2019 LOWER DESCHUTES RIVER MACROINVERTEBRATE HATCH ACTIVITY SURVEY REPORT

Deschutes River Alliance
April 2020

KEY FINDINGS:

- The majority of hatch surveys reported "none" (0's) present and indicated a low abundance of the major hatches of stoneflies, caddisflies, mayflies, and Diptera.
- Shifts in hatch timing were also observed, particularly for the pale morning dun mayfly, salmonfly, and golden stone. Adult emergence for these two stoneflies has consistently occurred four to five weeks earlier when compared to hatches observed in the pre-Tower period.
- Adult hatches for the salmonfly and golden stone showed slight improvement compared to prior years.
- Hatches of Diptera remain low. However, some recovery of the crane fly occurred.
- Changes in seasonal water temperature and annual water quality have led to changes in the abundance, distribution, and emergence timing of aquatic insects in the lower Deschutes River.

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Last, thanks to all of those who care about the Deschutes River and have contributed hours of their time and money to better understand the river's changing ecology, and protect its health. Many hundreds of people and numerous companies and foundations have made it possible to keep this work moving forward - THANK YOU.

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BACKGROUND

The effects of the Selective Water Withdrawal Tower (hereafter: Tower) on water quality in the 100 miles of the Deschutes River downstream from the Pelton Round Butte Hydroelectric Project (hereafter: Project) have been an ongoing concern since the Tower was completed in December 2009. A thorough discussion of the Tower's construction and operation was covered in the Deschutes River Alliance's 2016 water quality report (DRA 2017). The Deschutes River Alliance (DRA) began research on the issue in 2013 and has identified a number of water quality problems connected with the release of surface water from Lake Billy Chinook:

1. Surface water in Lake Billy Chinook is now discharged through the Tower and into the lower Deschutes River. That surface water is primarily water that originates from the Crooked River (Eilers & Vache 2019). Water quality in the Crooked River Basin is "poor" compared to the "excellent" water quality in most of the Upper Deschutes Subbasin (ODEQ 2012). This change in water quality discharged into the lower Deschutes River resulted in high pH measurements that exceeded the state water quality standard for the basin (DRA 2015, 2017, 2018a, 2019a). In addition, based on long-term data collected by the Oregon Department of Environmental Quality, the frequency of pH measurements above the basin's upper limit has increased since the Tower began operating (DRA 2019a). Temperature and dissolved oxygen also periodically exceed state standards for the basin as well as the water quality limits placed on the Project in the state's license (CWA § 401 Certification) for operation of the Tower (DRA 2017, 2018a, 2019a).
2. The water quality decline is in large part due to the high proportion of nitrates (NO_3) in Crooked River water (Eilers & Vache 2019). Nitrogen levels are highest in the Crooked River compared to the other major tributaries (Deschutes and Metolius rivers) of Lake Billy Chinook. The source of nitrogen is primarily from agricultural activities in the Crooked River Basin (DRA 2019b).
3. Releasing surface water from Lake Billy Chinook into the lower Deschutes River throughout the winter, spring, and early summer results in warmer water temperatures in the lower Deschutes River from November through early July—as compared to the pre-Tower period (Eilers & Vache 2019). This warmer water along with higher nutrient levels has promoted excessive algae and periphyton growth on the river's substrate. Extensive blooms of nuisance algae (in particular two species of diatoms) that produce felt-like mats are now common on the lower Deschutes River (DRA 2014). For further discussion on the *Potential Effects*

of Temperature Changes on Macroinvertebrates by Rick Hafele see the DRA 2013 Macroinvertebrate Hatch Activity Survey Results (link).

4. Declines in water quality and unfavorable changes in stream substrate for aquatic invertebrates have resulted in a decrease in the abundance of pollution sensitive aquatic insects in the lower Deschutes River (DRA 2014; Edwards 2018). In addition, annual hatch surveys indicate that the timing and abundance of adult aquatic insect emergence has changed (DRA 2018b). For further discussion on the *Potential Effects of Water Quality Changes on Macroinvertebrates* by Rick Hafele see DRA 2013 Macroinvertebrate Hatch Activity Survey Results (link).

5. Analysis of benthic macroinvertebrate samples from 2015 and 2016 indicates overall "poor" stream conditions in the lower Deschutes River (DRA 2019c). Samples collected during the study were dominated by pollution tolerant worms and snails. A high proportion of non-insects (primarily worms and snails) and a decrease in pollution sensitive aquatic insects are consistent with changes due to nutrient enriched eutrophic conditions, as is found in other rivers with high nutrient loads.

INTRODUCTION

In 2019, the DRA continued its annual survey program for adult aquatic insects in the lower Deschutes River. Between February-November, 2019, a total of 169 surveys were completed and submitted. The results from 2019 are consistent with prior years' surveys (DRA Macroinvertebrate Hatch Activity Survey Results 2013-2017). Survey results indicate a shift in the timing of the adult aquatic insect emergence and the overall low abundance of adults of the major insect hatches found in the lower Deschutes River (prominent hatches of mayflies, stoneflies, and caddisflies). Prior benthic macroinvertebrate studies (collections of nymphs and larvae that live on the streambed) have shown a decline in the number of pollution sensitive aquatic insects and an increase in the number of pollution tolerant non-insects (Nightengale & Shelly 2017). Overall these benthic studies have characterized the stream condition of the lower Deschutes River as "poor" (Edwards 2018; DRA 2019c).

Benthic macroinvertebrate samples are the most common approach used to monitor changes in aquatic life and assess stream quality (ODEQ 2009). However, this method fails to assess changes in adult insect emergence timing or abundance. To address this shortcoming, the DRA implemented a survey program in 2013 where river guides could document the presence and abundance of the major adult aquatic insect hatches during their guide trips on the river. Data were entered through a smart phone app or field form, and then uploaded to an online database. This report covers survey data collected in 2019.

SAMPLING METHODS

In 2019, the DRA partnered with Trout Unlimited to create a cell-phone app to make the survey process more streamlined and user-friendly. The surveys now use the online app “KoBo Toolbox”. Instructions for how to use and download the app are available at: https://deschutesriveralliance.org/aquatic-insect-survey-app-1. This new app allows users to collect data on a cell phone even when out of cell-phone service, provides photographs for identification, and contains other features to ensure the app is easy to use and that the data collected are accurate. When the phone is within cell-phone service range the app will automatically upload completed surveys to an online database. Table 1 shows the total number of surveys collected by stream reach and month for 2019. No surveys were submitted for January or December in 2019.

TABLE 1. Number of surveys collected by stream reach and month for 2019.

2019 Aquatic Insect Hatch Observation Survey Summary Results										
Month & Reach	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	**Total Surveys by Reach**
Warm Springs to Trout Cr.	1			5	1	1	1				9
Trout Cr. to Whitehorse	1			1	1						3
Whitehorse to Harpham	4	5	5	7	7	1				1	30
Harpham to Sandy Beach	1	1	1	21	12	4	2	2	2		46
Pine Tree to Mack’s Canyon		4	2	19	10	16	17	2			70
Mack’s Canyon to Mouth							2	9			11
Total Surveys by Month	7	10	8	53	31	22	22	13	2	1	**169**

As we have seen in prior years the majority of the surveys were submitted in May (Table 1). We believe this reflects the shift in emergence timing of most of the major hatches, including the salmonfly and golden stone hatches, to earlier in the year. The result is that the majority of trout fishing activity, including guided fishing trips, has also shifted to early in the season, and are now concentrated in May and early June. This is when the best opportunity for fishing during peak hatch activity occurs (and thus the opportunity for fishing success).

Table 2 shows the 18 major adult insect hatches typically found on the lower Deschutes River that were recorded in the 2019 survey app. Some species had too few entries to report and are not included in the results: Pink Alberts (*Epeorus* spp.), American Grannom (*Amiocentrus* spp.), and short-winged stone (*Claassenia sabulosa*). The level of abundance for each insect taxon observed was recorded as either a "0" indicating none were observed, "1" as low numbers observed, "2" as moderate numbers seen, or "3" indicating high numbers were observed. Additional information for date/time, location, weather, temperature (air and water if available), and fishing activity was also recorded.

Table 2. Major hatches covered by surveys.

INSECT ORDER			
MAYFLIES	**STONEFLIES**	**CADDISFLIES**	**DIPTERA**
Species name (Common name/Hatch name)			
Baetis sp. (Blue-winged Olive)	*Skwala americana* (Brown Willow Fly)	*Rhyacophila* sp. (Green Rock Worms)	Chironomidae (Midges)
Ephemerella excrucians (Pale Morning Duns)	*Hesperoperla pacifica* (Golden Stone)	*Hydropsyche* sp. (Net-spinning Caddis)	*Antocha* sp. (Crane Fly)
Drunella grandis (Green Drake)	*Pteronarcys californica* (Salmonfly)	*Glossosoma* sp. (Saddle-case Caddis)	
Rhithrogena morrisoni (March Brown)	Perlodidae (Yellow Sallies)	*Dicosmoecus* sp. (October Caddis)	**OTHER**
Heptagenia sp. (Pale Evening Dun)		*Hydroptilidae* (Micro Caddis)	*Petrophila* sp. (Aquatic Moth)
Paraleptophlebia sp. (Mahogany Duns)			

The survey results from 2019 for aquatic insect hatch abundance were organized and graphed in Excel. The methods used for calculations are described in the following section (RESULTS & DISCUSSION). Data from prior years were added to the graphs for comparison. Results from 2013 were omitted for comparison because too few surveys were submitted to compare. The survey was not performed in 2018 as the 2017 app could no longer be used because support for its software ended and the new app was under development.

We recognize that these surveys do not provide *quantitative* data on adult insect abundance. Gathering such quantitative information would require complex sampling methods and funding beyond the reach of this study. However, the survey data shown here still provide valuable information over extended periods of time, and represent the only attempt that we know of to systematically document changes in adult emergence timing and abundance. To maximize the accuracy and consistency of information gathered for these surveys, the surveys were completed by experienced fly fishing guides and a few anglers with a history of fishing and observing hatch activity on the lower Deschutes River. In addition, an identification training session was held for guides and interested anglers March 24th, 2019 in Maupin, OR, and an identification guide for the Deschutes River (Hafele 2015) was provided for reference.

Note: In April 2020 an online training video was created. The Deschutes River Hatch Survey & Identification Training by Rick Hafele is available here: https://vimeo.com/403088325

RESULTS & DISCUSSION

ASSESSMENT OF MAJOR ORDERS

The overall abundance ratings for the four major orders of aquatic insects (Ephemeroptera-Mayflies; Plecoptera-Stoneflies; Trichoptera-Caddisflies; and Diptera-True flies) are shown in Table 3. Each order is composed of several individual species or hatches (Table 2); thus, the total number of observations noted in Table 3 for each order equals the total number of observations for all hatches in that order. While the maximum possible number of observations for any individual hatch is the total number of surveys recorded, because each hatch is present as adults for only part of the year, only the observations made during each hatch's known emergence period are counted (see APPENDIX for emergence periods used in 2019).

For example, the total number of observations listed for the six hatches of mayflies in 2019 is 600 (Table 3), while the maximum number of possible observations is 1,014 (6 hatches x 169 surveys) if all hatches were present for the entire survey period. The total number of observations recorded with low abundance (1's) for all six species of mayflies was 95, or 16%, of the 600 total number of observations. Thus, the number of hatches within each order, and the number of surveys recorded only during their expected emergence period, determines the total number of observations for each order.

TABLE 3. 2019 Summary table of adult abundance for the four major insect orders.
0=*none observed* 1=*low abundance* 2=*moderate abundance* 3=*high abundance*

INSECT ORDER & TOTAL # OF OBSERVATIONS				
	STONEFLY ADULTS	**CADDIS ADULTS**	**MAYFLY ADULTS**	**DIPTERA ADULTS**
Total	346	565	600	326
# of observations with 0's recorded	175 = 50%	322 = 57%	355 = 59%	213 = 65%
# of observations with 1's recorded	49 = 14%	92 = 16%	95 = 16%	40 = 12%
# of observations with 2's recorded	61 = 18%	96 = 17%	116 = 19%	55 = 17%
# of observations with 3's recorded	61 = 18%	55 = 10%	34 = 6%	18 = 6%

The total number of observations received in 2019 was higher for all four orders compared to prior years. Additionally, the majority of all observations were recorded as "none" (0's) for all orders (Table 3). The percentage of surveys that reported low abundance (1's) remained below 16% for all four major orders. In addition, the percentage of surveys that reported moderate abundance (2's) remained below 19% for the four major orders. Lastly, the percentage of surveys that reported high abundance (3's) was low, <10%, for all orders except for stoneflies (18%). Figures 1-4 summarize differences in the observed relative abundance (% of total observations) of the four major insect orders compared to survey results since 2014.

Figure 1 shows the survey results for stoneflies. In 2019 we had the highest percentage of surveys with observed high abundance (3's-18%) for stoneflies compared to prior years. Surveys with low and moderate (1's-14% & 2's-18%) abundance were slightly lower compared to prior years. The number of surveys with no stoneflies observed (0's) accounted for 50% of the surveys submitted in 2019.

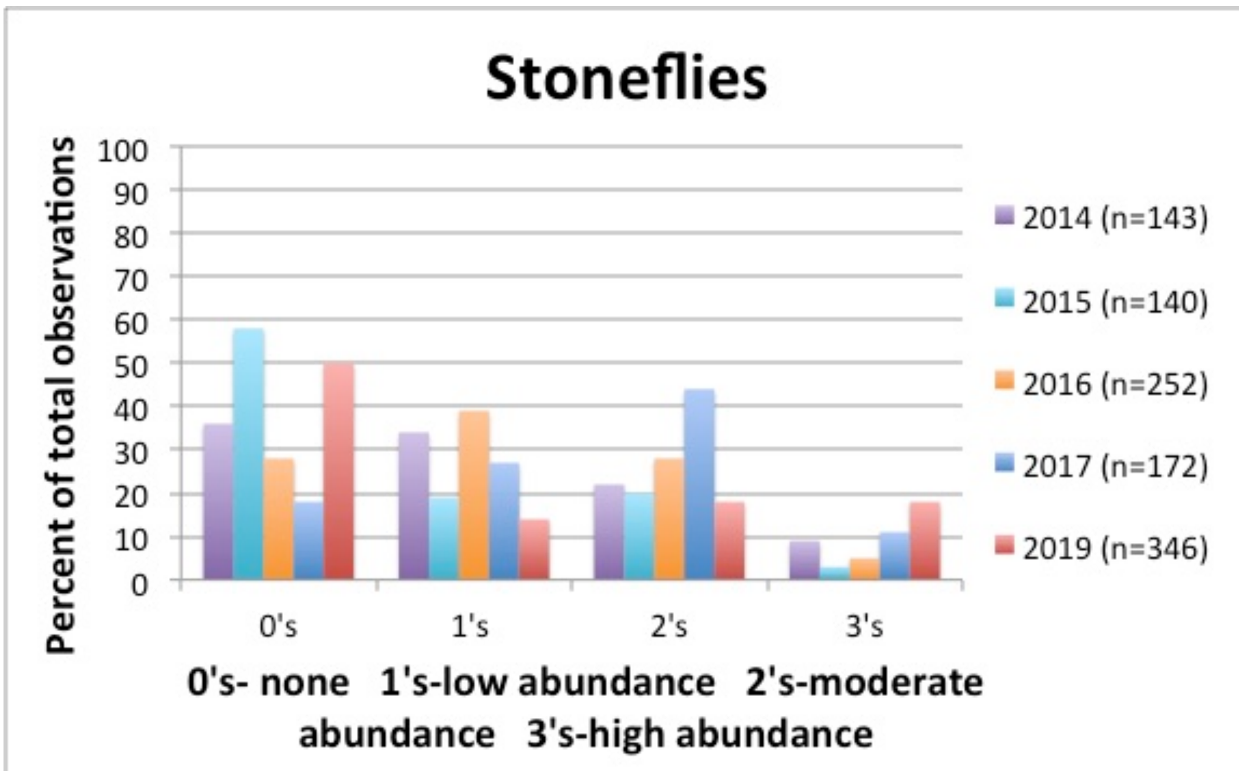

Figure 1. Adult stonefly abundance from 2014-2019 (no survey data from 2018).

Figure 2 shows the survey results for caddisflies. In 2019, the percent of surveys reported as "none" (0's-57%) for caddisflies was slightly higher than in prior years. The percent of surveys reported as low and moderate abundance (1's-16% & 2's-17%) in 2019 was slightly lower compared to prior years. A fairly high percent of 1's, 2's, and 3's were reported in surveys from 2015 when caddisflies were the most common order recorded on the surveys (DRA 2016). The percent of surveys that were reported as high abundance (3's) was 10% in 2019 and within the range observed in prior years.

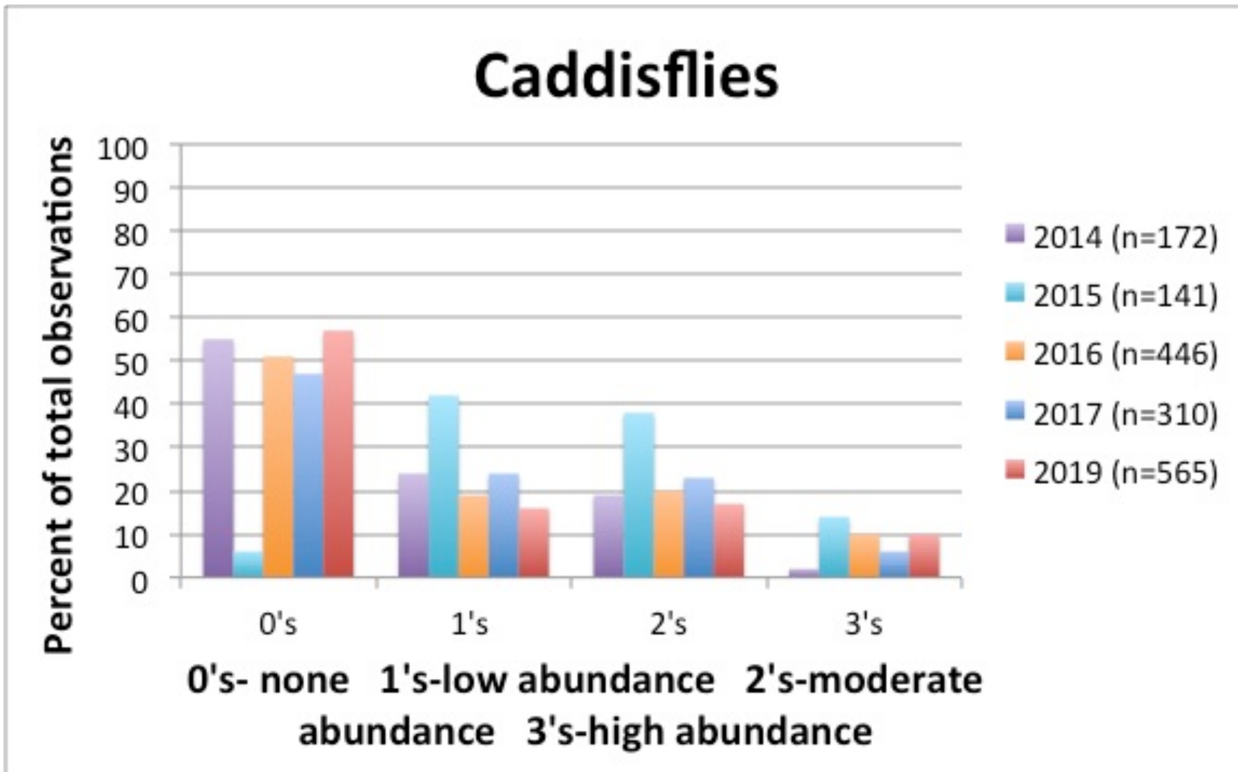

Figure 2. Adult caddisfly abundance from 2014-2019 (no survey data from 2018).

Figure 3 shows the survey results for mayflies. Adult mayfly abundance has been low for a number of years with a high percentage of observations reporting no adult mayflies (0's>50%) in the years 2016, 2017, and 2019. In addition, the percent of observations for low abundance (1's) has declined since 2014. Observations for moderate abundance (2's-19%) were slightly higher than prior years; however, within the range previously observed. The percent of surveys in 2019 that reported mayflies in high abundance (3's-6%) were slightly higher compared to prior years; however, 6% still represents very few mayfly hatches with high abundance, and the slight increase in 2019 was not large enough to indicate a noticeable improvement in overall adult mayfly abundance. Overall the results show a low abundance of adult mayflies present in 2019.

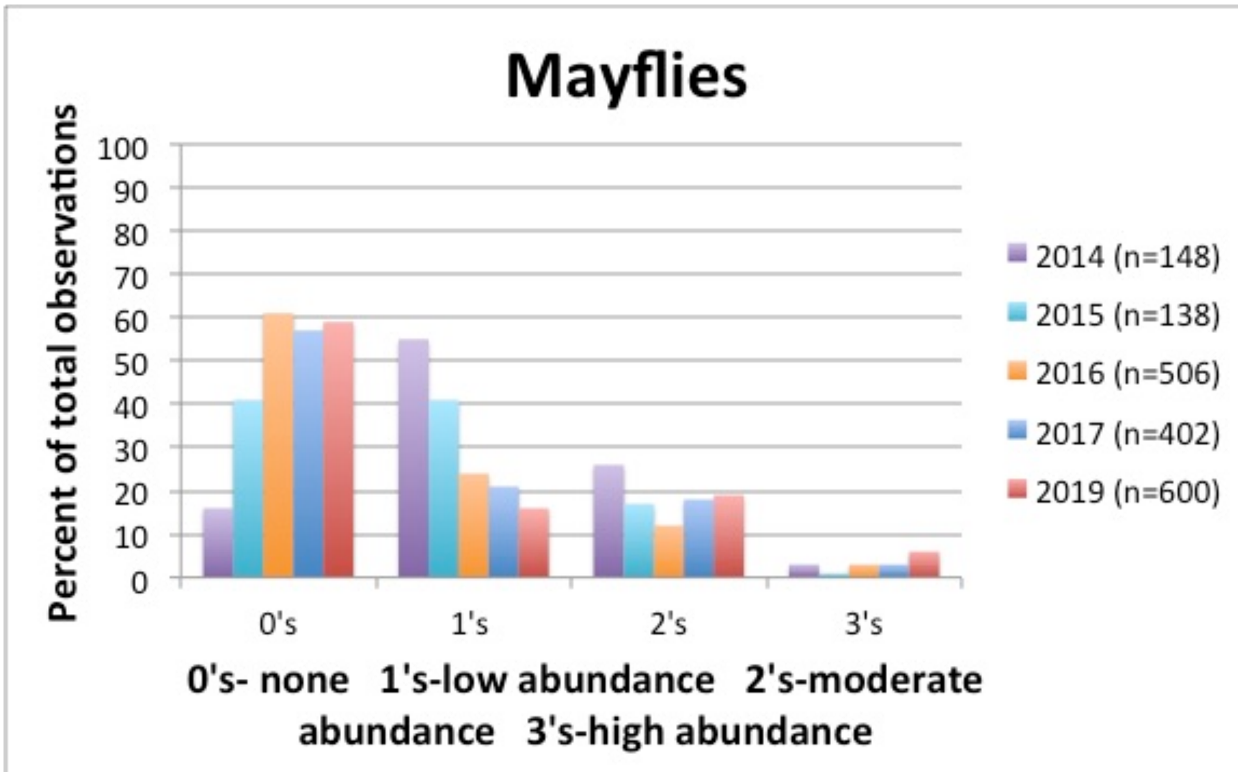

Figure 3. Adult mayfly abundance from 2014-2019 (no survey data from 2018).

Figure 4 shows the survey results for Diptera (true flies). Hatch activity was relatively low in 2019 with 65% of observations recording "none" (0's). The majority of surveys have reported "none" (0's) since 2014. The percent of surveys reporting low abundance (1's) has remained within the range observed in prior years. A slight decrease in the percent of surveys reporting moderate abundance (2's-17%) occurred in 2019. The percent of surveys that reported high abundance (3's-6%) was slightly lower when compared to the years 2015-2017. These results indicate that overall abundance for adult Diptera is low; however, it is worth noting that Diptera adult emergence spans a wide period of time from February 1-November 31. This long emergence period may result in under-reporting of Diptera on days in which hatches occur but no surveys (i.e., guide trips or fishing) are done.

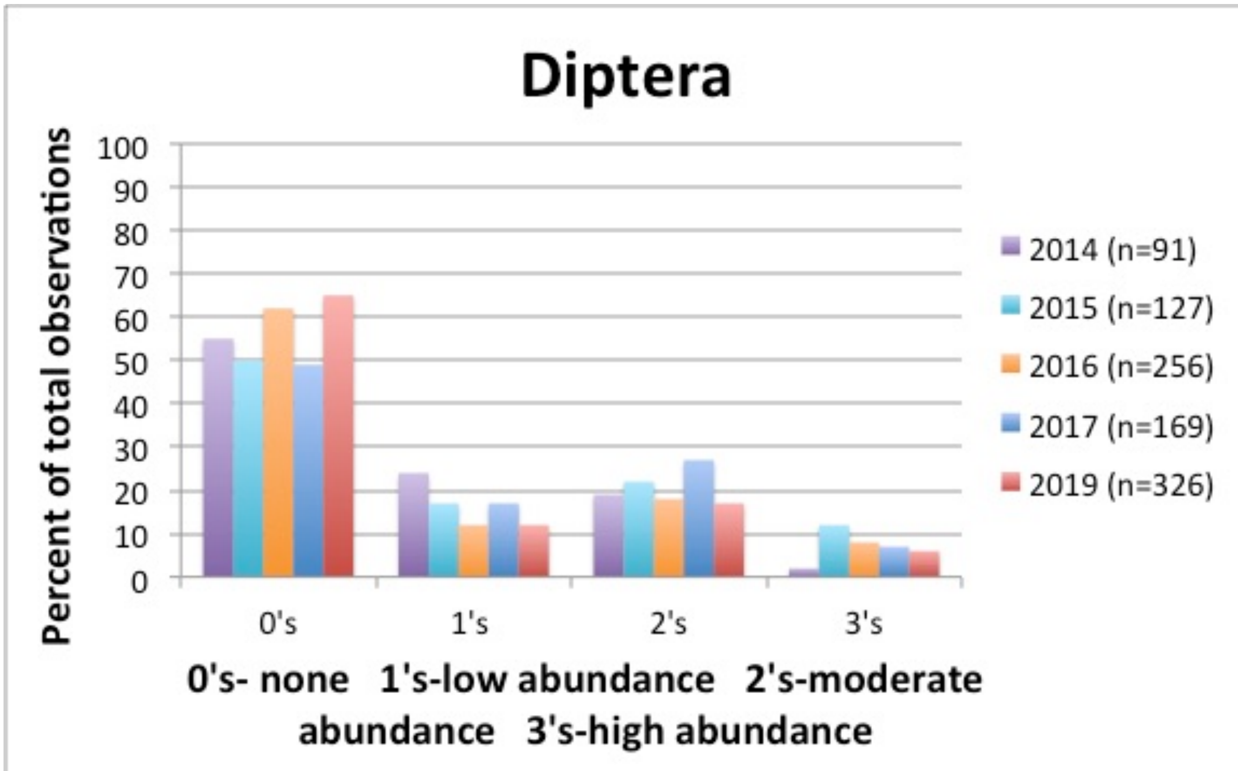

Figure 4. Adult Diptera abundance from 2014-2019 (no survey data from 2018).

Information about the different insect orders provides a broad picture of insect activity whereas the adult abundance of specific insect hatches (i.e., genus and/or species) within each order provides a more detailed understanding. For example, as the effects of organic pollution increase two species in the families Hydropsychidae (caddisfly) and Baetidae (mayfly) are known to increase in abundance relative to other families in their orders (Barbour et al. 1999). The following discussion summarizes the results for each of the major hatches within each order.

INDIVIDUAL HATCH ASSESSMENTS

STONEFLIES (PLECOPTERA)

Stoneflies require cool water temperatures, approximately 5-12°C (41-54°F) for some species, and adequate dissolved oxygen needs to be present for their nymph stages to thrive (Jewett 1959). Thus, many stoneflies prefer streams that have frequent moderate to fast riffles, cool water, and large rocky substrate (Hafele 2015). Their growth and development is directly affected by food availability and water temperature (Jewett 1959). Stonefly species vary in the duration of their life cycles and development. Some species have one-year life cycles, whereas other species may require multiple years before emerging and reproducing. The largest and longest-lived species (e.g., salmonflies) require up to four years as nymphs until adult emergence.

Table 4 shows the results for the four stonefly hatches observed in 2019. Observations for the short-winged golden stone (*Claassenia sabulosa*) were not reported (only one survey record during the emergence period), and no surveys reported other stonefly species. Though more than 25 stonefly taxa have been identified in the lower Deschutes, most are rare or emerge outside the sample period of the majority of guide surveys.

Table 4. Summary table of stonefly hatch abundance in 2019.

0=*none observed* 1=*low abundance* 2=*moderate abundance* 3=*high abundance*

	Salmonfly	Golden Stone	Brown Willow Fly	Yellow Sally
Feeding Guild	Shredder	Predator	Predator	Predator
Total # of surveys with expected presence	84	84	71	107
# of observations with 0's recorded	33 = 39%	29 = 35%	65 = 92%	48 = 45%
# of observations with 1's recorded	15 = 18%	15 = 18%	3 = 4%	16 = 15%
# of observations 2's recorded	12 = 14%	15 = 18%	3 = 4%	31 = 29%
# of observations with 3's recorded	24 = 29%	25 = 29%	0	12 = 11%

The salmonfly (*Pteronarcys californica)* and golden stone (*Hesperoperla pacifica)*, produce the most famous and important hatches on the lower Deschutes River creating excellent dry-fly fishing opportunities and drawing anglers from across the country

(Figure 5-6). Salmonflies are the largest of the stoneflies in North America (Figure 5). In Oregon, the emergence period for salmonflies is from early May to mid-June and generally begins when water temperature is close to 10°C (50°F); however, hatches have also occurred as late as mid-July (Hafele 2015). Nymphs require 2-4 years to complete development and can be found in multiple year classes in the lower Deschutes River (Hafele 2015).

Figure 5. Salmonfly adult. Photo by: Rick Hafele

The emergence period for the golden stone on the lower Deschutes River is currently from about May 1 to July 1 with peak emergence in mid to late May. Immature nymphs take 2-3 years to complete development (Hafele 2015). The golden stone is a predator and feeds on smaller aquatic organisms (Figure 6).

Figure 6. Golden stone adult. Photo by: Rick Hafele

In 2019, the majority of surveys that observed salmonfly and golden stone hatches occurred from May 6-June 4 (>61% of surveys with 1's-3's observed). The results of our survey and prior years' surveys (DRA Macroinvertebrate Hatch Activity Survey Results 2014-2017) indicate that adult emergence for these two stoneflies has consistently occurred four to five weeks earlier when compared to hatches observed in the pre-Tower period (prior to 2010). In addition to earlier emergence, which anglers have been adjusting to by fishing earlier in the year the overall abundance of these two species has remained relatively low. However, it is worth noting that in 2019 there was a higher percentage of 3's recorded for the golden stone (29%) and salmonfly (29%) when compared to prior years' surveys (golden stone 3's for 2016: 10%, 2017: 20%)(salmonfly 3's for 2016: 8%, 2017: 8%).

Yellow sally hatches consist of multiple species within the family Perlodidae. Prior to SWW Tower operations, yellow sally adults were common from late June through mid-August with peak adult abundance typically in mid July (Hafele 2015). In 2019, adults were observed from May-June with peak activity occurring in late May and early June. These observations are consistent with hatches observed in 2016/2017 and indicate a shift towards earlier emergence timing. In 2019, there was a higher percentage of 3's (11%) recorded for yellow sallies than reported in years 2014-2017 (range: 0-3%).

Brown willow fly hatches consist of two species in Oregon and are also within the stonefly family Perlodidae. They are very common throughout Oregon and typically emerge from mid-March to late May (Hafele 2015). Depending on location (elevation/latitude) emergence can occur from February-July (Hafele 2015). The survey results for brown willow fly in 2019 show very low abundance with 92% of surveys reporting "none" (0's). Only six records, or <8% of surveys, reported low to moderate abundance (1's & 2's)(Table 4).

Overall stonefly adult hatch activity showed a slight improvement in 2019 for salmonfly, golden stone, and yellow sally hatches compared to 2014-2017. However, the order as a whole had a high percentage of surveys reported as "none" (0's = 50%) observed and may indicate that the overall abundance during adult hatches is low (Figure 4). Brown willow fly hatches were not reported in prior years' surveys but indicated low abundance in 2019 (92% of surveys reported "none")(Table 4).

CADDISFLIES (TRICOPTERA)

Benthic studies have found almost 40 different caddisfly taxa in the lower Deschutes River (Nightengale et al. 2016). Most of these taxa are neither abundant nor common, and do not create large adult hatches, and therefore are not included in the hatch survey. In the period of time prior to the SWW Tower (before 2010), net-spinning caddis (family Hydropsychidae) typically produced the largest caddisfly hatches in the lower Deschutes River. Table 5 shows the results for five caddisfly hatches covered by the hatch survey in 2019.

Table 5. 2019 summary table of caddisfly hatch abundance.

0=*none observed* 1=*low abundance* 2=*moderate abundance* 3=*high abundance*

	Green Rock Worm	Net-spinning Caddis	Saddle-case Caddis	Micro Caddis	October Caddis
Feeding Guild	Predator	Filterer	Scraper	Scraper	Scraper
Total # of surveys with expected presence	143	141	149	110	22
# of observations with 0's recorded	107 = 75%	31 = 22%	109 = 73%	61 = 55%	14 = 64%
# of observations with 1's recorded	24 = 17%	21 = 15%	23 = 16%	18 = 16%	6 = 27%
# of observations 2's recorded	10 = 7%	54 = 38%	15 = 10%	15 = 14%	2 = 9%
# of observations with 3's recorded	2 = 1%	35 = 25%	2 = 1%	16 = 15%	0

In 2019, net-spinning caddis had the highest percent of observations with high abundance (3's-25%) compared to the other four caddis hatches. Net-spinning caddis belong to the family Hydropsychidae, and include several genera and numerous species (Figure 7). The percent of observations with 1's, 2's, and 3's for net spinning caddis was within ranges observed in prior years' surveys (DRA Macroinvertebrate Hatch Activity Survey Results 2014-2017). As their name suggests, the net-spinning caddis as larvae are filter feeders and construct spider-like webs on the surface of cobbles in riffle areas they inhabit to capture food. An expected response to increasing organic pollution - as the Tower has done by releasing surface water, and thus, released more algae into the lower Deschutes River - is an increase in the relative abundance of species in the family Hydropsychidae (Barbour et al. 1999).

Figure 7. Net spinning caddis adult (*Hydropsyche* sp.). Photo by: Rick Hafele

As stated above, food for filter feeders has likely increased as a result of the Tower releasing surface water, which entrains algae and cyanobacteria from the surface of Lake Billy Chinook and is released into the lower Deschutes River (Eilers & Vache 2019). In addition, the increased growth of nuisance algae has likely reduced food availability for aquatic insect scrapers (DRA 2014). At the time of this writing, no conclusive studies have been done to confirm changes in food availability for different aquatic insects. However, an increase in net-spinning caddis (a filter feeder) is consistent with the observed changes in water quality as a result of surface water releases from Lake Billy Chinook that likely provides more suspended material in the water for filter feeders like net-spinning caddis to feed on.

Before the Tower began releasing surface water in late 2009, net-spinning caddis produced very large numbers of adults throughout June, July, and August. In addition they provided a consistent food source for birds and other wildlife and often produced aggressive fish feeding behavior. Since the SWW Tower began operating, net-spinning adult activity is now concentrated in May and June, with sporadic adult activity seen in July and August (DRA Macroinvertebrate Hatch Activity Survey Results 2014-2017). However, in 2019 the results suggested a slight improvement in hatch timing compared to prior years; there were a number of surveys that recorded high abundance (3's) in late July through September.

Two other important caddisfly hatches are the green rock worm (genus *Rhyacophila*) and saddle-case caddis (genus *Glossosoma*). Survey results for these two caddis hatches showed "none" (0's) in 73-75% of surveys (Table 5). This was an increase in the percent of 0's when compared to prior years' surveys indicating a low overall abundance for both hatches. The green rock worm encompasses a diverse group of caddis species that inhabit cool and well-oxygenated streams. Emergence timing for the green rock worm typically occurs from early March-May and again from mid-September-October (Hafele 2015). For the purposes of this study, the period from March 1-September 1 was used for green rock worm hatches. Hatch activity was reported as low to moderate abundance (1's & 2's) during the spring hatch and peaked in mid-August with only two records with high abundance (3's). The saddle-case caddis hatch encompasses a number of species in the family Glossosomatidae. Hatches typically occur from February to mid-May and again from mid-September to late October (Hafele 2015). In 2019, adult emergence of saddle-case caddis occurred from May-June and again during late August. Very few surveys recorded high abundance (3's-1%) for saddle-case caddis in 2019.

The micro caddis hatch (family Hydroptilidae) is a group of very small caddis that has historically been abundant in the lower Deschutes River. The main genus found in the Deschutes is *Leucotrichia*. The larvae of this caddisfly live on the surface of clean cobbles and boulders where they hide under a silk-formed cover and feed on the periphyton layer covering the substrate. The growth of the mat-like algae, now common and covering the rocky substrate in the lower Deschutes River, appears to be reducing the amount of suitable substrate and food for *Leucotrichia* caddisflies (DRA 2018b). However, in 2019 the survey results for micro caddis showed a slight improvement. There were a higher percent of observations with high abundance (3's-15%) for micro caddis than previously reported (2015-2017 range: 4-6%). This corresponded with a lower percent of observations with "none" (0's-55%) reported (Table 5). The results for low and moderate abundance (1's-16% & 2's-14%) also showed a slight improvement in 2019.

The last caddisfly hatch recorded by the guide surveys is the October caddis (genus *Dicosmoecus*). This is the largest caddisfly found in the Deschutes River, and adult emergence generally occurs from mid-September through October, hence the common name October caddis. Very few surveys occurred during the period of October caddis emergence (22 total surveys with expected presence). Such few data records make it impossible to make any assessment of their abundance. However, the results for October caddis in 2019 were similar to results submitted in prior years' surveys.

MAYFLIES (EPHEMEROPTERA)

Six major taxa have historically produced the largest mayfly hatches in the lower Deschutes River. The survey results for mayflies in 2019 are summarized in Table 6. Benthic surveys of the aquatic insects at multiple sites on the lower Deschutes River have found around 30 mayfly taxa (Nightengale et al. 2016). Some mayflies, such as the March Browns (*Rhithrogena morrisoni*), emerge relatively early in the spring (mid March to late April) while others, such as the blue-winged olive emerge throughout the year.

Table 6. 2019 summary table of mayfly hatch abundance.

0=*none observed* 1=*low abundance* 2=*moderate abundance* 3=*high abundance*

	Blue-winged Olives	**Pale Morning Duns**	**Pale Evening Duns**	**Green Drakes**	**Mahogany Duns**	**March Browns**
Feeding Guild	Collector/ gatherer	Collector/ gatherer	Scraper	Scraper	Collector/ gatherer	Scraper
Total # of surveys with expected presence	169	144	123	47	78	39
# of observations with 0's recorded	119 = 70%	48 = 33%	59 = 48%	26 = 55%	75 = 96%	28 = 72%
# of observations with 1's recorded	22 = 13%	35 = 24%	22 = 18%	8 = 17%	3 = 4%	5 = 13%
# of observations 2's recorded	23 = 14%	46 = 32%	35 = 28%	7 = 15%	0	5 = 13%
# of observations with 3's recorded	5 = 3%	15 = 11%	7 = 6%	6 = 13%	0	1 = 2%

The pale morning dun (*Ephemerella excrucians*) (Figure 8), called the PMD for short, has typically been one of the most common and abundant mayflies in the lower Deschutes River and produced some of the best dry-fly fishing of the season. However, since the Tower has been operating PMD hatches have been severely depressed. Survey results for PMDs in 2019 showed a slight increase in the percent of surveys with low (1's-24%) and moderate (2's-32%) abundance compared to years 2015-2017 (range for 1's: 14-23% range for 2's: 17-28%). The percent of surveys with high (3's-11%) abundance was within the range previously observed (2015-2017 range: 2-13%).

Figure 8. Pale morning dun adult. Photo by: Rick Hafele

Historically, adult emergence of PMDs began in late May and continued into mid July. With the changes in water temperature following the start of surface water release, PMD emergence now begins in late April and ends in early June. However, in recent years a late hatch has been observed in September (DRA Macroinvertebrate Hatch Activity Survey Results 2016/2017). In 2019, a hatch of PMDs with six records for high abundance (3's) occurred during late August through early September. These fall hatches for PMDs are uncharacteristic and warrant further investigation as to the exact species.

The blue winged olive (BWO), produces hatches that start in mid-winter and continue into the fall (Hafele 2015), thus the observation period spans from February 1-November 2. In 2019, BWO hatches were within ranges observed in prior years, however, a higher percentage of observations reported "none" (0's-70%; Table 6). These results, with few records for 1's-3's, indicate that the overall abundance of BWO adult hatches was low. A low number of surveys (i.e., guide trips) reported in the late winter and fall likely contributes to their apparent low abundance.

Survey results for pale evening dun, mahogany dun, and March browns showed a high percent of observations with "none" (0's) observed and a low percent of surveys with low to high abundance (1's-3's)(Table 6). These results were consistent with prior years' surveys and show that hatch activity has been relatively low for these species. The green drake hatch showed a slight improvement in 2019. The percent of surveys that reported high abundance (3's-13%) for green drakes was higher than prior years. Overall, mayfly hatches were found primarily in low to moderate abundance when seen at all, with the greatest percentage of surveys observing no adult mayflies (Table 3).

TRUE FLIES (DIPTERA)

Two Diptera hatches were tracked in the guide surveys and are reported here; the family Chironomidae (chironomid or midges) and the crane fly of the genus *Antocha*. The results for Diptera hatches in 2019 are summarized below in Table 7.

Table 7. 2019 summary table of Diptera hatch abundance.

0=*none observed* 1=*low abundance* 2=*moderate abundance* 3=*high abundance*

	Chironomids	**Crane Fly**
Feeding Guild	Varied	Collector/ gatherer
Total # of surveys with expected presence	169	157
# of observations with 0's recorded	123 = 73%	90 = 57%
# of observations with 1's recorded	8 = 5%	32 = 21%
# of observations 2's recorded	22 = 13%	33 = 21%
# of observations with 3's recorded	16 = 9%	2 = 1%

In aquatic systems, the family Chironomidae typically dominates the Diptera fauna in both diversity and abundance (Ferrington et al. 2008). Chironomid adults are present throughout the entire year including the middle of the winter. Therefore, all surveys were included in the assessment of chironomid abundance. A few genera and species of Chironomidae are considered sensitive to poor water quality, but the family includes many genera and species that are tolerant to poor water quality, and the family as a whole often increases in relative abundance as water quality in streams decline (DeShon 1995). The survey results for chironomid hatch activity in 2019 showed a higher percent of surveys with "none" (0's-73%) observed compared to survey results from 2015-2017. The percent of surveys with low to high (1's-3's) abundance was within the range observed in prior years.

Prior to Tower operation (before 2010), the crane fly (*Antocha* sp.) was a common and very abundant hatch observed on the lower Deschutes River from mid June through August (Figure 9)(Hafele 2015). In the years following surface water releases, crane fly adults have been rarely observed (DRA Macroinvertebrate Hatch Activity Survey Results 2013-2017). Guide surveys in 2014 and 2015 only observed adult crane fly hatches three times. During survey years 2016-2017 and 2019 a greater number of adult crane fly were reported compared to 2014-2015 surveys.

Figure 9. Adult crane fly (*Antocha* sp.) hatch on the lower Deschutes River.
Photo by: John Hazel (2004)

In 2019, the percent of surveys with "none" (0's-57%) reported for the crane fly was within the range of prior years' surveys (2016 & 2017). A slightly smaller percent of records with high abundance (3's-1%) was reported in 2019 compared to 2016/2017 survey results. Overall, the results of our surveys show that a slight recovery of the crane fly may be occurring as indicated by the presence of adult hatches and a number of surveys with low to moderate (1's & 2's) abundance. However, it is worth mentioning that the analysis done by Portland General Electric in 2017 showed a statistically significant decrease in benthic abundance for crane flies in the post-Tower period (*Antocha* sp., Nightengale & Shelly 2017).

CONCLUSION

The effect of the SWW Tower on water quality in the lower 100 miles of the Deschutes River has been an ongoing concern in relation to aquatic life since the Tower began operations in late December 2009. Quantitative results from prior benthic studies combined with multiple years of qualitative studies, such as ours here, provide multiple measures of the impacts of the Tower on the aquatic insects of the lower Deschutes River. Wildlife agencies have also done studies on fish in recent years that documented high infection rates for diseases (Connolly and McLean 2017 & ODFW 2019). In addition to these impacts on aquatic life, guides and long-time river users have observed a loss of insect feeding birds. The results from this study can be summarized as follows:

- A low abundance of the major hatches of stoneflies, caddisflies, mayflies, and Diptera as indicated by the majority of surveys reported in 2019 as "none" (0's).
- Shifts in hatch timing are also observed, particularly for the pale morning dun mayfly, salmonfly, and golden stone. Adult emergence for these two stoneflies has consistently occurred four to five weeks earlier when compared to hatches observed in the pre-Tower period.
- Adult hatches for the salmonfly and golden stone showed slight improvement compared to prior years as indicated by a higher percent of surveys that reported high abundance (3's) in 2019.
- Hatches of Diptera remain low. However, some recovery of the crane fly occurred as indicated by surveys that reported low to high abundance (1's, 2's, and 3's) in 2019.
- Changes in seasonal water temperature and annual water quality as a result of Tower operations have led to changes in the abundance, distribution, and emergence timing of aquatic insects in the lower Deschutes River.

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APPENDIX

Order and Genus	Observation Period (used in this study)
Stonefly	March 15-August 1
Brown Willow Fly	March 15-June 1
Golden Stone	May 1-July 1
Salmonfly	May 1-July 1
Yellow Sally	May 1-August 1
Short Winged Stone	Too few entries to report
Mayfly	February 1-November 2
Blue Winged Olive	February 1-November 2
Pale Morning Dun	April 15-September 15
Green Drake	May 15-June 15
March Brown	March 15-May 15
Pale Evening Dun	May 1-August 15
Mahogany Dun	March 15-June 1? Sept 15-November 2
Pink Alberts (*Epeorus* spp.)	Too few entries to report
Caddisfly	March 1-November 2
Green Rock Worm	March 1-September 1
Net-spinning Caddis	May 1-October 1
Saddle-case Caddis	April 1-October 1
October Caddis	August 15-November 2
Micro Caddis	April 1-October 1
American Grannom	Too few entries to report
Amiocentrus spp.	Too few entries to report
Diptera	Entire Period of Record
Midges	Entire Period of Record
Crane Fly	March 15-October 1