Community-based Dragonfly & Damselfly Monitoring in Johnson Creek Watershed

Western Forktail (Ischnura perparva), Westmoreland Park; C.A. Searles Mazzacano

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Executive Summary

In 2017, Johnson Creek Watershed Council worked with CASM Environmental, LLC to continue a second year of community-based research monitoring populations of odonates (dragonflies and damselflies) in the Johnson Creek watershed. Surveys were continued at two sites that were monitored in the 2016 pilot project—Westmoreland Park (Crystal Springs Creek) and Brookside Park (Johnson Creek)—and a new site, Centennial Pond (Kelley Creek) was added. Volunteers received classroom and field training in odonate ecology, life history, identification, survey protocols, and data reporting. Self-assembled teams signed up for surveys on dates set at two-week intervals from June through October. Teams walked transects at each site and recorded odonate species, abundance, genders, and behaviors (mating, egg-laying, etc.). Volunteers were encouraged to net specimens for in-hand identification and take photo vouchers when possible. All data were reported on iNaturalist (http://www.inaturalist.org/projects/dragonfly-surveys-in-johnson-creek-watershed). CASM Environmental conducted monthly surveys to ensure quality control. A mid-season field session was held at the end of July to provide both a refresher in techniques and identification and an opportunity for volunteers to socialize.

Twenty-six volunteers worked a total of 150 hours and made over 200 observations of 23 odonate species among three sites (17 dragonfly, six damselfly). Diversity was greatest at Westmoreland Park, where 21 species were sighted (15 dragonfly, 6 damselfly); these numbers were similar to 2016, when volunteers found 22 species at Westmoreland (17 dragonfly, 5 damselfly), but two dragonfly species new to the project list were found at Westmoreland in 2017: Red-veined Meadowhawk (*Sympetrum madidum*) and Saffron-winged Meadowhawk (*S. costiferum*). Brookside Park had 17 species (11 dragonfly, 6 damselfly), which was also similar to 2016 (18 species; 13 dragonfly, 5 damselfly). Centennial Pond, the site with the lowest habitat quality, had the lowest diversity, with 15 species present (11 dragonflies, 4 damselflies). Eleven of the 23 total species were seen at all three sites.

Three of the five main migratory dragonfly species were present; Common Green Darner (*Anax junius*) and Variegated Meadowhawk (*Sympetrum corruptum*) were observed all sites, and Black Saddlebags (*Tramea lacerata*) was reported at Brookside and Centennial Ponds. Indications of breeding (mating pairs, egg laying) were seen for these migratory species where they occurred, but successful development (newly-emerged adults) was only observed at Westmoreland Park for one of the migratory species, Variegated Meadowhawk, with newly-emerged adults on a single date (18 August). While overall diversity was similar at the two sites surveyed in 2016 and 2017, seasonality, abundance, and adult emergence differed. This is likely due to a combination of both weather (i.e., an unusually cold wet spring and hot dry summer), and potential impacts of extensive western forest fires that resulted in heavy smoke and ash fall in late summer. In addition, proliferation of non-native invasive species at Westmoreland Park is impacting site hydrology and habitat quality.

Background

Although odonates are among the better-known insects, there is still much to be learned about their distribution, life history, and ecology. One of the best ways to fill these knowledge gaps is through long-term studies with regular observations at the same site. This type of ongoing monitoring allows changes in the composition and seasonality of local odonate populations to be detected, which can further reveal alterations in habitat quality as well as impacts of climate change.

Moreover, little is known about the phenomenon of dragonfly migration in North America, with questions about timing, triggers, flight pathways, overwintering grounds, staging areas, and the relationship between resident and migrant individuals of the same species. Because three of the five main migratory species in North America use the project sites for feeding and mating, long-term observations will inform what we know about migration patterns. Dragonflies and damselflies are also excellent subjects for studying the long-term impacts of climate change. Extensions of early and late flight dates are already being noted for many species in the U.S. (Abbott, 2006-2017), and several tropical species once considered vagrants in the southwest have recently established breeding populations (Bailowitz et al., 2016).

This project is the first systematic study of odonates in the Johnson Creek watershed. Characterizing odonate diversity and abundance at the regional scale is a first step in discovering stressors impacting local populations, incorporating odonate habitat needs into restoration plans, and learning the effects of restoration projects on different species. In the two years of this project, range expansions and new species observations for the county have already been noted, and changes in restored habitat may already be impacting odonate community composition at study sites.

This project is part of the Johnson Creek Watershed Council community-based science program, and is the second year of volunteer-based surveys of dragonflies and damselflies. Volunteers can make huge contributions to science; their participation greatly increases the frequency and scope of observations and data collection, and they can collect useful, high-quality data (McKinley et al., 2017; Dennis et al., 2017). These insects are compelling, beautiful, and easy to observe, and learning to identify local species is fairly straightforward. This project used protocols, training techniques, and survey methodologies established in the first year of the study to support self-organizing volunteer teams survey local odonates on a regular basis during the majority of the flight season at three sites in the Johnson Creek watershed.

Methods

Volunteer Training

Resources developed by CASM Environmental in 2016 were modified for the 2017 survey season in response to feedback from first-year volunteers. Changes included adding a detailed section to the protocols manual on how to log in and report survey data on the iNaturalist project site, and creating a Quick Guide to Dragonfly and Damselfly Families to help volunteers home in on the appropriate section of the field guide to use. JCWC staff also established a Volunteer Toolkit on the JCWC web site that included an interactive scheduling document, surveyor checklist, equipment checkout, contact information for volunteers and staff of JCWC and CASM Environmental, and links to additional resources.

JCWC reached out to their extensive network of volunteers to participate in the project, and six volunteers who participated in the first year returned as peer mentors. A full day of classroom and field training was done on 3 June 2017. A one-hour pre-training social period was held to give volunteers a chance to get acquainted; this was another aspect of the volunteer experience that was requested in the feedback from Year 1. The first half of the day was a classroom session in which volunteers learned about odonate ecology, life history, and behaviors; how to recognize common species in Multnomah County; key components for species identification; and how to use the monitoring protocol and reporting methods. The remainder of the day was spent in the field at one of the project sites (Westmoreland Park), where volunteers learned how to walk transects and net and identify individuals.

After the training session, volunteers signed up for survey dates spanning every 14 days in June-October at three different sites: Brookside Park, off of Johnson Creek (11201-11243 SE Brookside Dr, Portland, OR); Westmoreland Park, off of Crystal Springs Creek (7530 SE 22nd Ave, Portland, OR); and Centennial Pond, off of Mitchell Creek, (45.4679º, -122.4889º). A GoogleSheets document in the Volunteer Toolkit was used to sign up for surveys. Each site and date was filled in by two surveyors and one or two substitutes. Volunteers used additional columns to note whether the surveyors had contacted each other, the date each survey was done, and the date that their observations were entered into the iNaturalist project site. Volunteers were also able to sign out nets, field guides, maps, data sheets, sunglasses, and hand lenses from the JCWC office. A mid-season field session and social gathering was held at Westmoreland Park on 27 July to provide refresher training in survey and identification techniques and address questions from volunteers.

Survey techniques

The adult flight season for odonates in the Portland area runs from early May through late October, although early and late dates vary annually due to weather conditions. Because it is not possible logistically to have volunteers in the field that early in the season, CASM Environmental conducts regular surveys at the project sites as soon as

weather conditions are conducive to odonate activity, to ensure that the first flight dates, species records, and return of migratory species are captured. Once volunteers are trained, the goal is to survey each site once every 14 days, but due to changing weather conditions and volunteer availability, survey dates were often shifted slightly, such that in practice they occurred once every 8-16 days.

Surveys were done on days when weather conditions were optimal for odonate activity (Table 1). Volunteers survey a transect that runs along the water's edge, allowing them to view both the water and adjacent vegetation. Teams were given maps to guide their transect walks (Figure 1). Volunteers were encouraged to take photos and capture odonates for in-hand examination whenever possible. Observers filled out their data sheet (Appendix A) upon arriving at the site with start time, observer names, and weather conditions (sun, cloud cover, wind, precipitation). Surveyors slowly walked their transects and noted the following:

- Species: Volunteers were encouraged to capture specimens for in-hand examination and to take photographic vouchers of perched or in-hand specimens whenever possible. The method of identification was noted on the data sheet (visual, captured, photographed).
- Gender: Males and females are differentiated based on coloration, markings, and genitalia (structures on the terminal abdominal segment).
- Abundance category: uncommon (1-4 individuals seen), frequent (5-20), common (21-100), or abundant (>100)
- Reproductive stage: wheel (mating pair), tandem pair (male still holding female but not engaged in copulation), ovipositing (laying eggs), and teneral adult (newly-emerged)

Volunteers kept tallies of species abundances while conducting the survey; when finished, they recorded the final abundance categories, stop time, and weather conditions.

Table 1. Survey decision matrix for weather conditions conducive to odonate activity

Time range	**10:00 am - 4:00 pm**			**9:30 am - 4:30 pm**	
Temperature	<59°F (15°C)	59-65°F (15-18°C)	65-75°F (18-24°C)	>75°F (24°C)	>88°F (31°C)
Cloud cover >60%	No	No	Yes	Yes	No
Cloud cover <60%	No	Yes	Yes	Yes	No
Moderate to strong wind (tree branches swaying)	No	No	No	No	No
Rain	No	No	No	No	No

Figure 1. Survey transects for Westmoreland Park (left), Centennial Pond (right), and Brookside Park (bottom).

Data reporting

All data were entered into the iNaturalist project "Dragonfly Surveys in Johnson Creek Watershed (http://www.inaturalist.org/projects/dragonfly-surveys-in-johnson-creek-watershed). Data entry fields on the iNaturalist project site mirrored each entry on the data sheet. Data could also be entered in the field via the mobile iNaturalist app. iNaturalist was chosen for data reporting due to its ease of use, availability as a free mobile app on iOS and Android, and ease of data export for analysis and reporting. In addition, the crowdsourcing method of identification and verification provides a useful image gallery for volunteers (from the large numbers of identified, vetted photos in the iNaturalist database) as well as a way for volunteers to confirm identification of their uploaded photos. Volunteers also e-mailed CASM Environmental with questions about survey and reporting protocols and species identification.

QA/QC

CASM Environmental conducted 15 surveys at project sites from early March through the end of October to compare expert- and volunteer-collected data. These data were also entered on the iNaturalist project site. An additional field session was held on 27 July for volunteers who had not yet done a survey and/or those who wished to refresh their skills. To provide information for adaptive management, volunteer feedback was solicited directly at an end-of-season potluck, where a summary of the season's results was presented and volunteers were encouraged to share their impressions of the project and discuss challenge and strengths of the training, resources, and reporting. Project feedback was also solicited via the annual JCWC online survey to volunteers to capture input form those unable to attend the potluck.

Results & Discussion

Species diversity

Volunteers conducted surveys from 18 June - 27 September 2017. Those surveys, combined with additional surveys by CASM Environmental from 3 March - 28 October, enabled first and last flight dates for the 2017 season to be established (31 March and 28 October, respectively). Surveys were done on 21 days at Westmoreland Park, 15 days at Brookside Park, and nine days at Centennial Pond. The lower number of surveys done at Centennial was likely due to the fact that this site is located the furthest east and has more difficult access (a longer walk and an abundance of blackberry around the pond).

Overall species numbers were similar between 2016 and 2017 (22 species and 23 species total, respectively), but community composition differed slightly. A total of 17 dragonfly and six damselfly species was reported across all

sites in 2017, with the highest diversity at Westmoreland Park (15 dragonfly and 6 damselfly species) followed by Brookside (11 dragonfly and 6 damselfly species) and Centennial Pond (11 dragonfly and 4 damselfly species). Twelve of these 23 species were present at all project sites in both 2017 and 2016: Common Green Darner (*Anax junius*), Variegated Meadowhawk (*Sympetrum corruptum*), Cardinal Meadowhawk (*S. illotum*), Eight-spotted Skimmer (*Libellula forensis)*, Twelve-spotted Skimmer (*L. pulchella*), Common Whitetail (*Plathemis lydia)*, Blue Dasher (*Pachydiplax longipennis*), Western Pondhawk (*Erythemis collocata*), Blue-eyed Darner (*Rhionaeschna multicolor*), Pacific Forktail (*Ischnura cervula*), Western Forktail (*I. perparva*), and Vivid Dancer (*Argia vivida*). All of these species are common in the region and are frequently found in urban areas (Paulson, 2009; Kerst & Gordon, 2011).

Four species new to the project list were seen in 2017: Red-veined Meadowhawk (*Sympetrum madidum*) and Saffron-winged Meadowhawk (*S. costiferum*) at Westmoreland, and Striped Meadowhawk (*S. pallipes*) and Northern/Boreal Bluet (*Enallagma annexum/boreale*) at both Westmoreland and Brookside; these were all known previously in Multnomah County but had not been found at either project site in 2016. It is possible that Northern/Boreal Bluet (often called NoBo due to the difficulty of distinguishing between the two species without in-hand examination of the male genitalia) was present in 2016 but was not noted by volunteers, as the difference between these and Tule Bluets (*E. carunculatum*) is subtle and primarily noted in the field by a bigger ratio of blue to black on the first two abdominal segments of NoBos. Three species seen in 2016 were not found in 2017: *Sympetrum danae* (Black Meadowhawk) and *Libellula quadrimaculata* (Four-spotted Skimmer), both of which are more common at higher elevations and were thus unexpected sightings in 2016; and *S. vicinum* (Autumn Meadowhawk), a common late-summer species that would be expected in these sites.

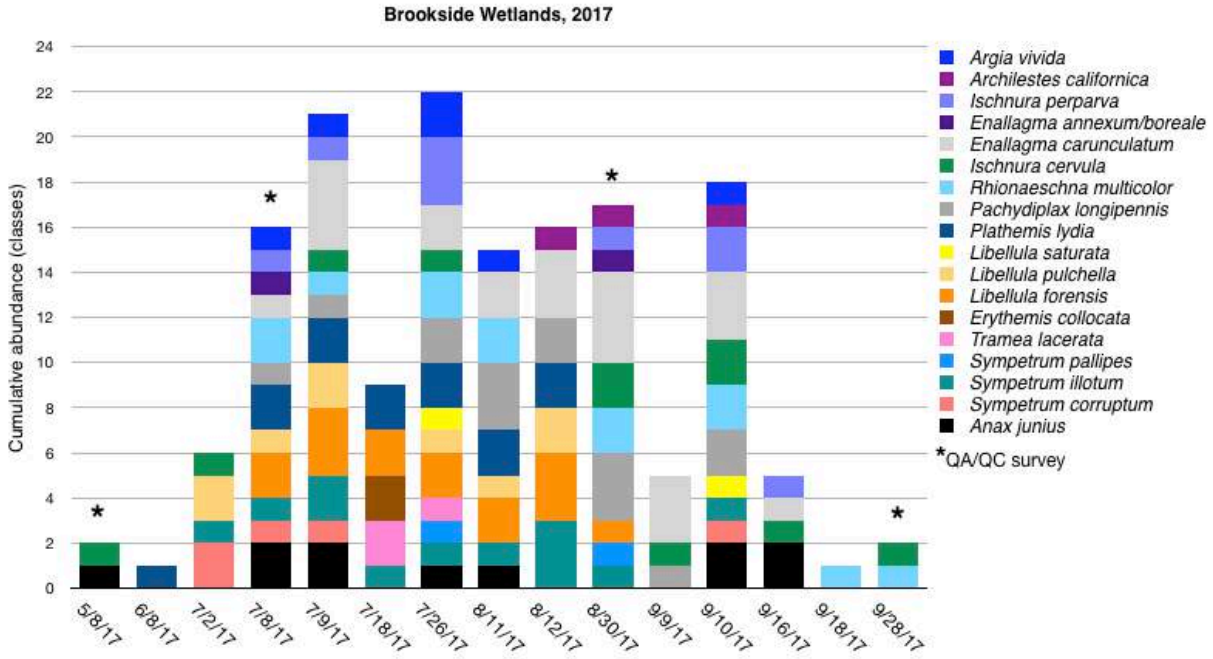
Seasonality and abundance

Brookside Park

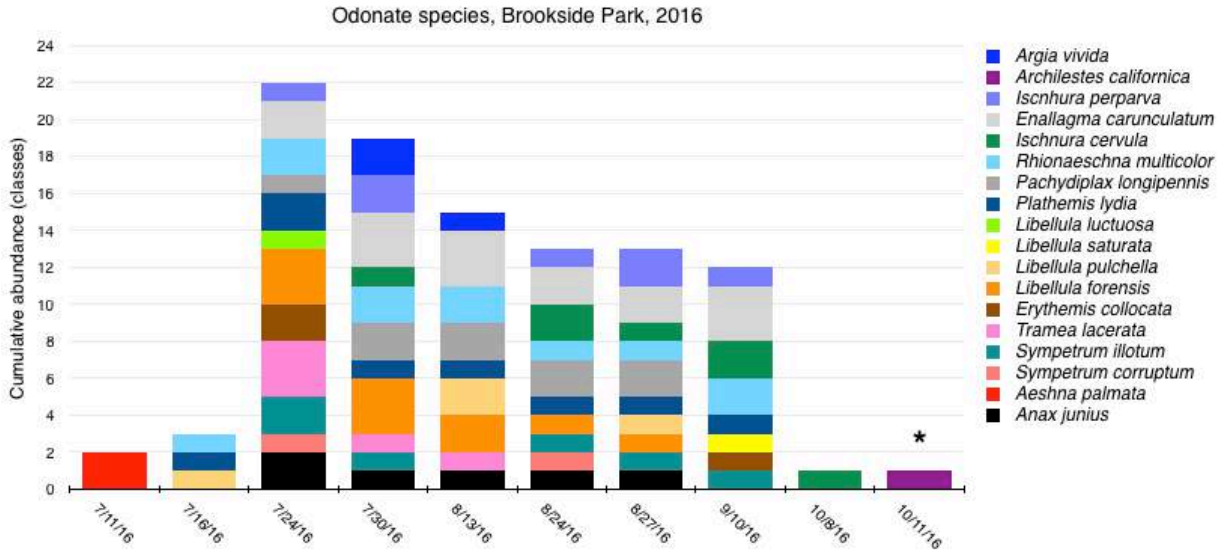
Patterns of seasonality and abundance were similar between years, with 17 species seen in 2017 and 18 species in 2016 (Figure 2), although earlier training and initial surveys dates allowed more surveys to be done in 2017. Pacific Forktail (*Ischnura cervula*) was one the first and last species to be seen on the wing at this site, as is typical for this species in the Portland area. Overall, abundance and diversity was greatest in both years in July. However, in 2017, the data from two volunteer survey dates appeared anomalous, with very low species abundances (five species on 18 July and three on 9 September). This is likely due to differing survey abilities of the volunteers on those dates. For example, the low-diversity survey on 9 September was done by two new volunteers, whereas a survey done at the same site the following day by a volunteer who also participated in the program in 2016 found 11 species. The fact that surveys were done at Brookside on two contiguous days also suggests a need for improved volunteer coordination and/or use of the interactive GoogleSheets scheduling document.

Figure 2. Odonate seasonality and relative abundance at Brookside Park in 2017 (A) and 2016 (B). Species abundances are in categories: 1 (uncommon, 1-4 individuals); 2 (frequent, 5-20); 3 (common, 21-100); 4 (abundant, >100). Asterisks indicate surveys done by CASM Environmental.

A. Odonates at Brookside Park, 2017.



B. Odonates at Brookside Park, 2016.



Westmoreland Park

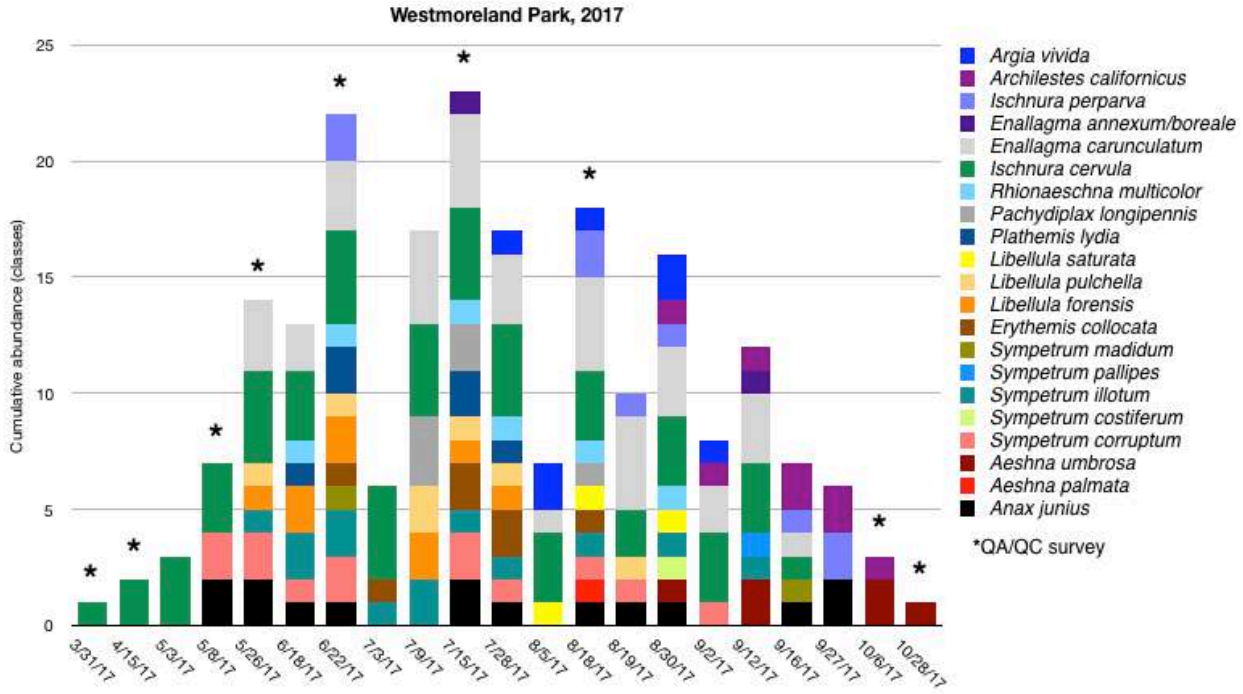
CASM Environmental surveys this park intensively in spring and fall to determine the first and last odonate flight dates for the area. In 2016 and 2017, the first resident species seen on the wing was, as expected, Pacific Forktail (*Ischnura cervula*). However, the first migratory species, Common Green Darner (*Anax junius*) and Variegated Meadowhawk (*Sympetrum corruptum*), were not seen until the first week of June in 2017, whereas in 2016, Variegated Meadowhawks were present throughout April. The spring movement of migrant dragonflies is governed in part by weather and accumulated degree-days, so the record-breaking wet, cold spring of 2017 likely slowed their advance north (see *Migratory species* below for further discussion). The last species on the wing at the park in both survey years was Shadow Darner (*Aeshna umbrosa*), although the earlier advent of cold wet autumn weather ended the odonate season one week sooner in 2017 compared to 2016.

The most dramatic changes in the vegetation at Westmoreland Park since restoration was completed in 2014 were seen in 2017, and the resulting alterations in site hydrology had a noticeable impact on odonate populations. While some invasive species have been spreading throughout the wetland area for the past few years, such as teasel, reed canary grass, and Himalayan blackberry, 2017 also saw explosive jewelweed growth. This plant has been present along the banks for years, but in 2017 dense growths extended well into the creek on both sides, choking the channel directly in some places and creating mats where additional debris caught and formed larger piles in others. Movement of jewelweed mats into the channel may have been aided by the fact that the banks are sinking and/or collapsing in some places due to high levels of nutria tunneling, to the extent that in some places it is no longer safe to walk along the banks of the creek. Jewelweed growth in the wetlands was unprecedented, with the areas adjacent to the creek covered in dense tangles over 5 feet high that were very difficult to walk through. While water levels in the wetland were higher than ever before, such that that the stream channel and wetlands remained physically connected all season in some reaches in the park, the dense jewelweed growth covered wet areas that had been open water in the last two years.

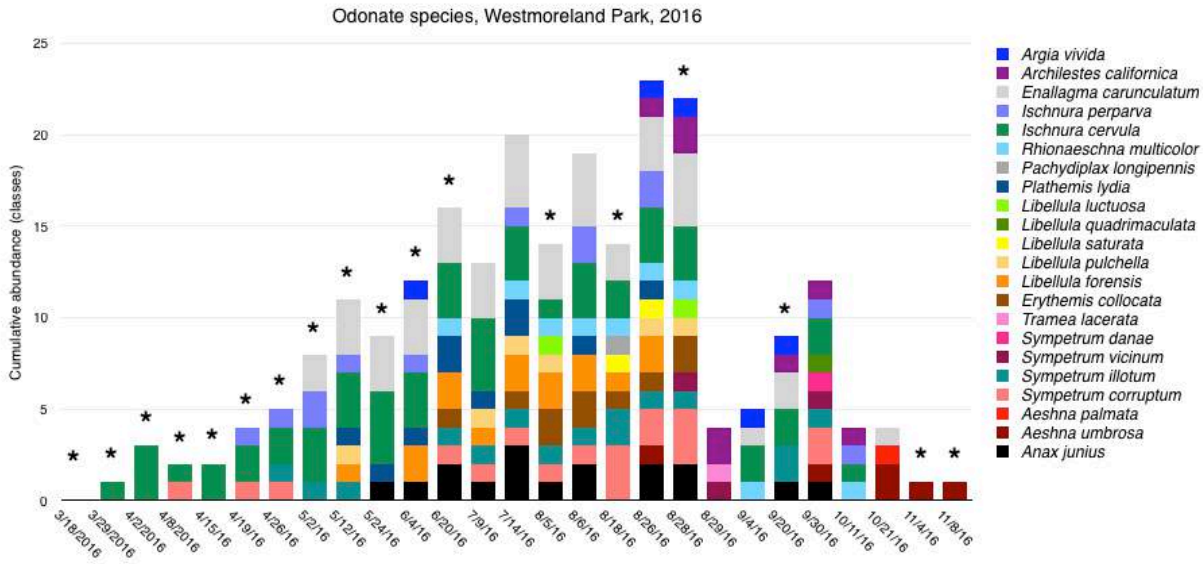
Abundance and diversity at the park peaked a few weeks earlier in 2017 than in 2016. Interestingly, Eight-spotted and Twelve-spotted Skimmers (*Libellula forensis* and *L. pulchella*), which were present in abundance through the end of August in 2016, especially at the large overlook pond, had virtually disappeared by the end of July in 2017. Their seasonality at the site may have been impacted by the changes in vegetation and hydrology described above, but the overlook did retain the open water they prefer in August 2017, and this diminution in *L. forensis* and *L. pulchella* was not localized to Westmoreland but was noted at other sites in both east and west Portland (C.A. Searles Mazzacano, pers. obs; D. Deck, pers. comm.). The decrease in these two species may have been more influenced by anomalous late-summer weather conditions, which included triple-digit temperatures as well as haze, smoke, and ash fall from extensive forest fires in the region.

Figure 3. Odonate seasonality and relative abundance at Westmoreland Park in 2017 (A) and 2016 (B). Species abundances are in categories: 1 (uncommon, 1-4 individuals); 2 (frequent, 5-20); 3 (common, 21-100); 4 (abundant, >100). Asterisks indicate surveys done by CASM Environmental.

A. Odonates at Westmoreland Park, 2017.



B. Odonates at Westmoreland Park, 2016.

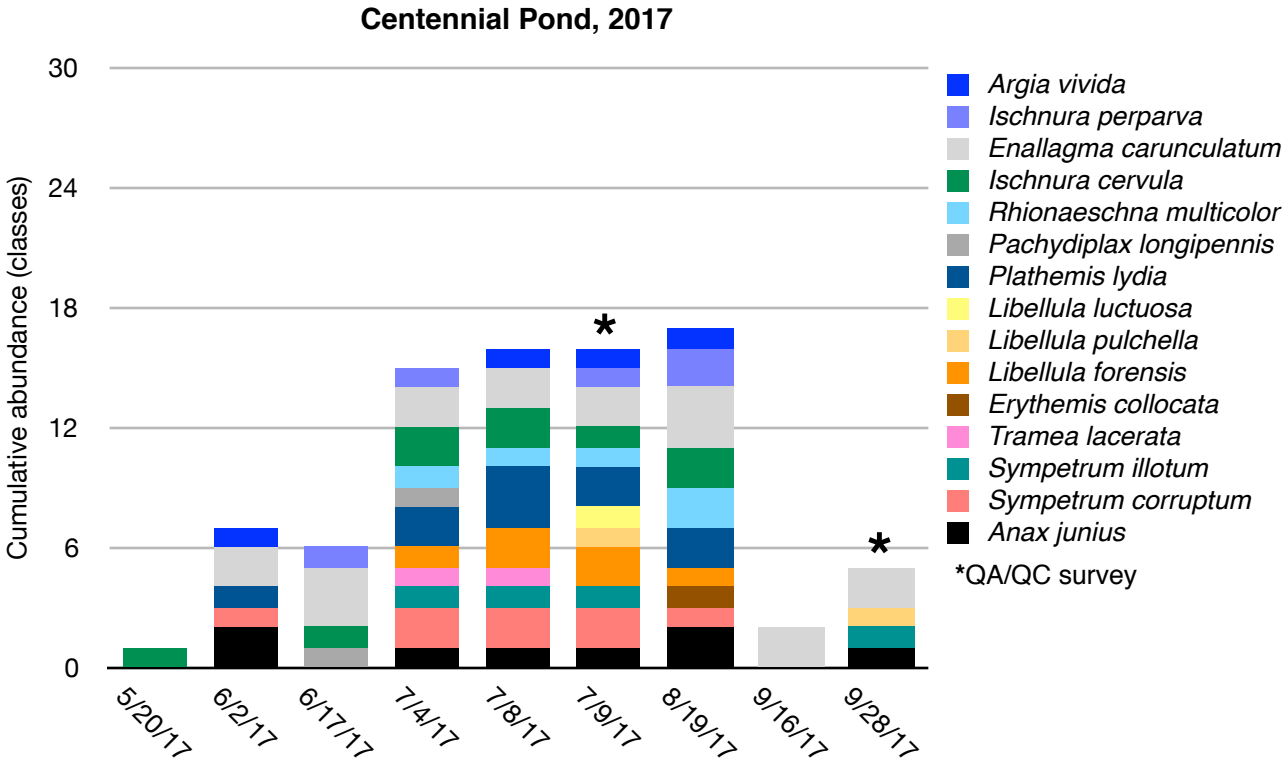


Centennial Pond

This is the first year of surveys at Centennial Pond (Figure 4). This pond will be removed in 2018 as part of ongoing restoration in the Johnson Creek watershed, so these surveys provide a baseline against which future changes in the odonate community can be measured.

Centennial had the lowest diversity of the study sites, with 15 odonate species (11 dragonfly, 4 damselfly). No unique species were seen at this site, although it was the only one of the three study sites where Widow Skimmer (*Libellula luctuosa*) was found in 2017 (however, this species was seen at Westmoreland and Brookside in 2016). This lower number of species is likely due to the fact that this habitat is currently the lowest-quality of the study sites, with little to no emergent or floating vegetation, and an upland largely composed of blackberry and old gravel road, with a narrow ditched creek reach lacking a riparian buffer adjacent to it. This site is also more difficult then the others to survey closely, as the ponds are deep depressions ringed by blackberry and most species must be observed in flight, so individuals resting on vegetation at the edge of the pond may not be noted.

Figure 4. Odonate seasonality and relative abundance at Centennial Pond in 2017. Species abundances are in categories: 1 (uncommon, 1-4 individuals); 2 (frequent, 5-20); 3 (common, 21-100); 4 (abundant, >100). Asterisks indicate surveys done by CASM Environmental.



Migratory Species

Three of North America's five main migratory dragonfly species use the habitat at the study sites (Figure 5): Common Green Darner (*Anax junius*), Variegated Meadowhawk (*Sympetrum corruptum*), and Black Saddlebags (*Tramea lacerata*). The other two migratory species, Wandering Glider (*Pantala flavescens*) and Spot-winged Glider (*P. hymenaea*) are not expected; though both are known in Oregon, there are only a handful of scattered records for *P. flavescens* in the state, and *P. hymenaea*, while more widespread and known from still water habitats in the Willamette Valley, is not common here (Kerst & Gordon, 2011).

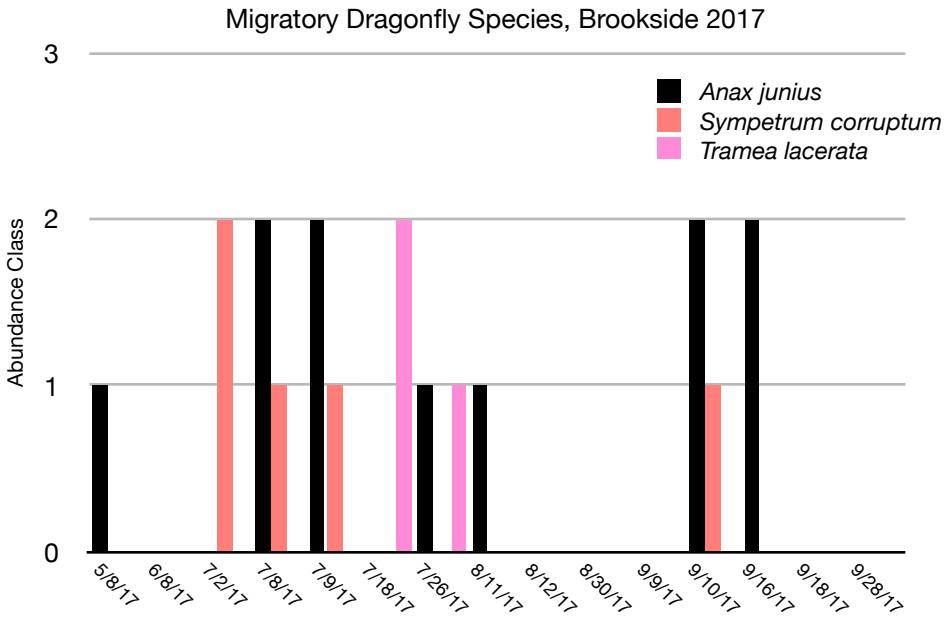
Black Saddlebags were found at Brookside and Centennial in 2017, but unlike 2016, they were not observed at Westmoreland Park (Figure 5). This species prefers larger open expanses of still water such as lakes and ponds, making Brookside and Centennial are more likely habitat at this point; observations of breeding activity (tandem pairs at both sites and oviposition at Centennial) support this. In 2016, Black Saddlebags were seen on only a single date at Westmoreland Park, and coverage of much of the open water at the park in 2017 by dense thickets of jewelweed may have rendered this habitat unappealing. Black Saddlebags are first seen later in the summer than the other migratory species (see below), and were found in early July at Centennial in 2017 and late July at Brookside in both 2016 and 2017.

Variegated Meadowhawk and Common Green Darner are the first migratory species to arrive in our region. In 2017, Common Green Darners arrived at Westmoreland and Brookside on 8 May, two weeks earlier than their first reports at Westmoreland in 2016. Interestingly, although in this species was seen at Brookside in 2016 two weeks after it was reported at Westmoreland, Common Green Darners were seen at both sites on the same date in 2017, but were not observed at Centennial Pond until early June. The presence of mating and ovipositing pairs at Brookside and Westmoreland indicate that this species in continuing to breed at these sites, but only males were reported for the entire season at Centennial Pond. Common Green Darner females lay their eggs in decaying wood and stems of submerged aquatic plants, both of which are lacking at Centennial, so while males patrolled the site it was evidently not considered suitable egg-laying habitat for passing females. Common Green Darners were not seen at any of the sites after late September, consistent with the behavior of a new generation of migratory adults flying south while resident members of the species overwinter locally as nymphs.

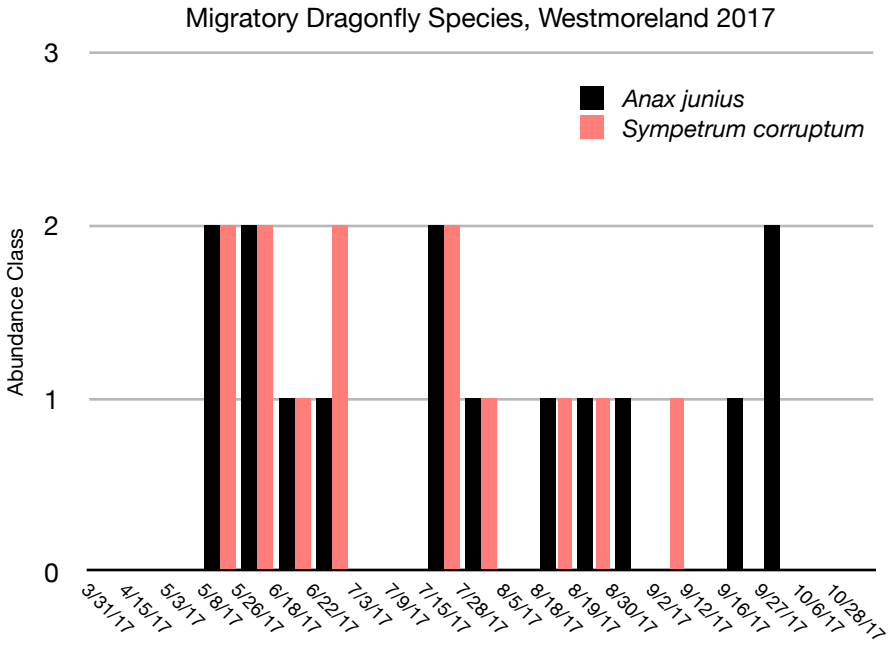
Variegated Meadowhawks arrived at Westmoreland Park a month later in 2017 than in 2016 (8 May vs. 8 April). This species was first seen in early June at Centennial and late July at Brookside (where it was also seen later in the season, i.e., early July, in 2016). This species was not reported at any of the sites after about mid-September. However, the expected late-summer emergence of large numbers of teneral adults (Paulson, 2009) that was noted at Westmoreland in 2016 and in 2015 (C.A. Searles Mazzacano, pers. obs.) did not occur in 2017.

Figure 5. Migratory species at Brookside (A), Westmoreland Park (B), and Centennial Pond (C). Abundance categories: 1 (uncommon, 1-4 individuals); 2 (frequent, 5-20 individuals); 3 (common, 21-100 individuals); 4 (abundant, >100 individuals).

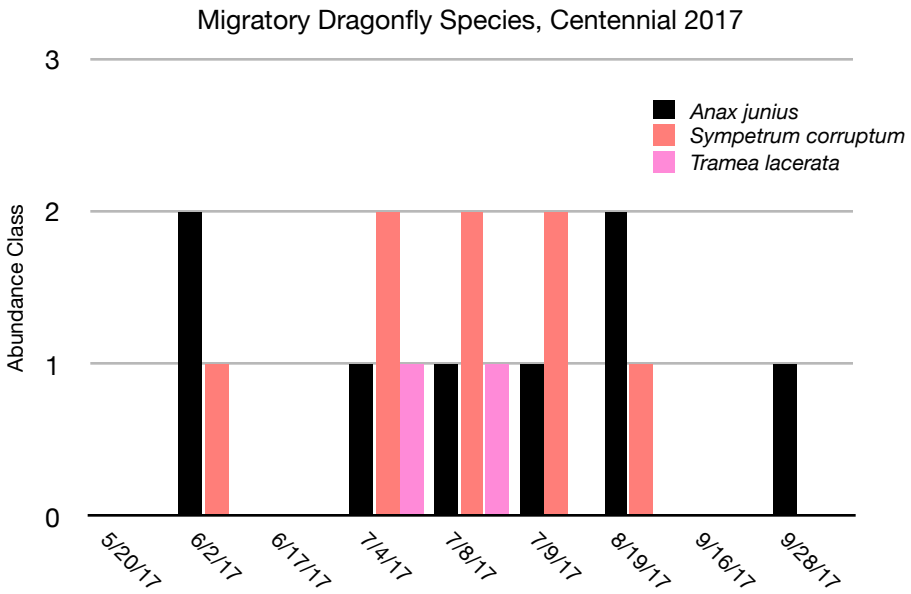
A. Brookside Park, 2017.



B. Westmoreland Park, 2017.

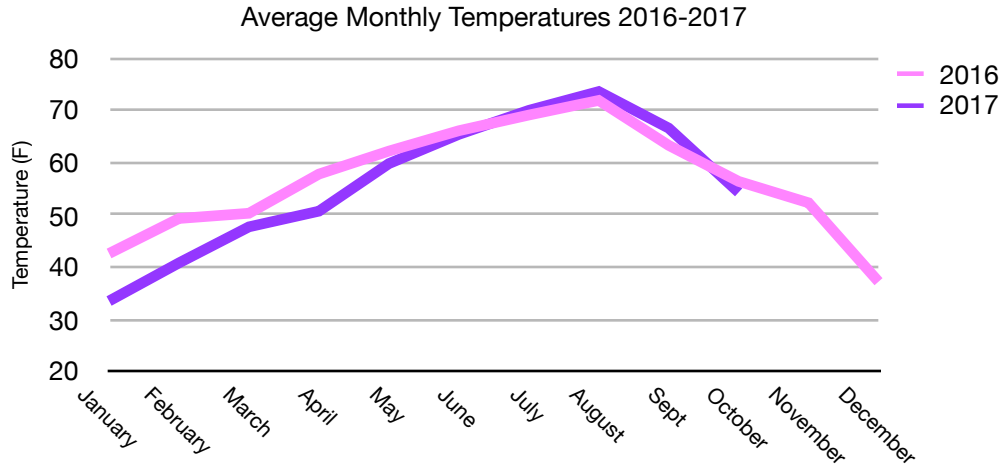


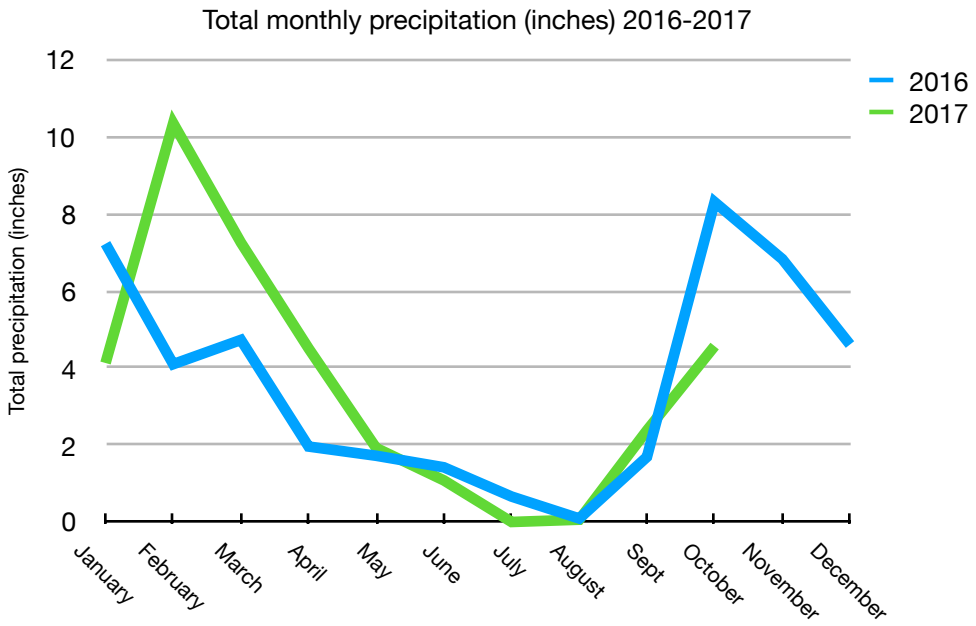
C. Centennial Pond, 2017.



The belated spring arrival of Variegated Meadowhawks may have contributed to the lower levels of adult emergence in late summer. Spring weather in 2017 was colder and wetter than in 2016 (Figure 6), which would slow the northward movement of returning migrants. These migrants mate and lay eggs as they move north, which hatch into nymphs that develop rapidly through the summer to emerge as a new generation of migratory adults in late summer/early fall. With the meadowhawks getting a later start on oviposition in spring, fewer of their offspring may have developed through to adulthood, even with hot summer temperatures favoring more rapid development, leading to the lower numbers of teneral adults seen in late summer.

Figure 6. Comparison of average monthly temperatures and total precipitation in both survey years. Data from NOAA station at the Portland airport (http://w2.weather.gov/climate/index.php?wfo=PQR).





Working with volunteers

Changes made to the project in 2017 based on feedback from participants in the 2016 pilot project were favorably received. More intensive training in 2017 included additional resources, specifically a quick family-level guide to help volunteers narrow down their initial identifications more easily before consulting the field guide; an expanded, detailed section in the Protocols handbook on use of iNaturalist for reporting; and additional iNaturalist training in the classroom and field portions of the training day. Training was also accomplished in a single day, such that all volunteers completed both the field ad classroom sessions, and an optional refresher session has held halfway through the season. Initial feedback from volunteers at the end of the 2017 season indicated that these changes were useful and well-received. A request was made to have the survey conditions rubric (see Table 1) provided on a laminated card for ease of reference, but that was the only substantive resource request made by volunteers.

Based on experiences during the training day and later in the season, it is vital that volunteers receive the formal training before being allowed to participate. Returning volunteers, i.e. peer mentors, should sign up for their survey dates before new volunteers, so that an experienced volunteer is always on a team, especially for the first part of the season while newcomers gain experience. Small children should not be allowed during classroom training, even if it means that some adults may not be able to participate, as this was shown in 2017 to be quite disruptive, with several volunteers complaining to the trainer afterwards about their inability to concentrate due to a noisy and poorly regulated child.

A successful sampling design for community science must strike a balance between having volunteers survey often enough to remain practiced and able to gather reliable, consistent data, but not so frequent as to become

burdensome and discourage participation (Theobald et al., 2015). Retaining experienced volunteers throughout a field season that runs from June through October has been a concern for this project, but changes made in 2017 had positive impacts. Volunteers used the interactive sign-up sheet to communicate among themselves, and expressed appreciation for that and the "toolkit" that JCWC staff assembled. All survey dates were covered, even if the actual date shifted due to weather conditions and/or volunteer availability (with the exception of an end-of-season survey that was persistently rained out), and the independent communication regarding scheduling, availability of substitute surveyors, and mid-season refresher/potluck helped maintain participation and interest.

In any community-based science project, there is always the question of data quality (Frietag et al., 2016). In this project, volunteers are encouraged to submit photo vouchers of all species reported for each date, but many records are sight observations only, which require the data to be accepted with a degree of faith. Species identifications made by volunteers from photos were usually correct, and the crowd-sourcing aspect of identification on iNaturalist, combined with CASM Environmental overview of photo records, provided additional quality control. However, despite additional training and resources, some volunteers appeared to have trouble using iNaturalist. The most common error was volunteers entering multiple reports for the same species during the same survey (i.e., one report for males and another for females), instead of entering a single record per species per survey as instructed that includes all observed genders, abundances, and behaviors. Individuals who submitted such records were queried so the data could be clarified and corrected.

While most of the volunteer survey data were similar to the QA/QC surveys done by CASM Environmental, there are some volunteer surveys that reported a much lower number of species than expected based on the results on surrounding dates. In some cases, records that were not accompanied by a voucher photo and not made by a team including an experienced volunteer were discarded due to either a lack of necessary detail (i.e., "darner" without any accompanying photo), or because of the likelihood of error from sight-only identification (i.e., Northern/Boreal Bluet). However, such records comprised less than 10% of the total records submitted. In the future, short monthly e-mails reminding people of the resources available to them and listing the essential instructions for data reporting could help improve data quality issues, as well as encouraging each team to have a dedicated photographer to capture at least one image of each species seen.

Conclusions

Long-term, place-based monitoring projects enable trends and changes in even common widespread species to be detected. In two years of surveys, this project has already added new odonate species records at both the county level and the site level. The northward expansion of the Flame Skimmer (*Libellula saturata*) continues to be documented; only two years ago, Portland represented the most northern records for this species, while in 2017, the species was first seen in southern Washington (Johnson, 2017) and is now a consistent, expected component of the local odonate population at Portland ponds and wetlands.

Local odonate populations are also responding fairly rapidly to changes in weather and habitat conditions. CASM Environmental initiated independent surveys at Westmoreland Park in 2014 (Searles Mazzacano, 2015) based on informal observations of increases in odonate species diversity and population abundances following stream and floodplain restoration at the park. This habitat has changed further since restoration was finished, with stream banks in some regions eroded and collapsing due to nutria burrowing, and areas of open water being choked out by dense growths of jewelweed, teasel, reed canary grass, and Himalayan blackberry. In 2017, diversity and abundance of dragonfly species peaked in mid-July, about the same time as in 2016, but dropped off more rapidly than in the previous year. In the case of the King Skimmer group (*Libellula* species), these changes were likely compounded by the impacts of hotter dryer weather, since species in that genus were absent earlier than expected at several areas wetlands examined. In contrast, odonate species persisted later in the year at Brookside in 2017 than in 2016; this may be due to the fact that the excessively hot dry summer left few other areas of large open water available locally. Climate conditions may also have been involved in observed changes in Variegated Skimmer populations, with a delay in spring migrant arrival due to cold rainy weather resulting in fewer adults emerging to fly south in late summer.

These surveys are noting patterns and changes in the local odonate community, but the data are also being used on a larger level. Individuals who “vet” the photographic voucher records on OdonataCentral, a site dedicated to monitoring the distribution, biogeography, biodiversity, and identification of dragonflies and damselflies in the Western Hemisphere (Abbott & Broglie, 2005), look increasingly to iNaturalist to find otherwise unreported species records, some of which have resulted in detection of new county records and early or late flight dates. iNaturalist data are freely available for download by interested researchers, and all verified ‘research grade’ records are uploaded to other scientific data portals such as Global Biodiversity Information Facility (GBIF) and Encyclopedia of Life (EoL). The iNaturalist data set has been downloaded over 1500 times from GBIF and overall, GBIF data contributes to over 20 peer-reviewed journal articles each month. The availability and usage of data collected by volunteers in projects such as this is part of the developing positive feedback loop for the practice of citizen science, as researchers avail themselves of data collected by citizen scientists and volunteers realize their data are being used for larger, real-world applications (McKinley et al., 2017). Indeed, at season-end volunteer potluck in 2017, where a summary of the year’s data is shared and volunteers provide feedback, a participant asked

specifically how the data they collect are being used, so this is clearly a motivating factor for volunteers as well. An additional larger impact of citizen science programs includes involving and inspiring the next generation of scientists; in this project, one of the most enthusiastic and effective volunteers began as a high-school student in 2016, returned as a peer mentor volunteer in 2017, and has said that he wants to pursue a career working with insects.

This project continues to generate new data about an understudied but charismatic group and is expanding our knowledge of local biodiversity, impacts of site restoration and habitat conditions on local biota, and effects of climate change on local life-history of both resident and migratory dragonfly species. We can continue to ensure accurate data in years to come through ongoing oversight by subject matter experts, classroom training and field sessions for volunteers, a strong push to submit photo- or video-vouchered records whenever possible, and encouraging volunteers from previous years to continue to be involved as peer mentors for new participants in the project.

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Appendix A. JCWC Dragonfly and Damselfly Community-based Monitoring Project Datasheet

DATE _____ **SITE NAME** _____ **START TIME** _____ **END TIME** _____

OBSERVER NAME(S) _____

WEATHER: Temperature _____ ºC / ºF Wind (calm, light, moderate, strong) % cloud cover _____

NOTES _____

_____

Species List: Record the species observed; circle 'M' and/or 'F' to indicate whether males or females were seen. Record abundance category and all ID methods and reproductive stages observed using the appropriate letter codes.

Identification method
(record all that apply)

V (visual)
C (captured)
P (photograph)

Abundance category

N (none, 0)
U (uncommon, 1-4)
F (frequent, 5-20)
C (common, 21-100)
A (abundant, >100)

Reproductive stage
(record all that apply)

W (wheel)
TP (tandem pair)
O (ovipositing)
TA (teneral adult)

Species Name	ID Method	Abundance	Reproductive stages
M F			
M F			
M F			
M F			
M F			
M F			
M F			

Appendix B. Species list for all survey sites, 2016-2017

		Westmoreland Park		Brookside Wetland		Centennial Pond
Species	**Common name**	**2017**	**2016**	**2017**	**2016**	**2017**
Anax junius	Common Green Darner	Y	Y	Y	Y	Y
Aeshna palmata	Paddle-tailed Darner	Y	Y	N	Y	N
A. umbrosa	Shadow Darner	Y	Y	N	N	N
Sympetrum corruptum	Variegated Meadowhawk	Y	Y	Y	Y	Y
S. costiferum	Saffron-winged Meadowhawk	Y	N	N	N	N
S. danae	Black Meadowhawk	N	Y	N	N	N
S. illotum	Cardinal Meadowhawk	Y	Y	Y	Y	Y
S. madidum	Red-veined Meadowhawk	Y	N	N	N	N
S. pallipes	Striped Meadowhawk	Y	N	Y	N	N
S. vicinum	Autumn Meadowhawk	N	Y	N	N	N
Tramea lacerata	Black Saddlebags	N	Y	Y	Y	Y
Erythemis collocata	Western Pondhawk	Y	Y	N	Y	Y
Libellula forensis	Eight-spotted Skimmer	Y	Y	Y	Y	Y
L. luctuosa	Widow Skimmer	N	Y	N	Y	Y
L. pulchella	Twelve-spotted Skimmer	Y	Y	Y	Y	Y
L. quadrimaculata	Four-spotted Skimmer	N	Y	N	N	N
L. saturata	Flame Skimmer	Y	Y	Y	Y	N
Plathemis lydia	Common Whitetail	Y	Y	Y	Y	Y
Pachydiplax longipennis	Blue Dasher	Y	Y	Y	Y	Y
Rhionaeschna multicolor	Blue-eyed Darner	Y	Y	Y	Y	Y
Ischnura cervula	Pacific Forktail	Y	Y	Y	Y	Y
I. perparva	Western Forktail	Y	Y	Y	Y	Y
Enallagma carunculatum	Tule Bluet	Y	Y	Y	Y	Y
E. annexum/boreale	Northern/Boreal Bluet	Y	N	Y	N	N
Archilestes californicus	California Spreadwing	Y	Y	Y	Y	N
Argia vivida	Vivid Dancer	Y	Y	Y	Y	Y