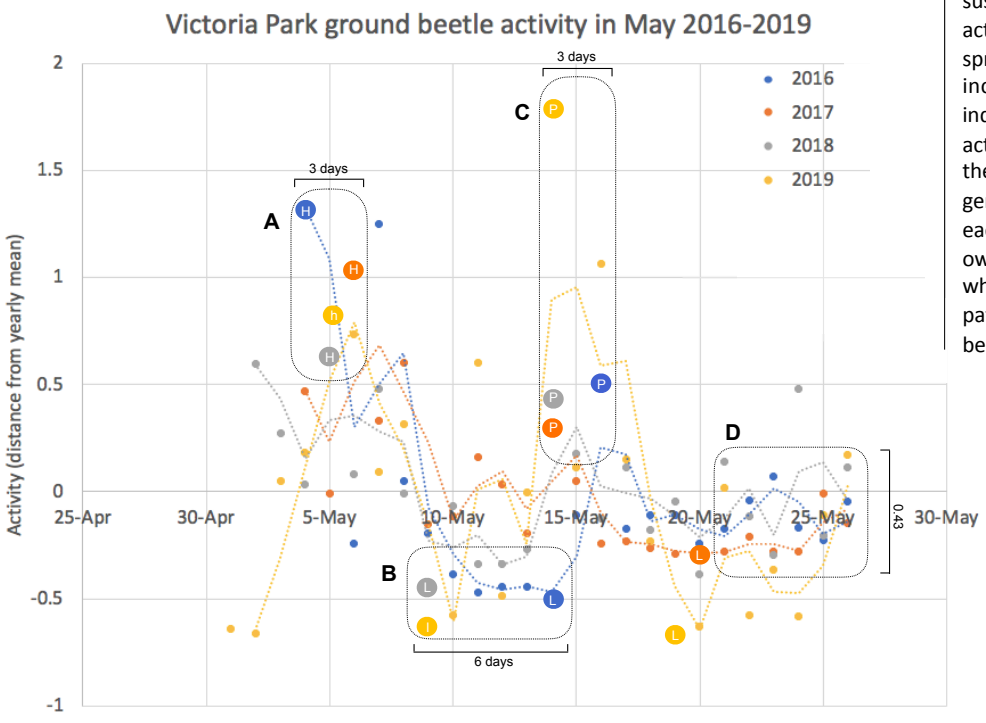

Fig. 10: Activity patters for the ground beetle assemblage at Victoria Park shows similarities each year in May. Overlaying a moving average on the distance from the mean shows three aligned patterns: (**A**) all activity highs (H) or second high (h) occur within a three day period at the beginning of May; followed immediately by (**B**) a six day area of lows (L) or second low (l) in 3 out of 4 years; followed by (**C**) a second activity peak (P) occurring within a three day period; followed by (**D**) a leveling out of activity where 88% of all activity in all years falls within 0.43 ground beetles per trap per day distance from the yearly mean.