Breeding Hudsonian Emerald (*Somatochlora hudsonica*, Hagen) Under Human Care

Final Report, 2021

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BUTTERFLY PAVILION

Introduction

In 2017 Butterfly Pavilion (BP) embarked on a multiyear investment in dragonfly conservation with support from Boulder County Parks and Open Space (BCPOS) and Regis University. Dragonflies remain poorly studied despite their outsized impact. Top-level invertebrate predators, dragonflies serve as indicators species of water quality and vegetation change as larvae, as keystone species that exert top-down pressures on their prey, and as habitat connectivity vectors as adults (Bried & Samways, 2015). And increasingly, fascinated odophiles (dragonfly-lovers) go dragonfly watching all over the world (Bried & Samways, 2015; Corbet, 1999; Paulson, 2009). Yet, we know surprisingly little about these animals. During a worldwide evaluation for 1,500 randomly chosen species, only 35% had adequate information to determine their level of threat (Clausnitzer et al., 2009). Of 453 species of North American odonata (dragonflies and damselflies), fewer than 20 have fully recorded life cycles (Tennessen, 2016). The Colorado Natural Heritage Program and Colorado Parks and Wildlife published a list of sensitive dragonfly species in an addendum to their Wildlife Action Plan (2015). For most dragonfly species in the plan, the state listed lack of information as a threat to their survival. Lack of knowledge certainly characterizes the Hudsonian emerald (*Somatochlora hudsonica*), a dragonfly found in Boulder County and listed as a Tier 2 Species of Greatest Conservation Need by Colorado Parks and Wildlife (CPW) and a sensitive species by the United States Department of Agriculture Forest Service (Colorado Natural Heritage Program, 2015; Packauskas, 2005). Boulder County lists this as a Species of Special Concern in the Environmental Resource Element of the Boulder County Comprehensive Plan (Boulder County, 2020). In October 2020, BCPOS wrote a Draft Species Conservation and Recovery Plan to map action needed to protect populations of *S. hudsonica.*

To support the conservation and recovery of *S. hudsonica*, our goal is to target areas of research still needed in the BCPOS Species Conservation and Recovery Plan. Our first step to successfully measure the effectiveness of management strategies is to track the existing population sizes of *S. hudsonica.* In addition to *S. hudsonica* we propose studying the population sizes of two additional members of the Corduliid family found to use the same habitats as *S. hudsonica*. The American Emerald, *Cordulia shurtleffi*, a Boulder County wildlife Species of Special Concern (#96) due to dependence on a restricted or isolated habitat, and the more common Mountain emerald, *Somatochlora semicircularis,* are both vulnerable to population decline due to threats such as climate change, forestry practices, grazing practices, and other impacts to water quality. All three species occur at the Delonde ponds at Caribou Ranch Open Space during the same flight season, July to August, allowing us to measure all three species with minimal additional effort. This will provide a more complete understanding of how environmental stressors affect the populations of species within this rarer family as a whole and if population trends vary by species or not.

The life history of *S. hudsonica* remains unknown, including the number of years for larvae to reach adulthood and if eggs overwinter. However, based on traits of congeners, Walker estimated that the larval phase of Hudsonian emeralds lasts two full seasons and eggs overwinter. He also estimated that adults live 1.5-2 months (Walker, 1925). Packauskas (2005) found all adult specimens in the region in July; the dragonflies probably started emerging in mid-June. During our work at BP (i.e., under human care), we found that it took the closely related mountain emerald 3 years for some larvae to emerge as adults, with the remaining individuals emerging in year four. Some larvae emerged from eggs prior to overwintering, while others overwintered for a season prior to emerging. We are currently summarizing the life history information we have for the mountain emerald.

In the wild, the years spent as larvae are the most dangerous. In shorter lived genera fewer than 10% of larvae survive to adulthood. Other corduliids have shown an even lower percentage of survivorship with 99.8% mortality over the five years spent as juveniles (Boulder County, 2020). Mortality in juvenile dragonflies most often results from predation pressure, so removing this factor can significantly increase survivorship. Rearing juveniles under human care (i.e., in a captive setting) to give them a head start may result in quicker population recovery by increasing the number of individuals able to emerge as adults and possibly re-establishing locally extirpated populations.

In August 2021, we collected eggs from the mountain emerald after failing to obtain eggs of the Hudsonian emerald (or even finding a female; although we did find a male) during 3 trips to the mountains to search for them. The mountain emerald eggs are currently developing under human care at BP and the first hatching could occur within the next few months, but definitely by spring. We found that maturation of mountain emeralds took a minimum of three years, thus reintroduction efforts from the current cohort could not occur until 2024 or 2025. This timing provides us with the opportunity to monitor existing populations of mountain emeralds, Hudsonian emeralds, and

American emeralds to assess the need for "head starting" (rearing young under human care through their most sensitive stages) of larvae. In addition, during 2022 and 2023 we will redouble our efforts to collect Hudsonian emerald and American emerald eggs to permit us to conduct life history studies and head start programs for both species, permitting reintroduction as early as July 2025 or 2026.

Due to the time needed to reach sexual maturity for all three species, the impact of reintroductions using head starting programs will take several years. This latency makes it imperative to begin recovery efforts now and collect yearly cohorts to ensure the future of these populations over the next several decades. Climate change may well force all the emerald dragonfly species into higher altitude habitat over the next several decades. Refining head starting programs now could prove crucial if assisted dispersal of these species becomes necessary.

We worked in 2021 to try to briefly capture adult female *S. hudsonica* from Boulder County Open Space properties, inducing those females to lay some eggs prior to releasing them back at their capture location (a process that takes just a few minutes), rearing the hatching larvae to their last instar or adulthood at Butterfly Pavilion, and then releasing those individuals back into the wild. Our plan was to maintain detailed records on the life history of *S. hudsonica*, information vital in case "head-starting" is warranted to help conserve the species and expand its range.

Methods

Field Collection

We obtained a Boulder County Parks & Open Space Research Permit through Boulder County to collect *S. hudsonica* eggs.

Upon arrival to site (the Delonde Ponds; Figure 1), we followed previously approved procedures for capturing adult female *S. semicircularis*. Researchers identified oviposition sites of *S. hudsonica* using previously collected data from 2017. During our work, we used sterilized waders to capture adult females while minimizing risk to aquatic habitat. We captured adult females near the water using soft aerial nets to reduce risk of injury. Once captured, we induced ovipositing of eggs into plastic vials (20 mL Clear Polystyrene Plastic Vials with White Caps; Freund Container and Supply, Lisle, IL, USA) of pond water by repeatedly tapping the dragonfly abdomens into water until oviposition occurred. We marked captured females from which we collected eggs unobtrusively on the carapace to help avoid additional collection. We counted eggs using a microscope at X40 magnification (OMAX) and then transferred them to plastic vials ¾ full of reverse osmosis, deionized water treated with Equilibrium (Seachem, Madison, GA, USA) in groups of no more than 50 eggs per vial. We are maintaining labeled vials with eggs in submerged water on temperature and photoperiod-controlled larva shelves that we check bi-weekly.

Rearing *S. hudsonica*

The rearing setup to support dragonfly eggs and larvae has successfully reared *S. semicircularis* from eggs to teneral emergence in three to four years. The rearing system to support eggs through emergence is built on a metal shelving unit. Three central shelves hold hydroponics trays (0.6m by 1.2m by 11.4 cm), Chlorophyll, Denver, CO, USA). A bottom shelf holds a sump tank that contains a Eflux DC Flow pump (Current, Vista, CA, USA) in addition to the intake pump/hose and outtake hose for a ¼ HP chiller (JBJ Arctica; TransWorld Aquatic Enterprises Inc., Inglewood, CA, USA). PVC pipes connect the trays to each other and to the pump. Three 91.4 cm Trulumen Pro

LED strips 12000 K (Current, Vista, CA, USA) on photoperiod timers light the three central shelves. We update timers periodically to reflect sunrise and sunset times in Colorado for accurate simulation of photoperiod.

Once the eggs hatch, we will separate hatchlings into 0.15 L plastic cups. The cups nest securely into trimmed cup bases affixed with silicon into 10 in (25.4 cm) plastic underwater planter baskets (Pond Boss, West Palm Beach, FL, USA). The planter baskets will sit, partially submerged, in the trays. This permits temperature-controlled water to circulate around the cups without water exchange and therefore without the risk of losing a larva into the larger

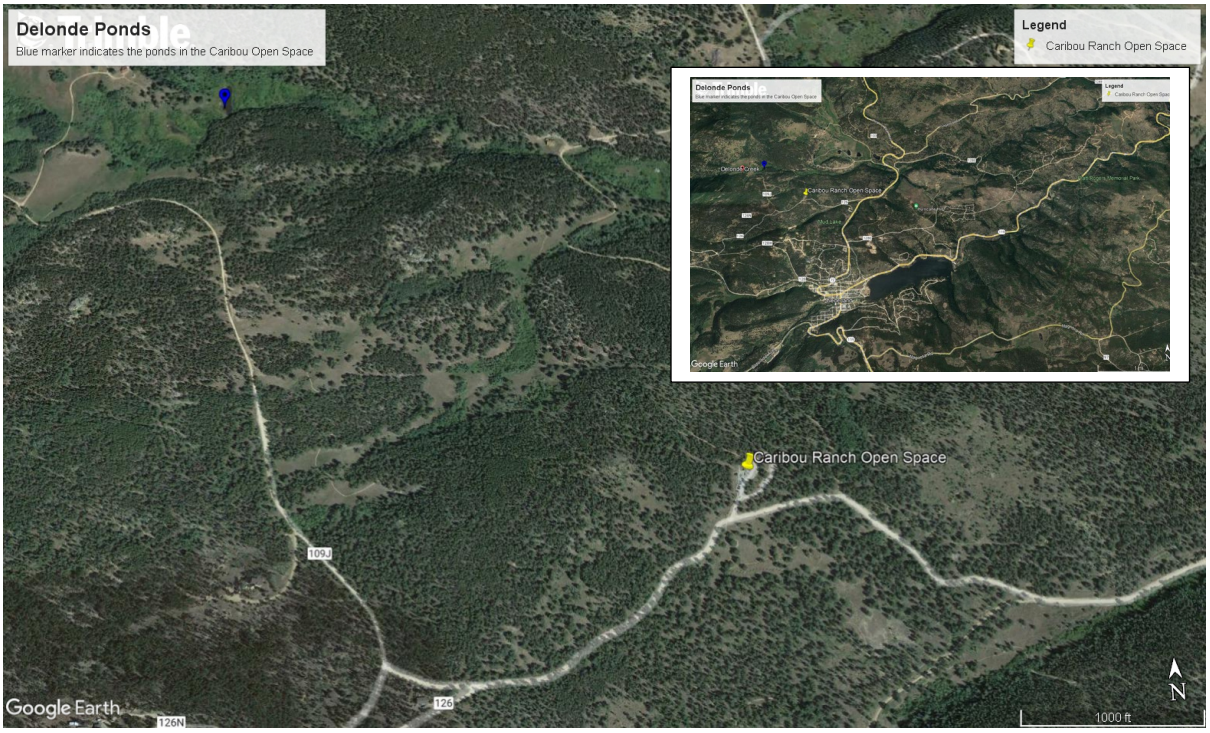

Figure 1. Location of the Delonde Ponds in the Caribou Ranch Open Space, Boulder County.

system or of exposing hatchlings to the scent of larger larvae.

We will feed hatchlings small *Daphnia* sp. (Carolina Biological) three times a week and perform 10% water changes tri-weekly to maintain water quality. Come winter, we will slowly lower the water temperatures to 4 °C by December and maintain that temperature until April to simulate overwintering and stimulate continued development.

We will use an additional system for 35 individuals to permit more precise control of water parameters within individual cups. The Pro Clear Aquatics grab n' go system (Pro Clear Aquatics) is 38"L x 27"W x 82"H. This closed circulation system has flow through to individual cups as well as a dedicated sump and filtration underneath. We will use this system as a control for measuring the impact of consistent water chemistry on the development and ecdysis of larval dragonflies utilizing parameters matching the water chemistry of the oviposition sites.

Results & Discussion

We traveled with 3-5 researchers to Delonde Ponds 3 times during July 2021 to search for female Hudsonian emerald dragonflies. We saw and captured only a single male Hudsonian emerald dragonfly (Figure 2) but did capture a single female mountain emerald (Figure 3) and collected eggs.

Figure 2. Male Hudsonian emerald dragonfly (*Somatochlora hudsonica*).

Upon arrival at Butterfly Pavilion we counted the eggs, which totaled 265. We split the eggs into 6 vials, with the number of eggs/vial ranging from 15 to 50. At hour 48 cellular development within the eggs allowed us to identify fertilized and unfertilized eggs, permitting us to calculate the fertilization rate per container (Table 1). The entire brood had a fertilization rate of 97%. We took photos of eggs to track development over time (see Figures 4-10).

While the fertilized eggs have experienced some development, we found no hatching or signs of broken eggs as of November 6, 2021. The temperature of the water in which the eggs are held may explain the lack of hatching to date. We have maintained the eggs at a median temperature of 11.8 °C (max 13.0 °C, min 10.8 °C). In 2017, the eggs that hatched prior to overwintering began emerging between the 40 to 63 day mark post oviposition. Unfortunately, we did not record the temperature of the water holding the eggs in 2017.

Table 1. Fertilization rate of mountain emerald dragonfly (*Somatochlora semicircularis*) eggs placed into vials. We sorted eggs on 8/4/21 and recounted them at the 48 hr mark when fertilization became visible.

Vial Identification Number	Fertilized Eggs	Unfertilized Eggs	Number of Eggs per Vial	Fertilization Rate
21-571201.1	47	3	50	94%
21-571201.2	50	0	50	100%
21-571201.3	48	2	50	96%
21-571201.4	48	2	50	96%
21-571201.5	49	1	50	98%
21-571201.6	15	0	15	100%

Table 2. Parameters taken using a YSI to measure water parameters of oviposition sites.

	Upper Pond		Second Pond	
	Max	Min	Max	Min
Temperature (C°)	15.3	14.3	19.6	18.8
Dissolved Oxygen (%mg/L)	12	8.5	7.4	5.1
pH	5.87	5.96	6.28	5.58
ORP	185.9	153.9	186.7	219.3

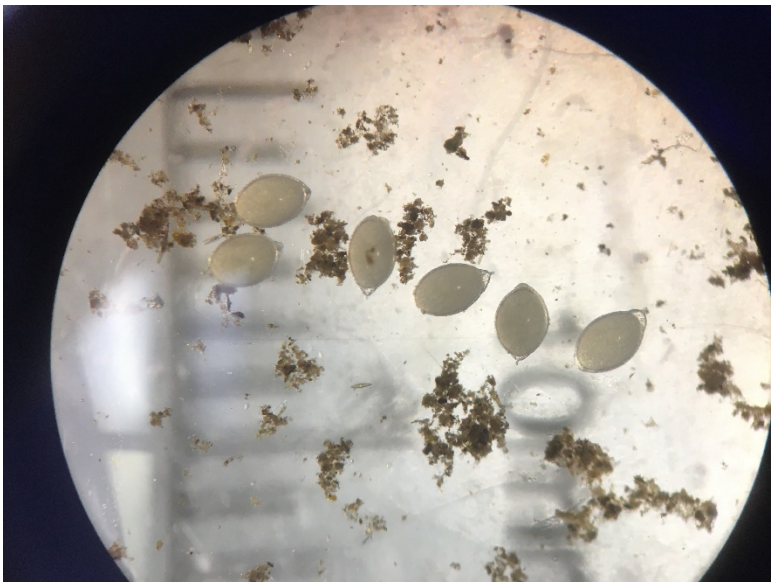

***Figure 4. Mountain emerald dragonfly (*Somatochlora semicircularis*) eggs 4 hrs post-oviposition. Eggs are white in color with a clear a* clear outer coating.**

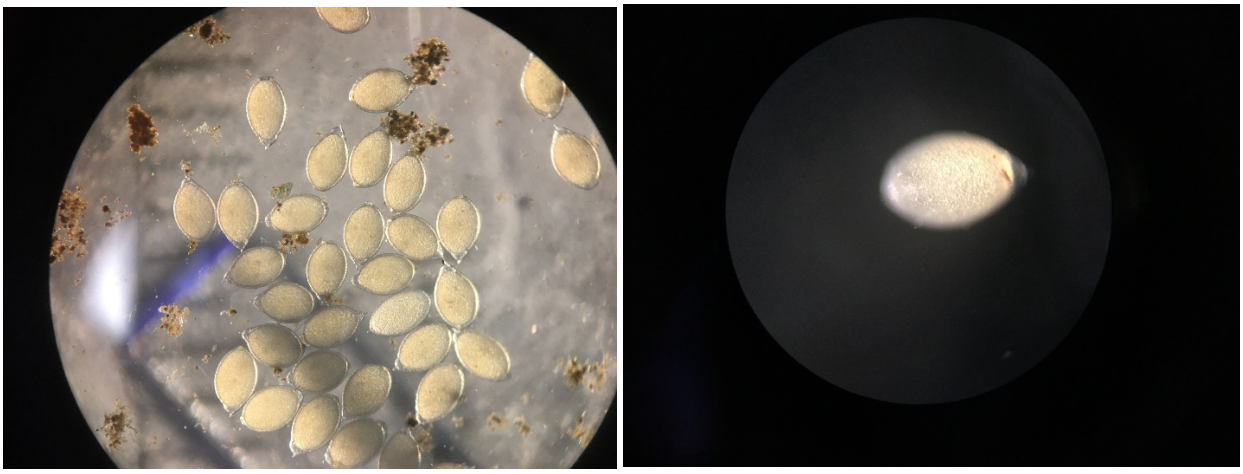

Figure 5. Mountain emerald dragonfly (*Somatochlora semicircularis*) eggs 24 hrs post-oviposition.

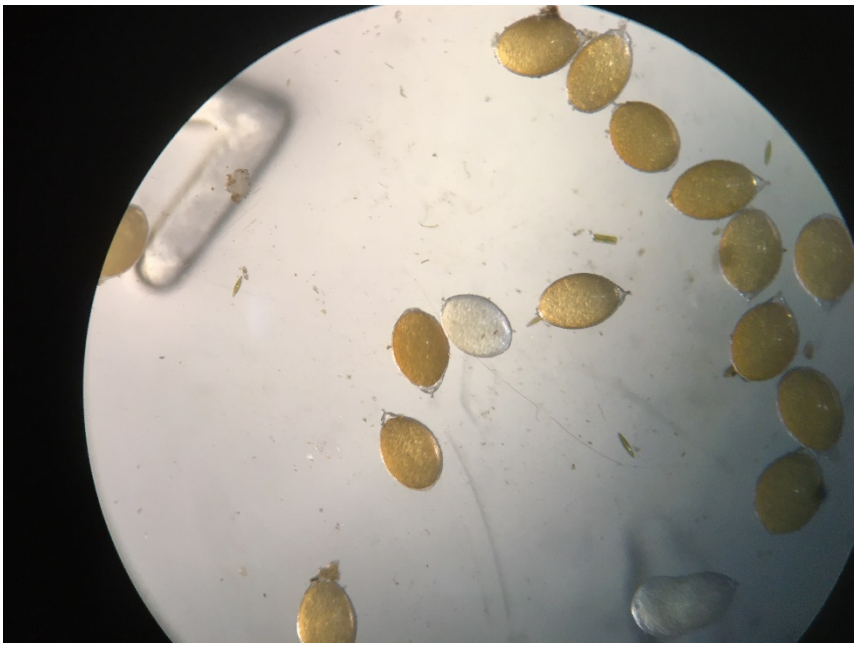

***Figure 6. Mountain emerald dragonfly (*Somatochlora semicircularis*) eggs* 48hrs post-oviposition.** Note the white, unfertilized egg in the center.

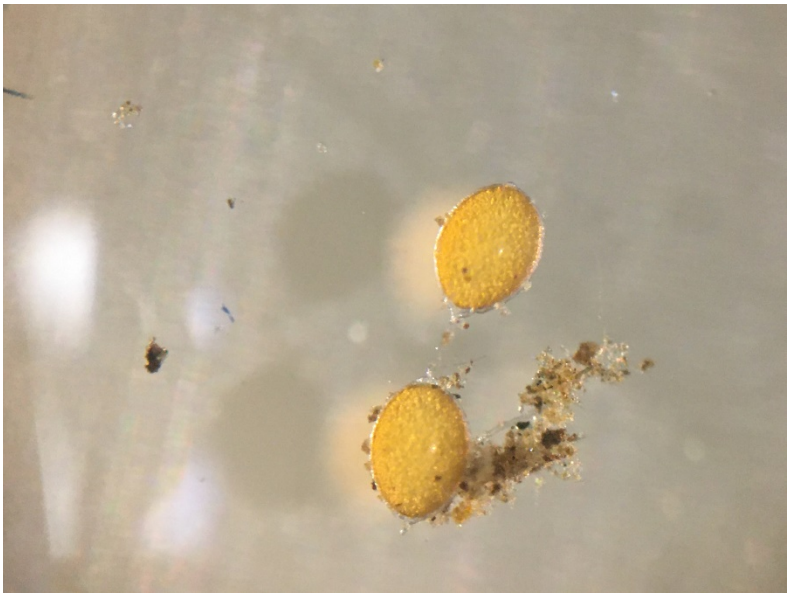

***Figure 7. Mountain emerald dragonfly (*Somatochlora semicircularis*) eggs* 72 hrs post-oviposition.**

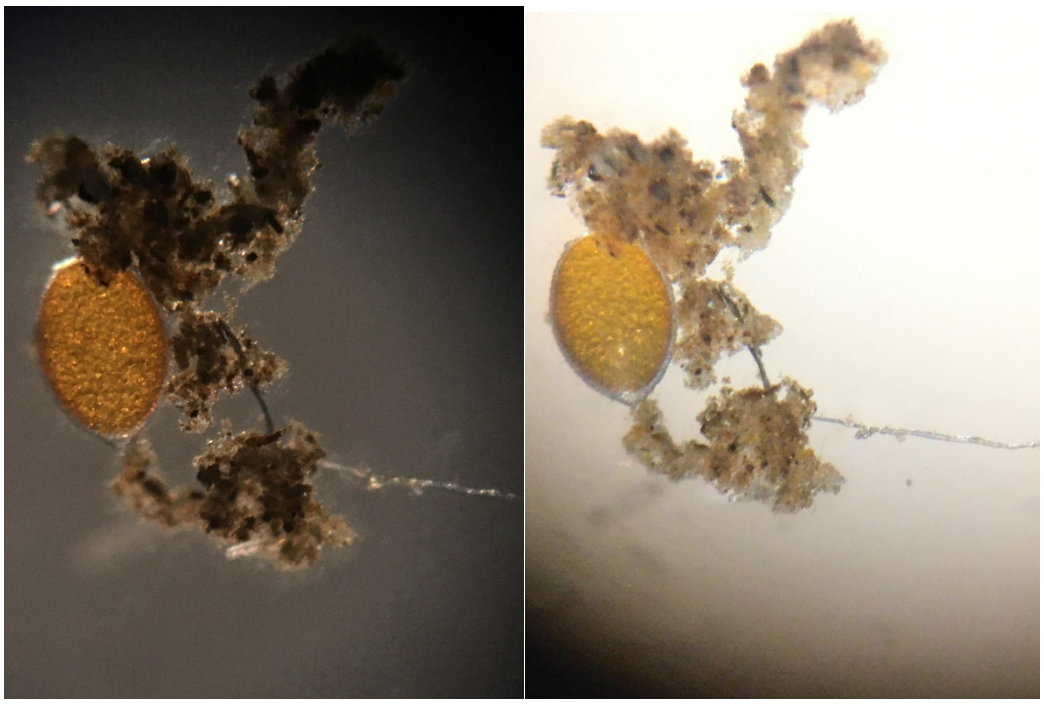

***Figure 8. Mountain emerald dragonfly (*Somatochlora semicircularis*) eggs* 7 days post-oviposition.**

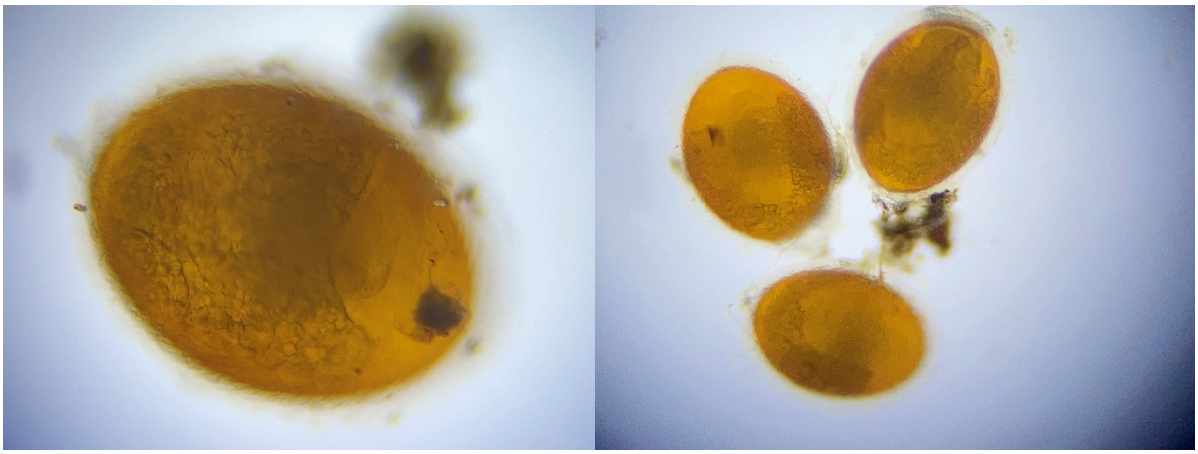

***Figure 9. Mountain emerald dragonfly (*Somatochlora semicircularis*) eggs* 30 days post-oviposition.** Note differentiation of the cells.

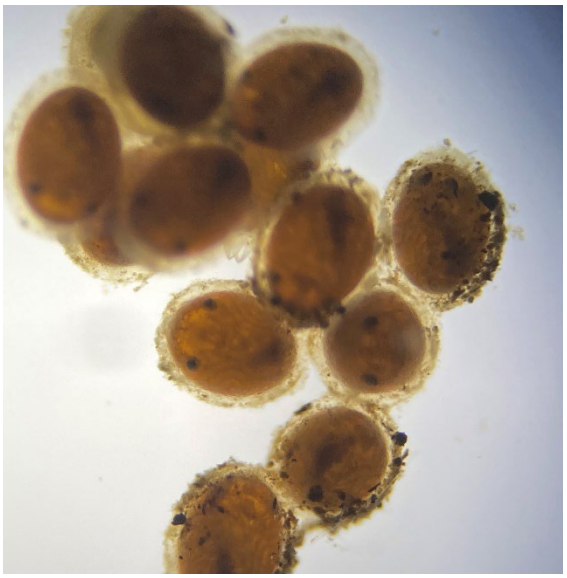

***Figure 10. Mountain emerald dragonfly (*Somatochlora semicircularis*) eggs* 85 days post-oviposition.** Note the eyes are now obvious.

A major goal of our study was to measure the impact of water quality stability on early development of Hudsonian emerald larva. Despite making 3 trips to the field, we were unable to find a female Hudsonian emerald, let alone one in the process of ovipositing. During our second trip, August 4th 2021, we found a single mountain emerald female in the process of ovipositing at the edge of the second pond. This specimen was the only female of any emerald species we found during the three trips.

Water temperatures at the ponds (see Table 2) fell within a relatively wide range of temperatures, from 14.3 C to 19.6 C. We have maintained the eggs at Butterfly Pavilion at water between 10.8 C to 13.0 C. Due to the lack of pre-winter hatching, but the development of the embryonic larva, we theorize that the temperatures caused the eggs to enter diapause and overwinter. We will follow 2017 protocols and drop the water to winter temperatures for a month, then slowly warm them to simulate thawing. This means that larva will most likely not hatch until Spring 2022.

Conclusions and Next Steps

Finding female Hudsonian emerald dragonflies, and really any female emerald dragon, proved more difficult than we anticipated. While we proposed making one field excursion to collect Hudsonian emerald eggs, we actually tried on 3 separate occasions without luck. Future work will therefore require far more trips to the field and lower expectations.

We did manage to collect a fairly large number of eggs from a mountain emerald dragonfly and will continue to maintain those eggs until they hatch or prove unviable. We will then raise the larvae under human care until their last instar or to adulthood, at which point we will release them back into the wild. We will continue collecting detailed data on the life history of the species, which we plan to publish eventually. Due to the lack of hatching from the eggs in our possession, we have been unable to track any early instar data. We have dropped the eggs down to winter temperatures to initiate diapause and will rewarm the eggs in spring to encourage emergence. Once we have emerged larva, we will be able to track early instar survivorship curves.

As we state in the introduction, we also believe that there is merit in trying to monitor all three species of emerald dragonflies (Hudsonian, mountain, and American), at least at one or a few sites, over several years. We believe the head starting may prove useful in efforts to conserve these species; however, given their prolonged larval stages, this

would take several years. We hope to partner with BCPOS and explore opportunities with local school districts to rear dragonfly larva in a classroom setting to help support conservation efforts, while encouraging student learning.

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