



Parks & Open Space

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MINUTES AND PROCEEDINGS OF THE PARKS AND OPEN SPACE ADVISORY COMMITTEE March 22, 2018

The meeting was called to order at 6:34 p.m. by John Nibarger in the Hearing Room of the Board of Commissioners, Third Floor, Boulder County Courthouse, Boulder, Colorado.

POSAC Members in Attendance

Present: Sue Anderson, Jenn Archuleta, Cathy Comstock, Jim Krug, James Mapes, Scott Miller, John Nibarger, Gordon Pedrow, and Heather Williams

Excused:

Staff in Attendance

Jason Vroman, Mac Kobza, Tina Nielsen, Renata Frye, Vivienne Jannatpour, Therese Glowacki, Sarah Andrews, Al Hardy, Jeff Moline, and Eric Lane

Approval of the February 22, 2018 Meeting Minutes

Action Taken: Jenn Archuleta moved to accept the February 22 minutes. Jim Krug seconded the motion. Motion carried unanimously.

Public Participation - Items not on the Agenda

None

Hudsonian Emerald in Boulder County: Status and Conservation of an Uncommon Dragonfly

Presenters: Dr. Kristofor Voss - Environmental Biology Director, Regis University and Katrina Loewy - Research and Conservation Coordinator, Butterfly Pavilion

Public Comments

None

Action Taken: Information only

Homelessness on Boulder County Parks & Open Space

*Staff Presenters: Jason Vroman - Lead Ranger and
Sue Cullen - BCSO Parks Deputy*

Public Comments

None

Action Taken: Information only

E-bikes Process Update

Staff Presenter: Tina Nielsen - Special Projects Manager

Public Comments

None

Action Taken: Information only

Director's Update

- The BOCC has approved the updated POS Rules & Regulations.
- The BOCC has approved the Brand property acquisition near Rabbit Mountain.
- Staff has completed the collaring of the Rabbit Mountain elk herd and staff are almost done collaring the Heil Valley Ranch elk herd.
- The City of Boulder and Boulder County commissioned a study by Colorado State University about sequestering carbon in agricultural and forest soils in Boulder County. The study is recently completed, and the final report is now available. The results of this study will be presented and the public is invited to attend: Wednesday, March 28, 4:45-6:30 p.m. at the Boulder County Recycling Center, 1901 63rd St. Boulder.
- The April 26 POSAC meeting will address results of the recent POSAC survey on operational effectiveness.

Adjournment

The meeting adjourned at 8:07 p.m.

The full audio, available staff memos, and related materials for this meeting can be found on our website: www.BoulderCountyOpenSpace.org/POSAC



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PARKS AND OPEN SPACE ADVISORY COMMITTEE MEETING

DATE: Thursday, March 22, 2018
TIME: 6:30 pm
PLACE: Commissioners' Hearing Room, 3rd Floor, Boulder County Courthouse,
1325 Pearl Street, Boulder, CO

AGENDA

Suggested Timetable

- 6:30 1. **Approval of the February 22, 2018 Meeting Minutes**
- 6:35 2. **Public Participation - Items not on the Agenda**
- 6:40 3. **Hudsonian Emerald in Boulder County: Status and Conservation of an Uncommon Dragonfly**
Presenters: Dr. Kristofor Voss - Environmental Biology Director, Regis University and Katrina Loewy - Research and Conservation Coordinator, Butterfly Pavilion
Action Requested: Information Only
- 7:10 4. **Homelessness on Boulder County Parks & Open Space**
Staff Presenters: Jason Vroman - Lead Ranger and Sue Cullen - BCSO Parks Deputy
Action Requested: Information Only
- 7:40 5. **E-bikes Process Update**
Staff Presenter: Tina Nielsen - Special Projects Manager
Action Requested: Information Only
- 8:10 6. **Director's Update**
- 8:15 7. **Adjourn**

Available staff memos & related materials for this meeting may be viewed on our website:

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PARKS & OPEN SPACE ADVISORY COMMITTEE

TO:	Parks & Open Space Advisory Committee
TIME/DATE:	Thursday, March 22, 6:30 p.m.
LOCATION:	Commissioners Hearing Room, 3 rd floor, Boulder County Courthouse, 1325 Pearl Street, Boulder, CO
AGENDA ITEM:	Hudsonian Emerald in Boulder County: Status and Conservation of an Uncommon Dragonfly
PRESENTERS:	Dr. Kristofor Voss - Environmental Biology Director, Regis University Katrina Loewy – Research and Conservation Coordinator, Butterfly Pavilion
ACTION REQUESTED:	Information only

Although birds and mammals frequently serve as the poster children for species preservation, the large balance of global animal biodiversity resides in terrestrial and aquatic insects. One order of aquatic insects, the odonates (damselflies and dragonflies), is well-recognized by even casual observers as iconic freshwater inhabitants. Dragonflies not only enhance the aesthetic value of freshwater habitats, but they also function as apex predators of invertebrates and prey for fish, amphibians, and birds, thereby linking aquatic and terrestrial habitats. Consequently, the presence or absence of sensitive dragonfly species near water bodies can indicate whether an aquatic ecosystem functions properly to support a diverse array of organisms.

One dragonfly species of particular concern in Boulder County, CO is the Hudsonian emerald (*Somatochlora hudsonica*, Hagen). Although widely distributed at higher latitudes, the Hudsonian emerald is more sparsely distributed and less common in Colorado, the southernmost edge of its range. Here, the Hudsonian emerald is a sensitive species whose local distribution and specific habitat requirements are generally poorly understood. Indeed, as of 2005 very few specimens had been collected and vouchered within Colorado, most of which were collected decades earlier. Within Boulder County, confirmed sightings or collections occurred at Rainbow Lakes, Brainard Lake, and Red Rock Lake. However, within Boulder County Parks and Open Space (BCPOS) properties, odonate surveys within the last several years have not documented sightings of the Hudsonian emerald. Because of its rarity in the region, the Hudsonian emerald is listed as a Tier 2 Species of Greatest Concern by Colorado Parks and Wildlife (CPW) and as a sensitive species in Region 2 by the United

States Forest Service. Furthermore, in their Wildlife Action Plan the Colorado Natural Heritage Program and CPW listed lack of basic information as a threat to the Hudsonian emerald's survival. Thus, at this point we have limited information about where and when the Hudsonian emerald is found and the ecological requirements of the species. To monitor and manage habitat for Hudsonian emerald, these three critical pieces of information should be formally assessed for BCPOS areas. The goal of this study is to fill this critical research gap. In this study, we estimated likely habitat for the Hudsonian emerald in Boulder County, CO using standard ecological models that predict habitat suitability from prior occurrences. We then ground-truthed these suitability maps by surveying for Hudsonian emerald adults and exuviae (cast larval skin) at ponds and lakes during the summer of 2017. During our surveys we also collected a suite of water quality and habitat variables to correlate with the presence of the species. We also collected eggs from a closely related species, the mountain emerald (*Somatochlora semicircularis*) during our surveys. We then incubated these eggs under controlled conditions in the laboratory to assess the feasibility of life cycle studies in the lab. Although Hudsonian emeralds were quite rare when present, we did find Hudsonian emeralds at Caribou Ranch, Duck Lake, and Barron properties throughout the summer. In addition to documenting the Hudsonian emerald for the first time on BCPOS properties, our surveys also showed that currently published flight times of the species should be extended into June. Furthermore, ponds where we found the Hudsonian emerald tended to be at higher elevation, have a higher percentage of intact forest within 500m, and have better water quality than those ponds where dragonfly was absent. Together, these results indicate the necessity of protecting small, snow-fed mountain ponds from anthropogenic disturbances that would prevent them from providing adequate habitat for this thermally restricted species.

Hudsonian Emerald (*Somatochlora hudsonica*, Hagen) in Boulder County

December 8, 2017

Kristofor Voss, Department of Biology, Regis University, kvoss@regis.edu
Katrina Loewy, Department of Research and Conservation, Butterfly Pavilion,
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Abstract

Dragonfly conservation in parks serves the dual purpose of protecting iconic species of aesthetic value to park visitors as well as preserving aquatic ecosystem function. The Hudsonian emerald dragonfly (*Somatochlora hudsonica*, Hagen). *S. hudsonica* is the only Colorado dragonfly listed as sensitive by the US Forest Service. Little is known about *S. hudsonica*'s habitat associations, distribution, and life history, all essential for future management of the species. We began answering those basic questions with literature-based habitat suitability models followed by a ground-truthing survey of adults across Boulder County Parks and Open Space (BCPOS) properties that span the suitability gradient to determine the local habitat variables that influence probability of occurrence. To determine breeding habitat, we also conducted an exuvial survey, and set the groundwork for captive rearing. The information collected as part of this project will provide critical baseline data necessary for BCPOS to draft habitat management and monitoring plans for the Hudsonian emerald.

Introduction

In the Anthropocene, human activities that destroy and degrade habitat are extirpating species at alarming rates, resulting in unprecedented levels of global biodiversity loss¹. While iconic charismatic megafauna typically serve as the poster children for species preservation², the large balance of global animal biodiversity resides in terrestrial and aquatic insects³. Compared to terrestrial species, those of aquatic origin are particularly vulnerable to human threats due to their highly endemic distributions and typically restricted environmental requirements⁴. One such order of aquatic insects, the odonates (damselflies and dragonflies), are well-recognized by even casual observers as iconic freshwater inhabitants. Not only do dragonflies serve to add aesthetic value to freshwater habitats, but they function as apex predators of invertebrates and prey for fish, amphibians, and birds, thereby linking aquatic and terrestrial habitats⁵. Thus, dragonfly conservation serves the dual purpose of preserving ecosystem function and enhancing the aesthetic value of aquatic resources.

Of 453 total species of North American odonata (dragonflies and damselflies), fewer than 20 have fully recorded life cycles⁶. The Colorado Natural Heritage Program and Colorado Parks and Wildlife published a list of sensitive dragonfly species in an addendum to their Wildlife Action Plan⁷. For most dragonfly species in the plan, the State listed lack of information as a threat to their survival. Lack of knowledge certainly threatens the Hudsonian emerald (*Somatochlora hudsonica*), a dragonfly found in Boulder County and listed as a Tier 2 Species

of Greatest Concern by Colorado Parks and Wildlife and as a sensitive species in Region 2 by the USDA Forest Service^{7,8}.

The Hudsonian emerald is an uncommon species found throughout Canada and mountainous regions of Alaska, Montana, Wyoming and Colorado^{8,9}. Within Colorado *S. hudsonica* has only been observed within Park, Larimer, and Boulder Counties, the southernmost end of its distribution. Because these counties lie on the periphery of the Hudsonian emerald's distribution, individuals tend to be locally restricted and not commonly found. Consequently, while *S. hudsonica* is stable globally, the species is vulnerable to habitat degradation in areas where it occurs within the state¹⁰. Indeed, as of 2005 very few specimens had been collected and vouchered within Colorado, most of which were collected decades earlier⁸. Within Boulder County, confirmed sightings or collections occurred at Rainbow Lakes, Brainard Lake, and Red Rock Lake¹¹. However, within BCPOS properties, *S. hudsonica* has not been officially documented in recent odonate surveys¹²⁻¹⁴, but based on habitat requirements is potentially present in or near the following BCPOS areas: Steamboat Mountain, Heil Valley Ranch (Geer Canyon & Marrietta Canyon), El Dorado Springs (South Draw), Caribou Ranch, and Reynolds Ranch (Giggey Lake)¹⁵.

The 2005 assessment cited seven instances of *S. hudsonica* in Colorado at altitudes of over 1,524 m. The closest BCPOS parcels with significant water sources are Barron, Duck Lake, and Caribou Ranch. Habitat use in the United States is extrapolated from those few adult sightings as well as observations in Canada where the species occurs more widely¹⁶. At northern latitudes, *S. hudsonica* inhabit bogs, lakes, ponds, and (especially for larvae) the edges of woodland streams¹⁷. An early guide to the genus suggested that *Somatochlora* larvae only develop in water with summer temperatures of 16–20 °C (61-68 °F)¹⁸. Within its range, the Hudsonian emerald typically inhabits elevations above 1500 m in lentic (i.e. still water) habitats, but has been incidentally found in some small mountain streams within pool microhabitats⁸. The lentic habitats have been described as sedge-bordered, boggy lakes, ponds and streams with nearby or adjacent forest for foraging and mating^{8 19}.

Like many dragonflies, *S. hudsonica*'s habitat use changes over its life cycle. Larvae are aquatic, pre-reproductive adults leave the water source and hunt among the tree tops, and reproductive adults return to water to breed^{9,20}. The rate of natal philopatry and dispersal distance remain unknown. Females may exploit different habitats than males²¹. We need knowledge of habitat associations for all ages and genders, and the dispersal ability of adults for preservation or restoration of *S. hudsonica*.

Until a detailed study occurs, threats to *S. hudsonica* remain speculative. Hypothesized threats to the Hudsonian emerald habitat include those that impact water quality (i.e. from sedimentation, mining, or pesticide application) or vegetation loss (i.e. from livestock grazing, trampling or tree loss)⁸. If adults require trees close to the banks where they emerge, as other *Somatochlora* species do, clearing land near water sources could threaten their survival⁸. Predation by fish or other dragonflies could prevent larvae from persisting in ponds or streams^{22,23}. Lack of sufficient cover by aquatic vegetation could increase predation rates.

The life history of *S. hudsonica* also 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 months¹⁸. All adult specimens in the region were found in July; the dragonflies could start emerging in mid-June⁸.

This lack of basic ecological information is compounded by the lack of recent survey/occurrence data from areas within the county, especially from those areas managed by BCPOS. Thus, at this point we have limited information about **where and when** the Hudsonian emerald is found and **the ecological requirements** of the species. To monitor and manage habitat for Hudsonian emerald, these three critical pieces of information should be formally assessed for BCPOS areas. The goal of this study is to fill this critical research gap.

Objectives

- 1.) To determine the presence or absence of *S. hudsonica* on Boulder County Parks and Open Space land.
- 2.) To conduct a habitat assessment for the Hudsonian emerald in Boulder County Parks and Open Space (BCPOS) areas with the purpose of providing a map of estimated habitat suitability throughout Boulder County. Using this map, to conduct a pilot ground-truthing study that surveys Hudsonian emeralds in BCPOS areas that span the habitat suitability gradient. The goal of this survey will be to estimate site occupancy and local habitat factors that correlate strongly with occurrence of Hudsonian emeralds.
- 3.) To conduct an exuvial survey to determine the breeding habitat of *S. hudsonica*, including a) correlation with adjacent forest b) correlation with fish stocking, and c) co-occurrence with other dragonfly species. To successfully rear *Somatochlora* species and other common dragonflies in captivity to assess potential for “head-starting” *S. hudsonica* and other sensitive odonates.

- 4.) To successfully rear *Somatochlora* species and other common dragonflies in captivity to assess potential for “head-starting” *S. hudsonica* and other sensitive odonates.

Questions and Hypotheses

This research aims to answer four questions:

Q1. In which areas of Boulder County Open Space is the Hudsonian emerald predicted to occur?

H1a. A comprehensive habitat suitability model will provide a data-driven approach to assess potential habitat for the species. We expect to find higher suitability in areas that possess boggy ponds and lakes above 1500 m in elevation.

*H1b. We expect to find *S. hudsonica* in Caribou Ranch and Barron parcels, near historical sightings.*

Q2. How well does the habitat suitability model (Q1) reflect current occupancy by the Hudsonian emerald?

H2. Given the limited occurrence data for the Hudsonian emerald, we expect that the habitat suitability model may overestimate presence of the dragonfly in certain areas. Ground-truthing of the model with on-the-ground surveys enable us to assess the success of the model.

Q3. What local-scale habitat features (e.g. water quality, vegetation management, etc.) tend to correlate strongly with presence of Hudsonian emeralds?

H3: Extremely limited data has been collected to assess the local factors that make suitable habitat for the Hudsonian emerald. Collection of such data during ground-truthing surveys will likely show that Hudsonian emeralds respond positively to better water quality and protection of riparian areas from livestock watering and grazing.

Q4: How does proximity of forested area, presence of fish, and co-existence with other anisopterans impact breeding habitat?

*H4: Breeding habitat will occur in areas a) within 200 m of a forested area, b) without stocked fish, and c) without other dragonfly species, except the mountain emerald (*S. semicircularis*).*

Methods

Habitat Suitability Modeling

We used a two-pronged approach to construct habitat suitability models to forecast areas where the Hudsonian emerald likely occurs. First, we used an approach where we chose several habitat variables that have been shown (or are assumed) to correlate positively or negatively with Hudsonian emerald occurrence. While we attempted to find a comprehensive set of articles about *S. hudsonica* habitat requirements, the primary source for our scoring system was information reported by Packauskas in 2005⁸. The habitat variables we used and scored were: (1) proportion of forest within 500-m (from National Land Cover Database, 0% = 0, 100% = 1), (2) proximity to lentic or lotic water source (from National Hydrography Dataset, 0 m = 1, 500 m = 0), (3) proximity to forested wetland (from National Wetland Inventory, 0 m = 1, 500 m = 0), (4) elevation (from National Elevation Dataset, scaled from 0 to 1 between 1500 and 3000 m, decreasing after 3000 m), (5) proportion of developed land within 500 m (from National Land Cover Database, 0% = 1, 100% = 0), (6) proportion of rangeland/pasture (from National Land Cover Database, 0% = 1, 100% = 0), and (7) distance to nearest road (0 m = 0, 500 m = 1). Using ArcGIS, we scored each of the habitat variables as indicated above and combined them into a habitat suitability index using two methods, the geometric mean and the arithmetic mean²³. The geometric mean is more restrictive than the arithmetic mean because any attribute scored as a 0 is indicated as unsuitable. The arithmetic mean is more permissive allowing compensation by attributes. Essentially this technique uses information from a literature review to create a scoring system for each habitat attribute where higher numbers indicate more suitable habitat.

While this approach was useful in the absence of a many occurrence records, it is based on expert judgement. Consequently, we supplemented the literature-based method with a traditional habitat suitability model that relates habitat variables to the probability of occurrence of Hudsonian emeralds within North America^{24,25}. To do so, we curated a collection of occurrence records from known summaries of occurrences⁸, digital collections (iDigBio, iNaturalist), and other odonate sighting data at Odonata Central known from local naturalists. These digital records collate records in the database from some museums. All records were confirmed by third-party taxonomic experts and by the authors using provided photographs.

After georeferencing these occurrences, we built a species distribution model from lower dimensional variables defined by principal components analysis (PCA) of bioclimatic data and land use data (e.g., summaries of temperature, precipitation, land use, and nearby lentic

habitat). We used nine well-known models for species distribution modeling using a randomly assigned subset of 80% of the data for model-building (Bioclim, Domain, Mahalanobis, generalized linear models, generalize additive models, maxent, boosted regression trees, random forest, and support vector machine). We used synthetic PCA variables rather than the raw variables because of the high degree of correlation among the variables. In this way, the model uses orthogonal, uncorrelated summaries of climate and land use within the study area as the major sources of variation across the landscape. We combined the presence-absence maps from each of the models, weighting each model by its area under the curve (AUC) calculated from a plot of the true positive rate versus the false positive rate in a cross-validation that predicted presence-absence from the remaining 20% of the data. The AUC is a measure of model accuracy describing how well the model predicts presence/absence in the 20% holdout dataset not used to train the model. Each model uses species occurrence data as presence data and randomly generated “pseudo-absences” to build a model that predicts probability of occurrence from the habitat parameters. This model can then be used to project the probability of occurrence across the landscape into a map. We then used these maps in conjunction with recent occurrence records in Boulder County to identify candidate sites for a ground-truthing study.

Ground-Truthing Adult Pilot Survey

At each site identified from habitat suitability mapping (see Results), we conducted Hudsonian emerald surveys along transects that circled the perimeter of each pond, lake, or pond complex. We used established protocols that control for time of day, weather, and walking speed^{26,27}. Briefly, the perimeter of the water body was divided into 20-m or 50-m transects which were walked in opposite directions by two observers. Each observer recorded a count of the number of Hudsonian emeralds, other dragonflies (not identified), and damselflies. Additionally, each observer visually estimated the percent sun to the nearest 10%, the time of day, and the depth one meter toward the lake center. Sites were visited from June 26, 2017 to August 19, 2017, a period identified as the known flight time of adult Hudsonian emeralds (mid-July to mid-August)¹⁹. We revisited each site twice to repeat transect surveys over the course of the summer. While 90% of transects were visited between 9:30am and 3:30 pm, we did attempt to revisit sites at different times of day on subsequent visits. The first time we found a Hudsonian emerald at a site, we photographically confirmed presence by catching, photographing, and releasing the specimen.

Habitat and Water Quality Analysis

At each of the study sites, a brief local habitat survey was conducted on August 14, 2017 or August 15, 2017 to assess the extent of emergent vegetation cover, proximity to forest habitat, other noticeable disturbances, and water quality (dissolved oxygen, TDS, pH, temperature, nitrate, phosphate, alkalinity, metals). Water samples were taken just under the water surface by syringe near the edge of the pond or lake in clean, acid-washed bottles and brought back to the lab or sent out for analysis according to standard EPA methods. To determine which habitat variables corresponded to presence/absence of *S. hudsonica*, we used two methods. First, using a bootstrap resampling procedure, we compared the mean difference in habitat variables between sites where *S. hudsonica* was observed and sites where *S. hudsonica* was not observed. Secondly, we conducted a non-metric multidimensional scaling ordination of habitat variables on the Gower's distance matrix of habitat variables among sites. Gower's distance allows a distance between sites to be calculated when different types of variables are in the data table (i.e. categorical, ordinal scale, numeric, asymmetric binary). This allowed us to show whether sites where *S. hudsonica* was observed and sites where it was not observed differed in multivariate habitat space.

Exuvial Surveys and Analysis

We conducted an exuvial study in randomized 2 m X 2 m plots along water features with emergent vegetation in Caribou Ranch, Barron and Duck Lake parcels. We walked the perimeter of potential habitats in early June (July for Caribou Ranch locations due to access restrictions) and used GPS units (Garmin, Canton of Schaffhausen, Switzerland) to map areas of potential dragonfly emergence. After uploading the resulting lines to ArcMaps, we used ArcGIS tools to assign ten randomized sample plots per site. We chose small plots to avoid unnecessarily trampling of sensitive aquatic vegetation. We drew this technique from an exuvial study on Hine's emerald dragonflies²⁹.

Sampling occurred from June 17th to August 18th, 2017. We attempted to visit each site once a week to collect exuviae. A previous study noted that exuvial persistence decreased exponentially after three weeks³⁰. We collected all anisopteran exuviae within the plots in small plastic vials, which we brought to Butterfly Pavilion for identification. We identified Corduliid exuviae to species, and all other dragonfly exuviae to genus using two different dichotomous keys^{17,31}.

Marking Method Test

As we collected exuviae, we also attempted to capture *Somatochlora* species adults. We held several adult males briefly to affix a queen bee marker (Bee Works, Oro-Medonte, ON, Canada) to their thorax behind the head and to the side. Researchers marking *S. hineana* moved from using colored paint on wings to small, numbered tags (Fig 1), and we replicated their marking procedure.



Figure 1: *Somatochlora hineana* with numbered tag. Photographer: Daniel A. Soluk.

Rearing Methods

Butterfly Pavilion staff assembled a rearing setup to support dragonfly eggs and larvae through emergence. The odonata rearing setup was built on a metal shelving unit. The three central shelves hold hydroponics trays (0.6m by 1.2m by 11.4 cm), Chlorophyll, Denver, CO, USA). The 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). The trays are connected to each other and the pump with PVC pipes. The three central shelves are lit by three 91.4 cm Trulumen Pro LED strips 12000K (Current, Vista, CA, USA) on photoperiod timers. The timers are updated periodically to reflect actual sunrise and sunset times in Colorado.

We collected eggs from females of two common dragonflies: mountain emeralds (*Somatochlora semicircularis*), and eastern or western pondhawks (*Erythemis* spp.). Females released eggs into plastic vials (20 mL Clear Polystyrene Plastic Vials with White Caps; Freund Container and Supply, Lisle, IL, USA) of pond water upon contact of water with their ovipositors. The eggs were kept shaded and cool until arrival at the Butterfly Pavilion lab. We counted all *S. semicircularis* eggs using a microscope at X40 magnification (OMAX). We then transferred the eggs to plastic vials ¾ full of reverse osmosis, deionized water treated with Replenish (Seachem, Madison, GA, USA) in groups of no more than 34 eggs per vial. Labeled vials with

eggs stayed submerged in the temperature and photoperiod controlled larva shelves and were only removed for short bi-weekly checks.

Upon discovering hatchling(s), we separated *S. semicircularis* larvae into individual 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 sit, partially submerged, in the trays. This allows temperature controlled water to circulate around the cups without water exchange, without the risk of losing a larva into the larger system, or of exposing hatchlings to the scent of larger larvae.

Hatchlings are fed small *Daphnia* sp. three times a week, and get 10% water changes tri-weekly. Due to their small size and lack of fat reserves, we plan to keep them at 10°C over the winter and continue to feed them. Alternatively, the remaining *S. semicircularis* and *Erythemis* eggs will be slowly lowered to 4 °C by December and kept at that temperature until April to simulate overwintering and stimulate continued development. We expect eggs to hatch once we begin to raise the temperature in Spring of 2018.

Data Analyses

We used Excel 2013 (Microsoft, Redmond, WA) and R (R Development Core Team, 2017) for all statistical analyses and calculations.

Exuviae relative abundance was calculated as mean exuviae per plot (2m X 2m, or 4m²) for the selected taxon divided by total mean exuviae per plot. We used exuvial discovery date as a proxy for dragonfly emergence date. Since we visited each site weekly, we expected the actual emergence to be no more than one week off. The major exception was exuviae collected during the first visit to a site, which may have been there for significantly longer.

There were so few entries for just *S. hudsonica* that we combined those points with *S. semicircularis* into a single entry for *Somatochlora* spp. to facilitate emergence time comparisons. To find peak emergence time by taxon, we log transformed exuvial density, then calculated the peak time from 2nd degree parabolic lines of best fit. We chose to use quadratic polynomials because they have a single line of symmetry and, therefore, display a single “best time” for emergence monitoring. The standard quadratic equation is $y = ax^2 + bx + c$. In this equation, a and b are coefficients, and c is the y-axis line intercept. On a graph in which x represents time, and y represents exuvial density, the peak emergence time is calculated as $b \div (-2a)$.

We expect some species and even more genera to exhibit polymodal emergence times in nature, thus the calculation only answers the question, “What is the *single best time* to find

evidence of the taxon emerging, based on exuvial survey data?" The R^2 value included with each equation addresses how well the quadratic equation fits the data.

Results

Using records from multiple databases, we collated 35 unique locations where *Somatochlora hudsonica* specimens have been collected or identified in the continental United States over the last century (1914 – 2014). These specimens were collected from four states (37% Colorado, 23% Montana, 11% Utah, and 29% Wyoming) at a median elevation of 2702 m. Specimens were collected from June 23 to September 4.

Specimens at higher latitudes were found significantly later in the season ($p = 0.006$, Fig 2). Linear regression of specimen latitude on observation date (Fig 2) indicates that at 40° latitude (the southern edge of Boulder County), individual specimens could be found from June 12 to August 23. For each 0.5° increase in latitude, specimen observation date increases by 2.8 days (95% CI: 0.8 – 4.8 days). Additionally, we found a strong negative relationship between the elevation and latitude where specimens were found ($p = 0.00008$). Linear regression of latitude on elevation (Fig 3) indicates that at 40° latitude (the southern edge of Boulder County), specimens are likely to be found from 2524 to 2983 m. For each 0.5° increase in latitude, average elevation decreases by 125m (95% CI: 68 – 183 m).

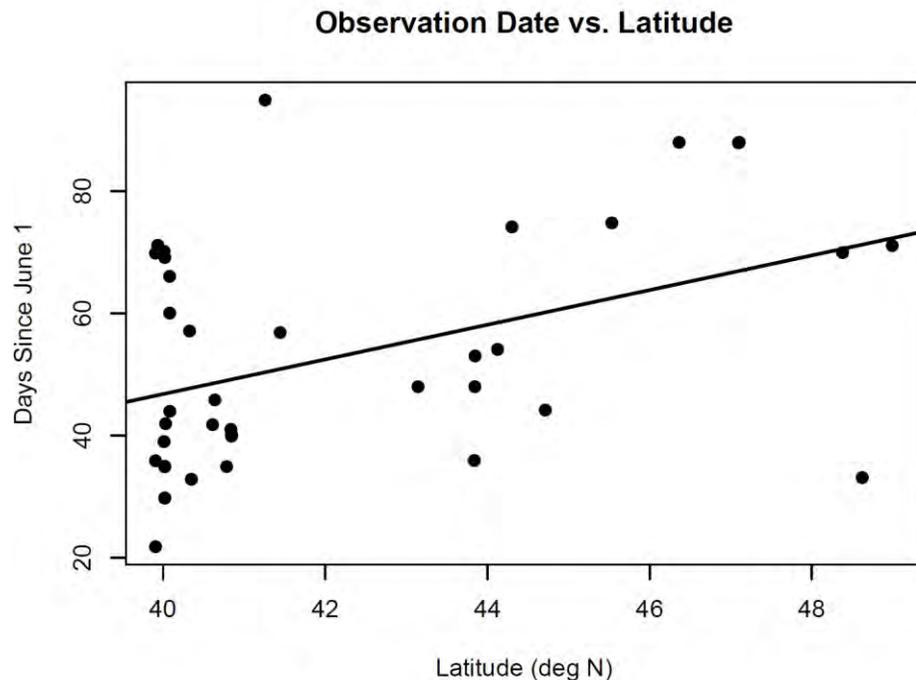


Figure 2. *S. hudsonica* observation date increases at higher latitudes.

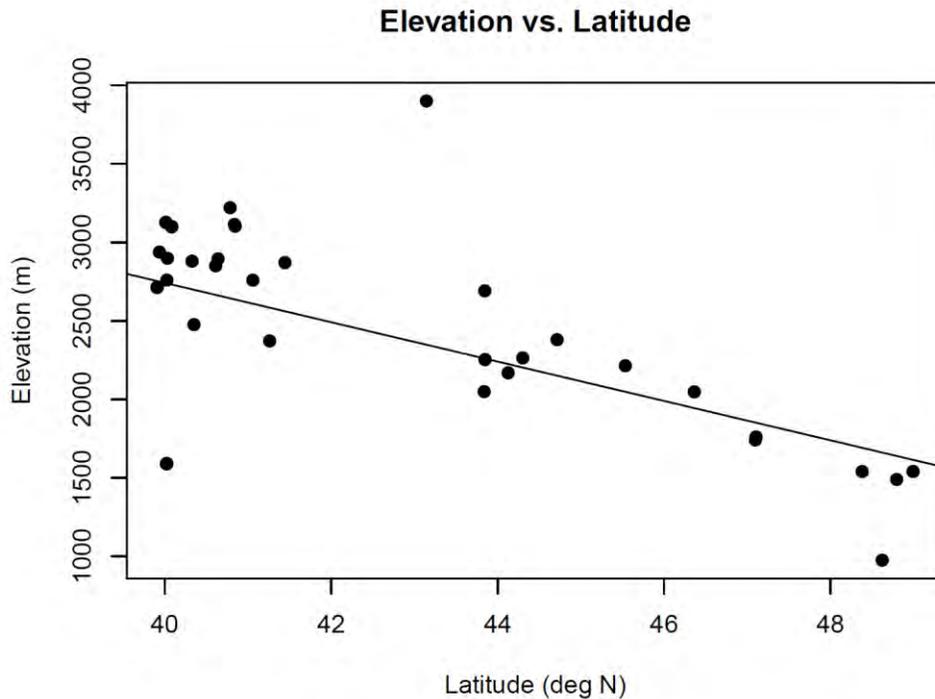


Figure 3. Specimens are found at lower elevations at higher latitudes.

We constructed three habitat suitability maps using the arithmetic mean habitat suitability index (Fig 4), the geometric mean habitat suitability index (Fig 5), and the proportion of bioclimatic models that predicted *S. hudsonica* presence (Fig 6). The average habitat suitability score across all parcels was 0.424 ± 0.120 , 0.115 ± 0.149 , and 0.303 ± 0.309 for each of the three indices respectively. Based on these models, prior occurrences of *S. hudsonica* within Boulder County and initial site reconnaissance, we chose eight sites at which surveys for exuvia and/or adults would be conducted: Barron NE (exuviae and adults, 40.0975 °N, 105.5144 °W), Barron SW (exuviae and adults, 40.0926 °N, 105.5212 °W), Caribou North (exuviae and adults, 40.0087 °N, 105.5422 °W), Delonde Ponds (exuviae and adults, 39.9899 °N, 105.5302 °W), Duck Lake (exuviae and adults, 40.0834 °N, 105.5129 °W), Giggey West (adults, 39.9499 °N, 105.4737 °W), Minnick-Thompson (adults, 40.0008 °N, 105.5022 °W), and Mud Lake (adults, 39.9777 °N, 105.5098 °W). Habitat suitability scores for all BCPOS parcels can be found in Appendix A.

Arithmetic HSI for *S. hudsonica*

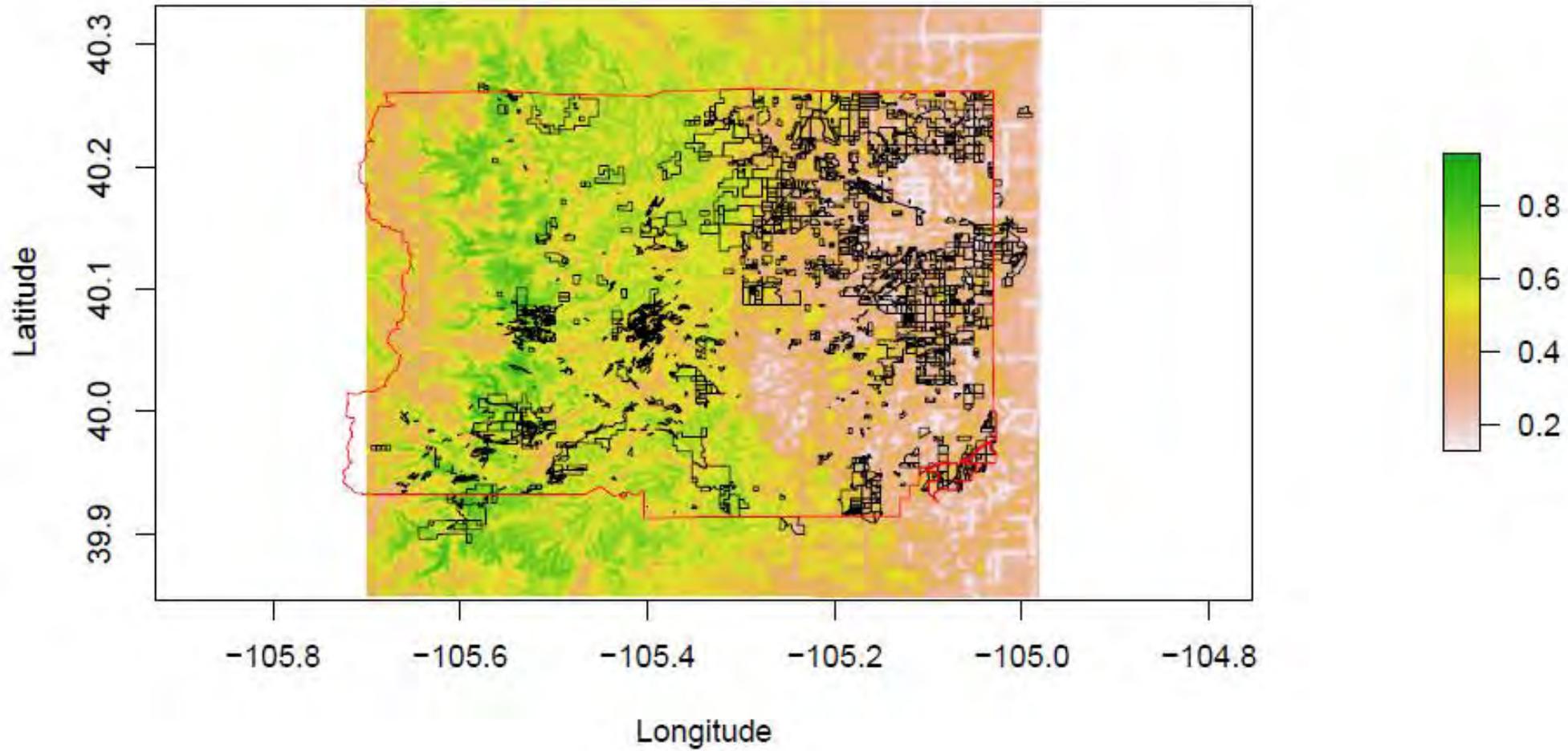


Figure 4. Arithmetic habitat suitability index

Geometric HSI for *S. hudsonica*

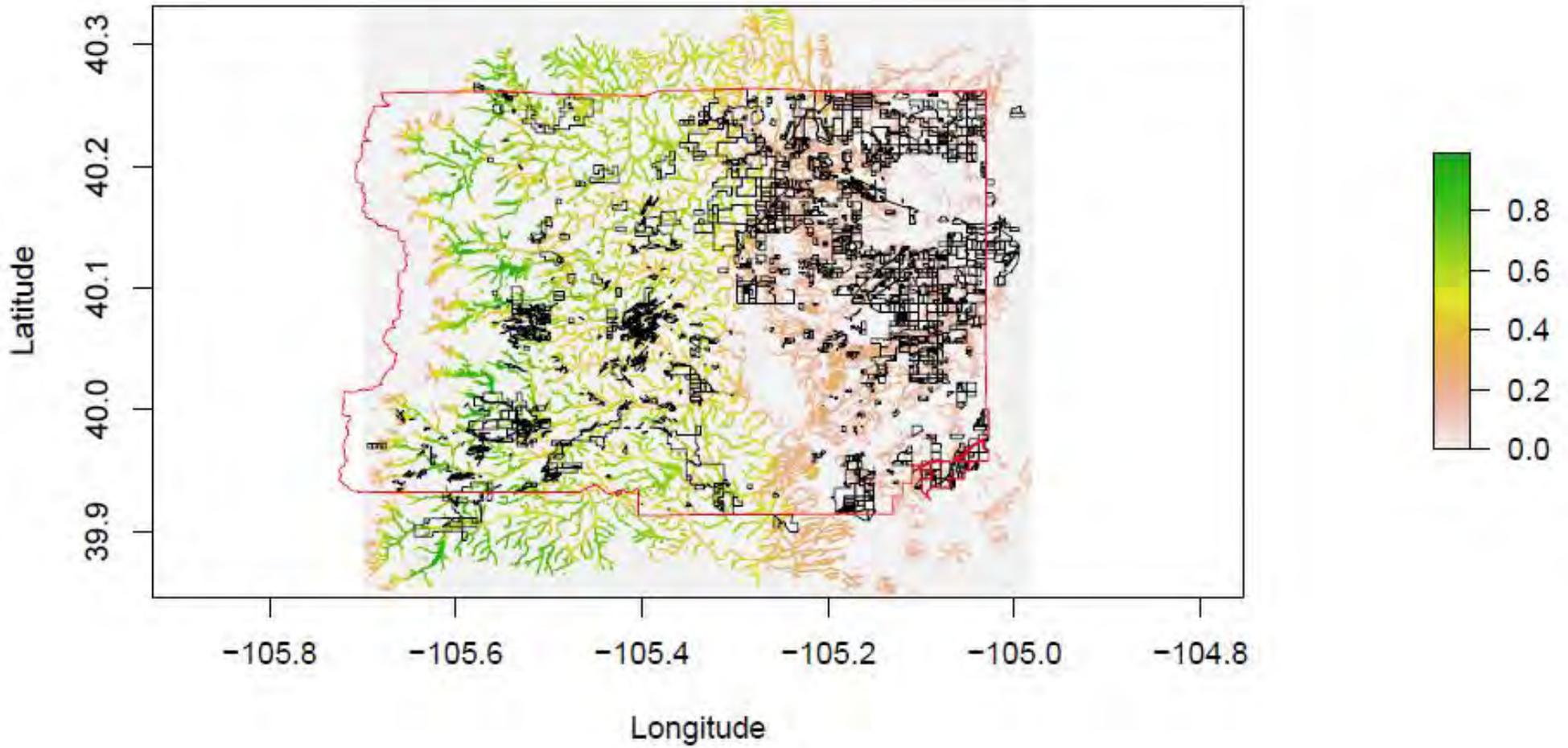


Figure 5. Geometric habitat suitability index

Model HSI for *S. hudsonica*

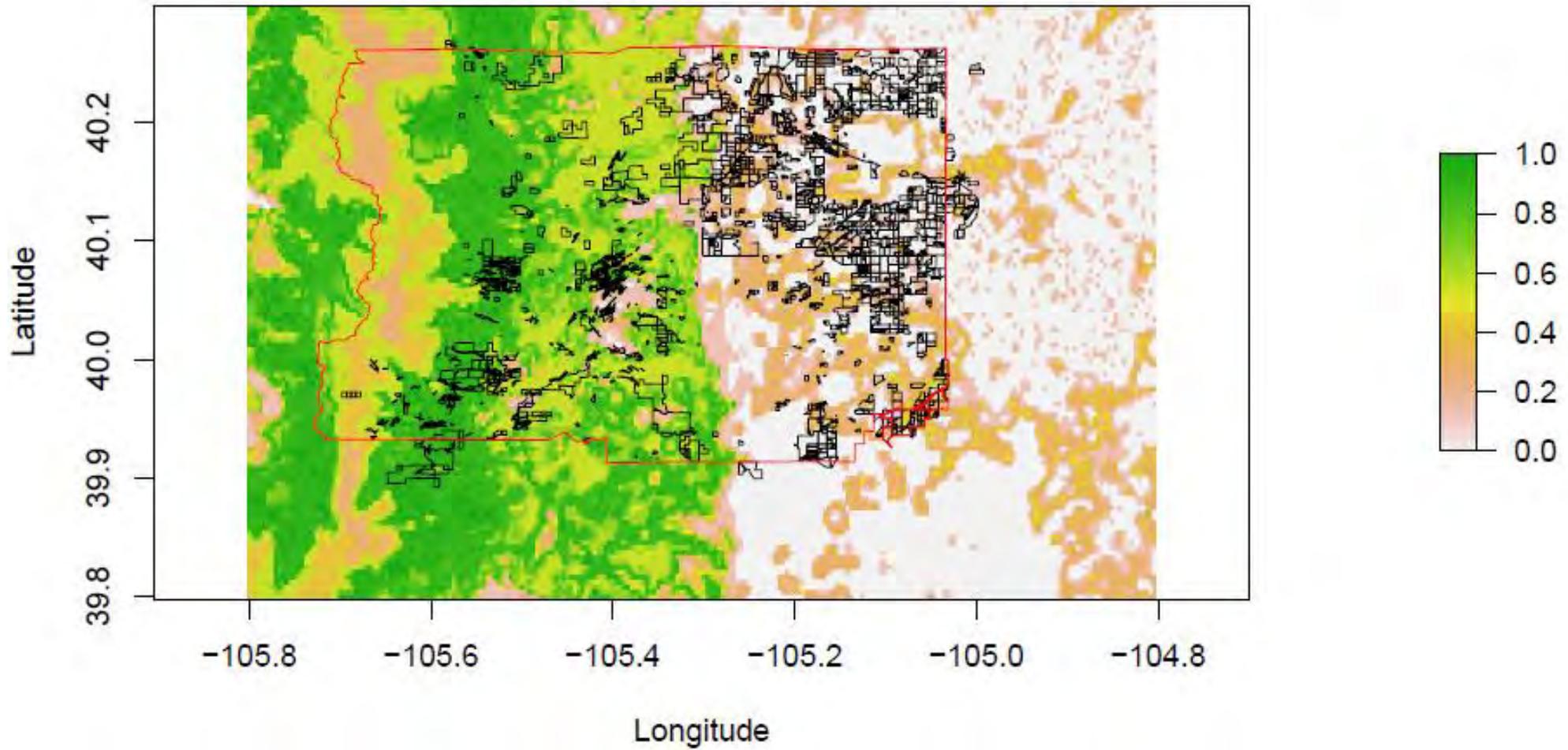


Figure 6. Model average habitat suitability

Exuvial Survey Results

Rarity of Somatochlora hudsonica

Out of 236 dragonfly (Suborder: Anisoptera) exuviae from five locations, two belonged to *S. hudsonica* (see Table 1). One exuvia was retrieved from Barron SW on June 30th, 2017. It was one of 71 dragonfly exuviae recovered from Barron SW during 2017. The second *S. hudsonica* exuvia came from Delonde Ponds on July 12th, and was one of only 7 total dragonfly exuviae recovered from that location. See all raw exuvial survey data in Appendix B.

Across five sites, relative abundance of *S. hudsonica* exuviae was 0.59% (Table 1). Genus *Sympetrum* was 26 times more dominant than genus *Somatochlora* (Fig 7).

Table 1. Raw summary of dragonfly exuviae collected by location. The counts are *not* controlled by number of site visits and number of plots sampled. Relative Abundance reported in this table is based on density, which considers the number of site visits and plots sampled.

Site	Somatochlora hudsonica (Hudsonian Emerald)	Somatochlora semicircularis (Mountain Emerald)	Cordulia shurtleffii (American Emerald)	Genus: Aeshna/Rhionaeshna	Genus: Libellula	Genus: Leucorrhinia	Genus: Sympetrum
Barron NE	0	0	0	19	2	4	49
Barron SW	1	3	28	0	1	23	15
Caribou Kettle	0	4	0	0	3	4	170
Delonde Ponds	1	0	1	3	0	0	2
Duck Lake	0	0	3	2	2	1	0
Total Counts	2	7	32	24	8	32	236
Relative Abundance (%)	0.59	2.05	9.38	7.04	2.35	9.38	69.21

The relative abundances of *S. semicircularis* and *Cordulia shurtleffii* (American Emerald) of Family Corduliidae were analogous with other dragonfly taxa. The relative abundance of *C. shurtleffii* exuviae was the same as that of *Leucorrhinia* (white face) species, and *S. semicircularis* was only 0.3% less abundant than *Libellula* spp. However, *S. hudsonica* stands out as the least abundant taxon (Table 1 and Fig 7).

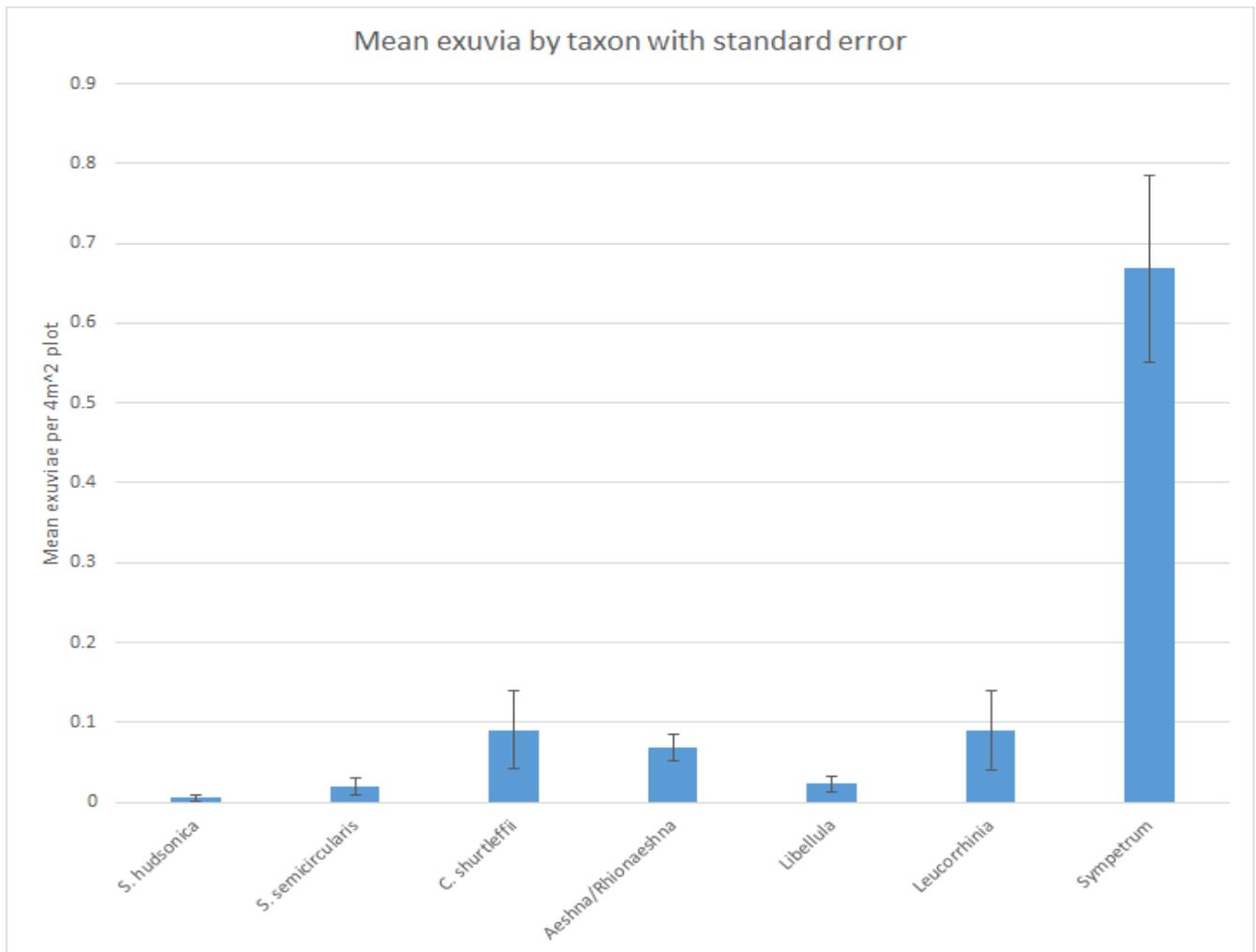


Figure 7. Mean exuvia per plot separated by species (Corduliidae) and genus (all other dragonflies). Error bars shown are standard error.

Emergence Timing

Here, we use exuvial discovery date as a proxy for dragonfly emergence date. Since we visited each site weekly, we expect the actual emergence to be no more than one week off. The major exception is exuvia collected during the first visit to a site, which may have been there for significantly longer. For a possible example, see *Cordulia shurtleffii* in Figure 9.

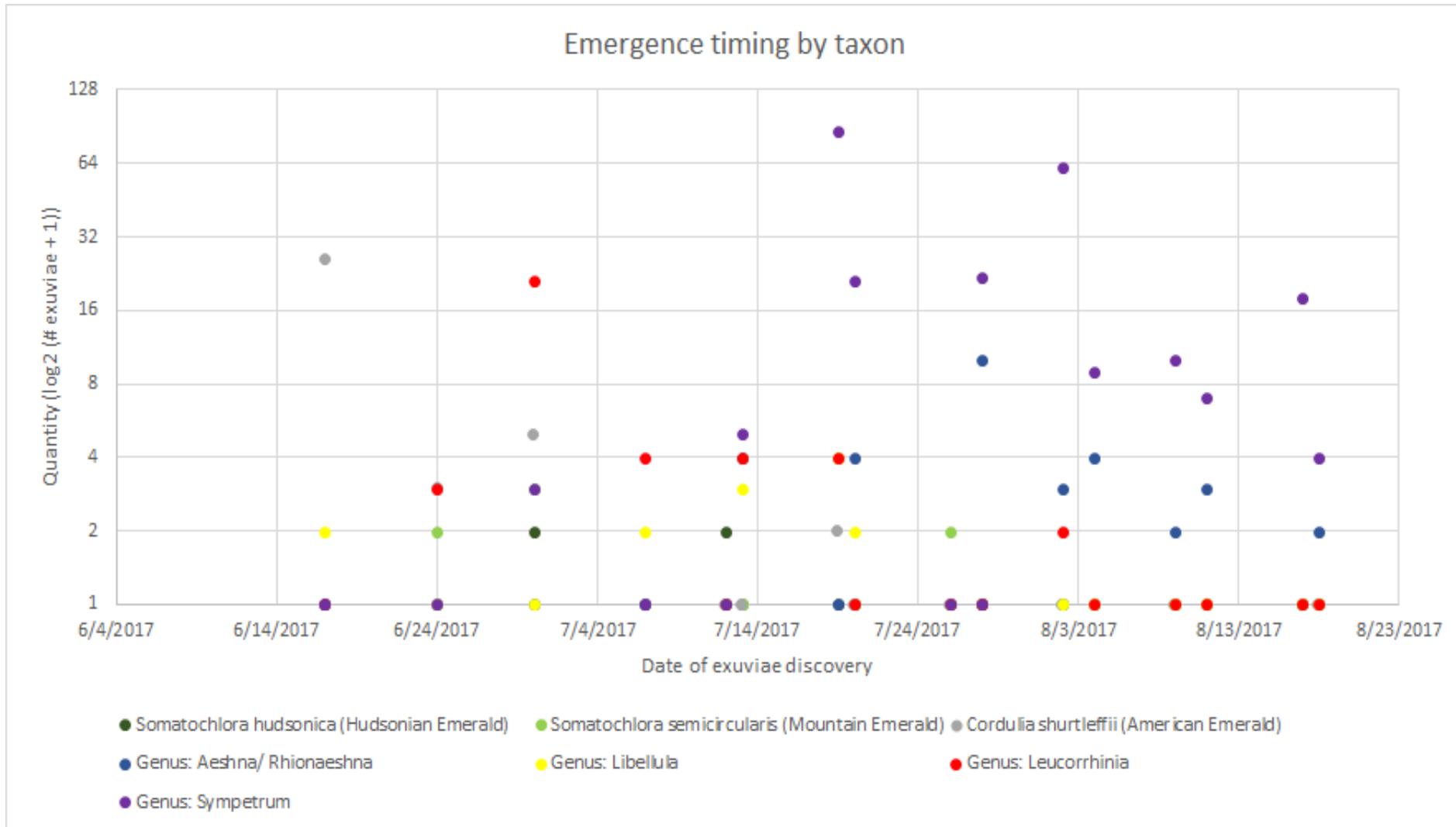


Figure 8. Exuviae of all anisopteran taxa discovered by calendar date. All quantities were increased by 1 because zeros are not represented on the log transformed y axis.

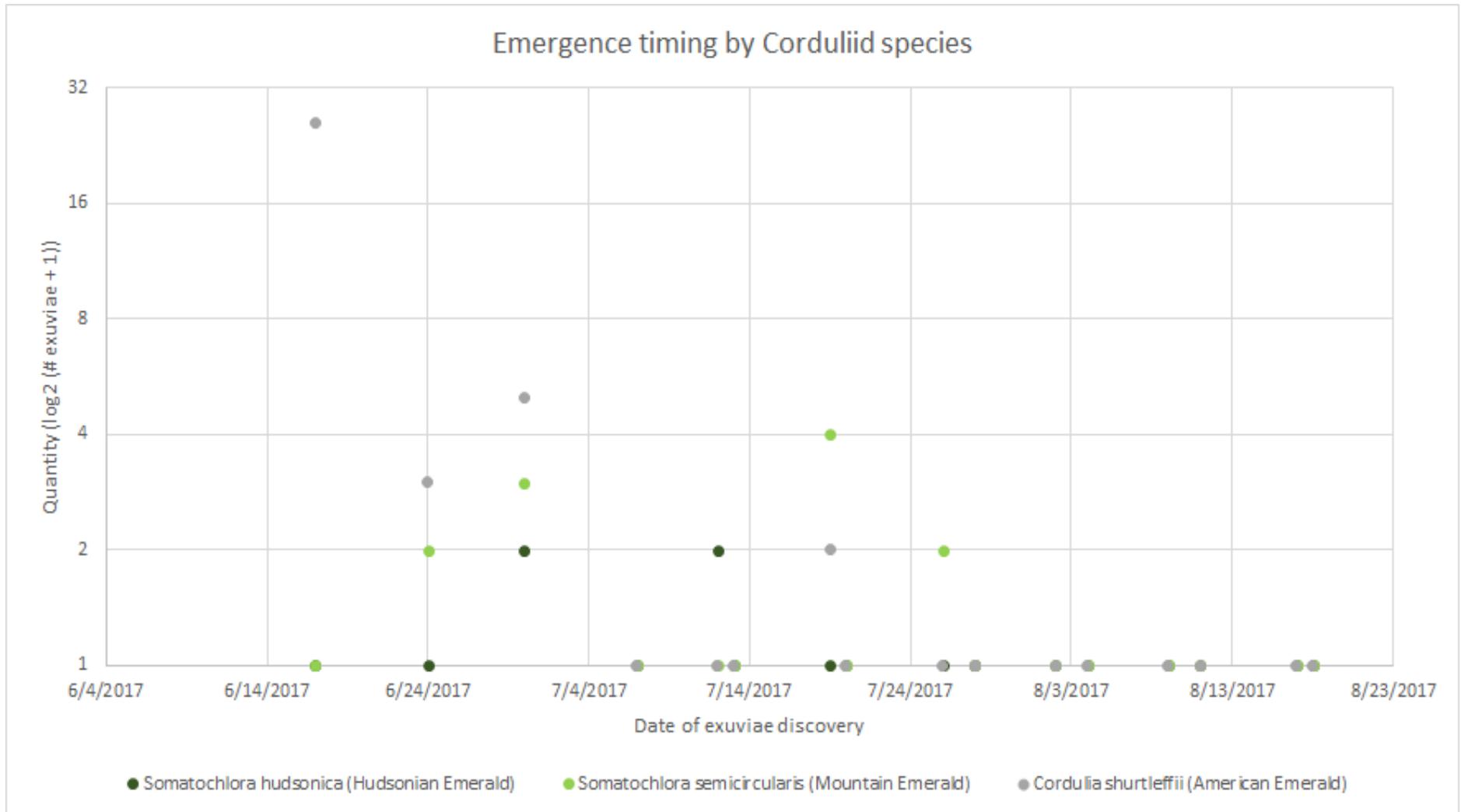


Figure 9. Exuviae of Corduliid species discovered by calendar date. All quantities were increased by 1 because zeros are not represented on the log transformed y axis.

Somatochlora emergence peaks at 20 days (7/5/2017). 53 days (8/7/2017) is the peak of all dragonfly emergence. 52 days (8/6/2017) is the peak time for *Sympetrum* emergence. (Fig. 10). Peak emergence time for all dragonflies is driven by *Sympetrum* spp. The low R² for the gently sloping parabola of best fit for all dragonflies suggests that different species were emerging regularly throughout the 2017 sampling season.

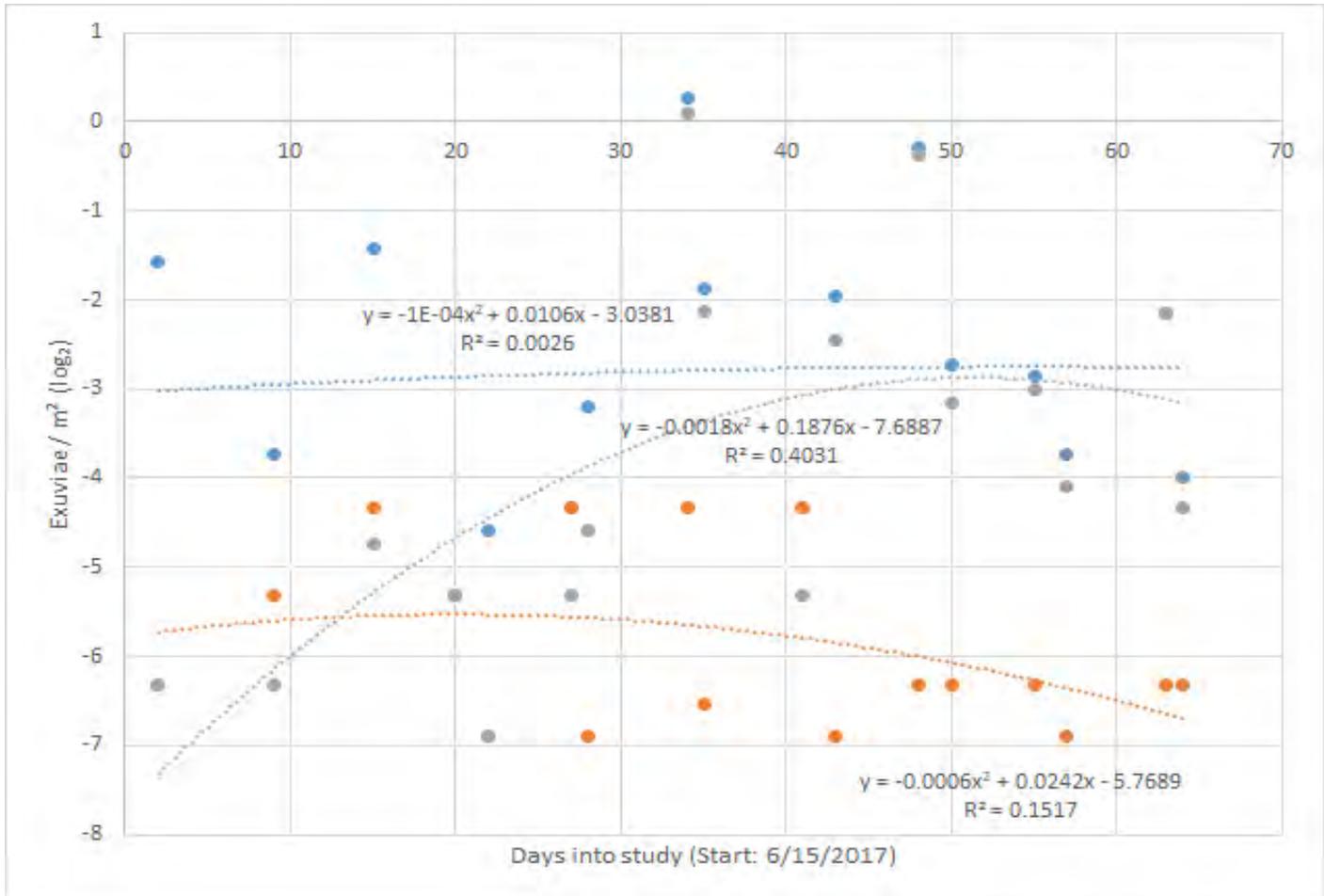


Figure 10. Emergence times for *Somatochlora* sp. (orange), *Sympetrum* sp. (gray), and all dragonflies (blue) with parabolic lines of best fit, equations of those lines, and R² values. To accommodate calculations, dates are represented on the x axis as the number of days after 6/15/2017.

Site Variation in Exuvial Density

Some sites were far more productive than others. We discovered the majority of exuviae at Caribou Kettle Pond, Barron North East, and Barron South West (Fig. 11). Bias was introduced by the late discovery of Barron NE for exuvia sampling, and late entry onto seasonally closed Caribou Ranch (Fig. 11).

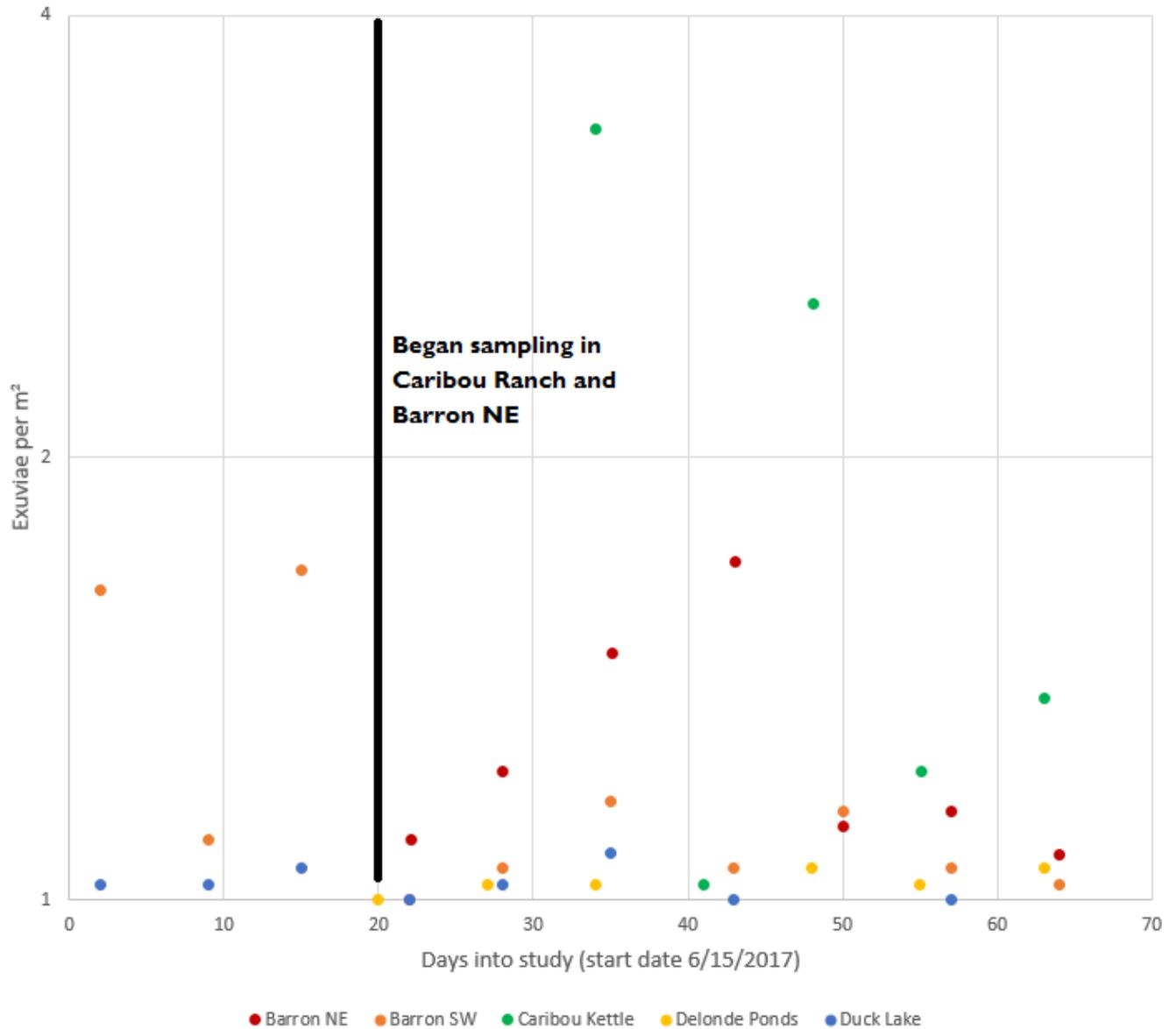


Figure 11. Density of exuviae - all dragonfly taxa - over time. Broken down by collection site. Log₂ y scale transformation to increase visibility of low density sites. Exuvial density was increased by one to appear on logarithmic y axis.

The temporal and spatial dynamics of exuvial surveys is summarized by a two-dimensional non-metric dimensional scaling ordination (Figure 12).

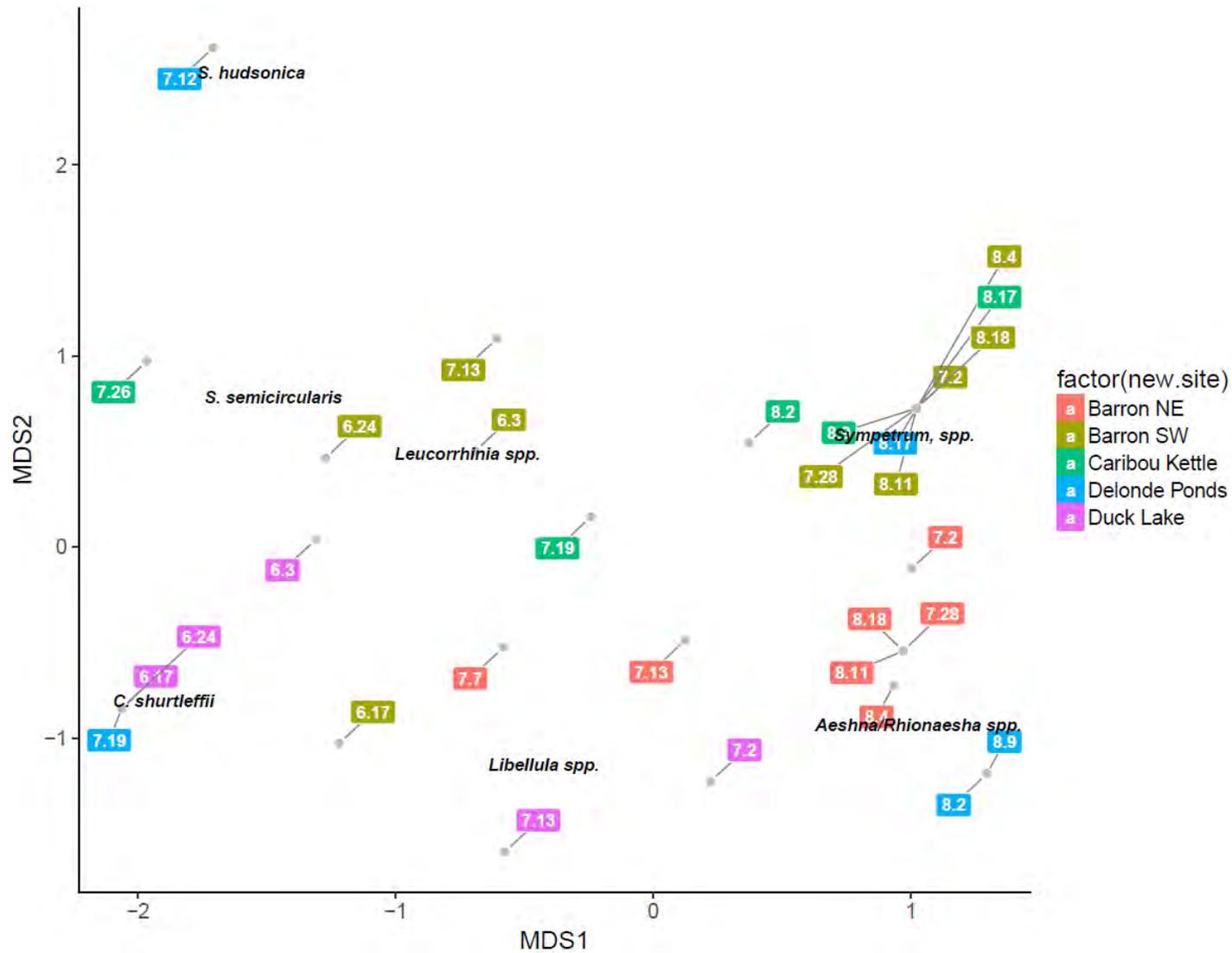


Figure 12. Spatiotemporal variation in exuvial community structure.

Habitat Associations from Exuvial Survey

The two *S. hudsonica* exuviae came from two different sites: Barron SW, an isolated, rocky-bottomed, high-altitude kettle wetland (precipitation-fed) in the Barron parcel, and Delonde Ponds, a lower-altitude string of mucky ponds along Delonde Creek near the well-traveled Delonde homestead. The two sites are significantly different from one another (see Figure 18). Because of the very small sample size (n=2), and the diversity of the sites, it is

difficult to draw any conclusions about habitat associations. Exuvial survey data combined with adult surveys informs habitat association analysis in Figure 18 and Table 4.

Table 2. Summary of the two sites where *S. hudsonica exuviae* were recovered, regarding the habitat association hypotheses of this paper.

	Barron SW	Delonde Ponds
Forested area within 200 m of water?	Yes, all around	Yes in some parts, not in others
Presence of fish?	No	Yes
<i>S. semicircularis</i> exuviae?	Yes	No, but adults were captured
Presence of other dragonfly taxa?	Yes	Yes

Captive Breeding of Somatochlora sp. at Butterfly Pavilion

We collected eggs from three female *S. semicircularis* at Barron NE on 7/7/17, 7/13/17, and 7/20/17 respectively. They are labeled chronologically as broods 1, 2, and 3. Hatchlings were observed swimming among the eggs of broods 1 and 3 starting on 8/29/2017. As of November 15th, 2017, all 24 *S. semicircularis* larvae that were discovered as living hatchlings remain living. That represents a 64% survival rate for hatchlings from Brood 1, 37% survival rate for hatchlings from Brood 3, and an overall survival rate of 49% (Table 3). Brood 2 was very small (3 eggs) and none of them hatched in the fall. Most eggs in each brood contain developing embryos visible through a microscope (x40), and will diapause over winter (Table 3).

Most wild dragonfly larvae die before they emerge as adults. Among the most generous estimates is that “fewer than 10%” or 3-10% survive to emergence (measured for *Plathemis lydia*, *Libellula luctuosa*, *Ladona deplanata*, *Epitheca cynosure*, *Epitheca semiquea*, and *Celithemis fasciata*)^{32,33}. Long-lived *Cordulia aenea amurensis* experienced 99.8% mortality over five years spent as an aquatic juvenile³⁴. Soluk and DeMots estimated that Hine’s Emeralds survival rate from egg to mature larvae is less than 1-5.5%³⁵. Most mortality in the wild is due to predation, including from conspecifics³⁶. Much of early mortality in this case can be explained by cannibalism. The 100% survival of *S. semicircularis* after separation of hatchlings is a positive indicator of the Butterfly Pavilion’s ability to raise *Somatochlora* larvae in captivity.

Table 3. Summary of findings from captive rearing of *Somatochlora semicircularis* from eggs in 2017.

	Brood #		
	1	2	3
Oviposition date	7/7/2017	7/13/2017	7/20/2017
Total eggs	62	3	143
Live hatchlings (days since oviposition)	14 (53)	0*	6 (40); 7 (43); 10 (63)**
Hatched/broken eggs by November 15, 2017	22	0	27
Unfertilized eggs	0	0	9
Remaining viable eggs by November 15	40	3	107
Proportion eggs hatched pre-winter	35%	0%	19%
Larval survival past 2nd instar	64%	n/a	37%
Range larval lengths on November 15 in mm	2.5 - 3.5	n/a	1.3 - 3.0
Mean larval length on November 15 in mm (n)	3.0 (5)	n/a	2.3 (8)

* Brood 2 includes only three eggs, none of which have hatched as of November 15th, but all appear fertilized (darkened).

** Numbers of hatchlings are additive. In this case, larvae hatched on three occasions, producing 6, 1, and 3 live hatchlings for a total of 10.

Marking Trial

We chose one site, Barron NE, to mark individuals over a two week (two visit) period. On July 13th and July 20th, 2017, we captured three total adult male *S. hudsonica*, which we marked and released taking care to minimize handling time (Fig 14). The numbered markers appeared well affixed, and once released, the dragonflies flew quickly and strongly high into the trees of the adjacent forest. During following weeks, we searched for the marked individuals at each exuvial study site, but did not see or recapture them.



Figure 14: Marked *S. hudsonica*. Photograph by Katrina Loewy and Nick Coon

Adult Survey Results

After conducting three transect surveys at each of the eight survey locations, we caught and released *S. hudsonica* adults at four sites: Barron NE, Caribou North, Delonde Ponds, and Duck Lake. Across all eight sites, the relative abundance of *S. hudsonica* compared to total dragonflies (damselflies excluded) is 4.8%. Including damselflies, the relative abundance of *S. hudsonica* is only 1.2% on average across all eight sites. If we focus only on sites where *S. hudsonica* was found, these average numbers rise to 6.6% and 1.8% respectively. Encounter rates for dragonflies (i.e. number of dragonflies/m) and *S. hudsonica* varied significantly by site (Fig. 15). Our highest encounter rate for dragonflies occurred at Barron NE, Caribou North, Delonde Ponds, and Minnick-Thompson. *S. hudsonica* encounter rate was most prominent at Caribou North and Barron NE.

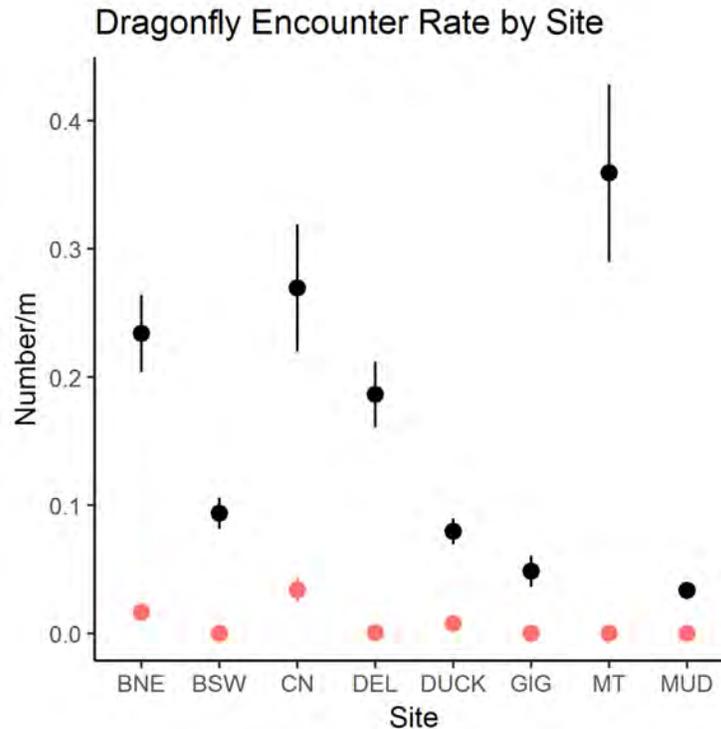


Figure 15. Average encounter rates by site (black = all dragonflies, red = *Somatochlora hudsonica*)

For all dragonflies and *S. hudsonica*, we modeled the $\log(x+1)$ encounter rate using a linear mixed model. The fixed effects in the model included percent sun, days since June 15, and quadratic time of day, average habitat score, and an interaction between percent sun and time of day. The random effects included observer, site, and transect within site. For all dragonflies we find a positive relationship between % sun and encounter rate ($p = 0.0034$) such that a 10% increase in sun exposure corresponds to a 20% increase in the median encounter rate of dragonflies (Fig. 16). Furthermore, we found a significant quadratic relationship with time of day ($p = 0.0004$), indicating a peak encounter rate at roughly 12:30 pm (Fig 17). We did not find a significant effect of habitat score ($p = 0.95$), days since June 15 ($p = 0.21$), or the interaction between percent sun and time of day ($p = 0.31$) in our model. Residual random variation in $\log(\text{encounter rate})$ is driven by all four random effects: 34% due to variation by sites, 10% due to variation in transects nested within sites, 20% due to interobserver variation, and 26% to residual variation.

The same fixed effects were not significant in a similar model of encounter rate of *S. hudsonica* in sites where it was found. Only days since June 15 showed a marginally significant negative effect on encounter rate ($p = 0.098$) such that median encounter rate decreases by 8%

for every month that elapses during the summer. Residual random variation in log(encounter rate) for Hudsonian emeralds is driven by three random effects: 49% due to variation by sites, 14% due to variation in transects nested within sites, and 37% due to residual variation. Limited interobserver variability occurred for Hudsonian emerald encounter rate.

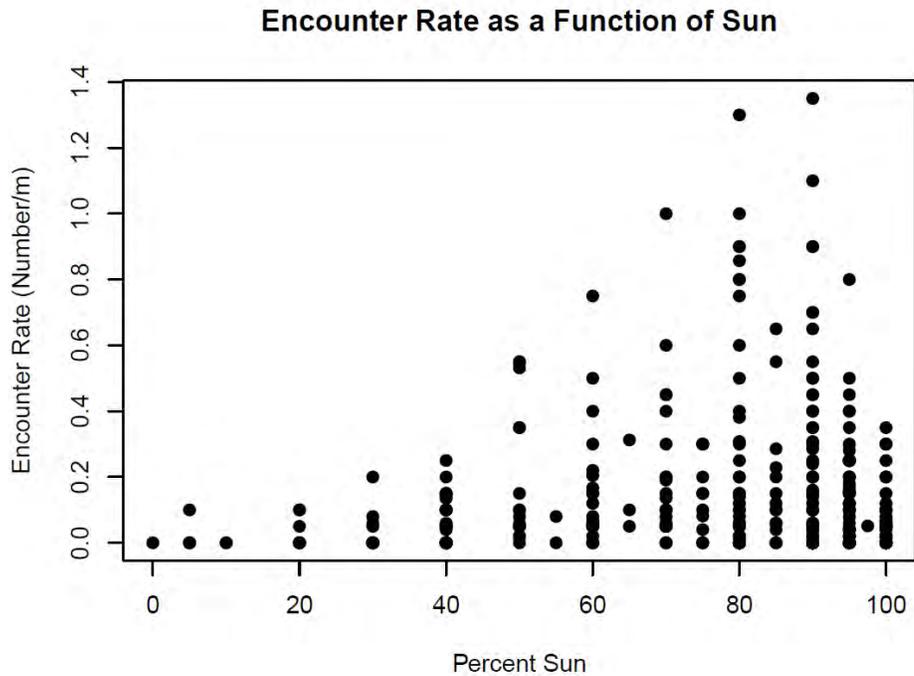


Figure 16. Total dragonfly encounter rate increases as % sun increases.

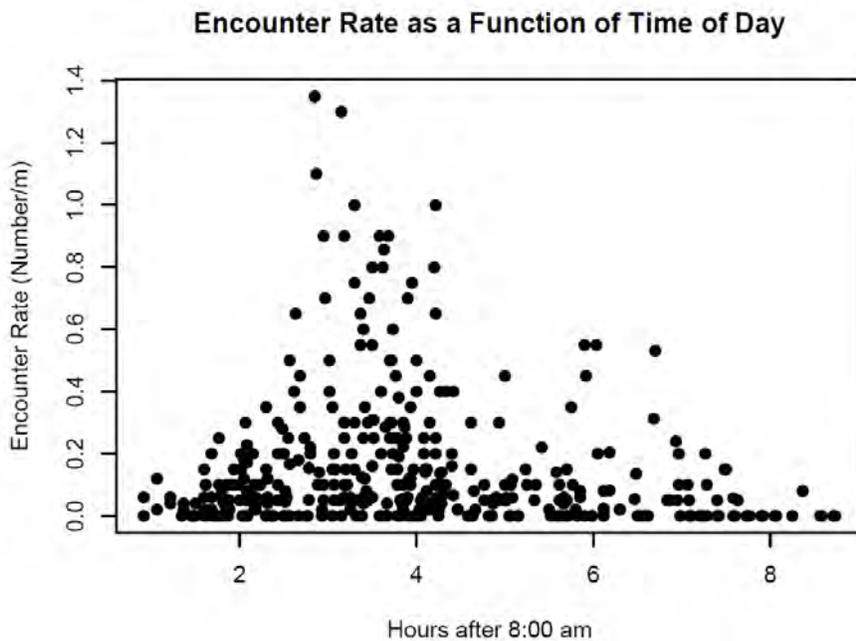


Figure 17. Total dragonfly encounter rate as a function of time of day.

Habitat Associations

We also examined those habitat factors (both physical habitat and water quality) that differ between those sites where we observed and did not observe *S. hudsonica*. A two-dimensional NMDS ordination of the habitat distance (Gower's) among sites explains 53% of the variation in habitat among sites. Notably, sites where we observed *S. hudsonica* were distinct in ordination space from those where we did not observe the species ($R^2 = 0.32$, Fig. 18). Sites where we observed the species tended to be higher in elevation, forest land cover, emergent vegetation, substrate size (% gravel, % bedrock). In terms of water quality, sites where we observed *S. hudsonica* have lower pH and lower dissolved ions than those sites where we did not observe the species. Significant differences among habitat variables at $\alpha = 0.05$ between areas where the Hudsonian emerald was found compared to where it was not found are indicated in Table 4.

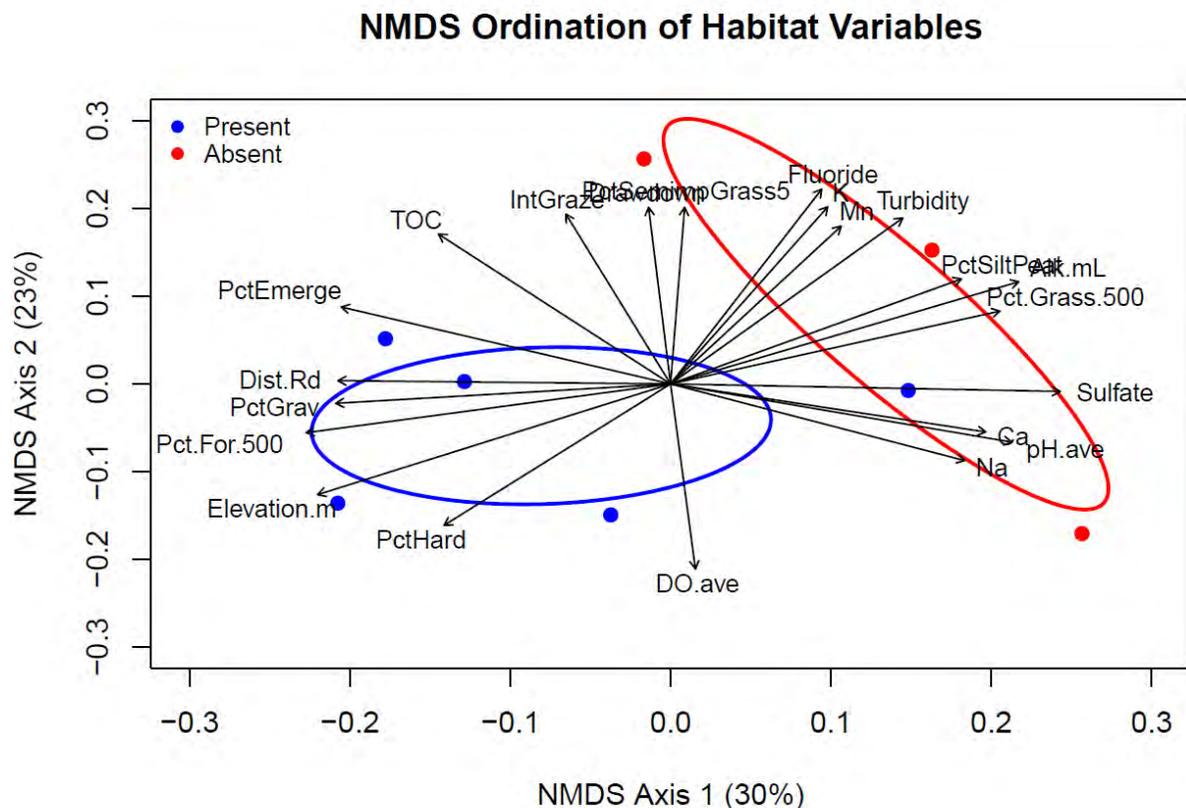


Figure 17. Sites where *Somatochlora hudsonica* was found differ in physical habitat and water quality from those where *Somatochlora hudsonica* was absent.

Table 4. Significant differences in habitat variables between ponds where *Somatochlora hudsonica* is present and where it is absent.

Variable	90% Lower	90% Upper	Mean Absent	Mean Present
Elevation (m)	141.73	328.07	2591.67	2834.20
% of Margin with Overhanging Veg.	-19.17	-2.83	15.00	4.00
Turbidity - Visual	-1.27	-0.17	2.17	1.43
Percent Silt/Peat Substrate	-54.67	-10.67	90.00	57.67
Percent Hard/Bedrock Substrate	10.67	38.00	0.00	23.67
Percent Semi-Improved Grassland within 5 m	-36.67	-3.33	20.00	0.00
Water Quality for Amphibians - Visual	0.40	1.40	2.83	3.77
Potassium (mg/L)	-5.95	-1.70	5.33	1.50
Sodium (mg/L)	-28.39	-4.14	18.70	2.66
Magnesium (mg/L)	-11.59	-3.02	8.67	1.40
Calcium (mg/L)	-29.99	-6.09	23.40	5.56
Chloride (mg/L)	-123.59	-8.94	66.43	0.17
Fluoride (mg/L)	-0.20	-0.03	0.13	0.02
Total Dissolved Solids (mg/L)	-141.07	-33.45	102.72	15.71
Distance to nearest Road (m)	87.00	431.53	128.00	389.00
Percent Forest within 500m	6.00	28.67	71.67	90.00
Percent Grassland within 500 m	-27.00	-8.00	25.00	7.00
Percent Barren within 500 m	-5.00	-1.67	3.33	0.00
Alkalinity (mL titrant)	-8.81	-5.14	12.40	5.38

Finally, as an independent assessment of our *a priori* habitat suitability scores, we examined the average differences in habitat suitability between ponds where we observed *Somatochlora hudsonica* and ponds where we did not. Sites where the Hudsonian emerald was found had significantly higher ($p < 0.1$) values of all three habitat suitability scores including a composite score consisting of the the sum of arithmetic, geometric, and model-based. All but the geometric mean score also significantly correlated with the NMDS ordination of habitat factors in our study ponds in the same direction as ponds where *S. hudsonica* was observed.

Discussion

Prior to this study, we knew little of the whereabouts and ecological requirements of *S. hudsonica* in Boulder County. Not only have we confirmed the presence of this rare dragonfly species on Boulder County Parks and Open Space lands, but we have also learned more about the basic biology of this organism through a combined modelling and field approach. This newfound knowledge of the habitat associations, emergence timing and finer scale distribution of *S. hudsonica* can be used along with our burgeoning program of captive rearing to establish management and monitoring plans for its protection.

For the first time, we have documented the occurrence of *S. hudsonica* on Boulder County Parks and Open Space properties notably in Caribou Open Space, Duck Lake, and Barron land parcels. Both exuvial and adult field surveys indicate that *S. hudsonica* is quite rare. Because Boulder County lies at the southern-most edge of the known distribution of the species, it is unsurprising that the species comprises no more than 1-5% of the dragonfly assemblage in our exuvial and adult field surveys. The relative rarity of *S. hudsonica* highlights both the importance of identifying prime habitat for the species and the need for this study describing its habitat requirements and biology.

Based on past studies and observations of *S. hudsonica* and other *Somatochlora* species, we made several predictions regarding the habitat *S. hudsonica* would prefer in our region. Our observations and analysis corroborates Walker's prediction that *S. hudsonica* aquatic habitat would be found very near highly forested areas¹⁸. This finding indicates not only that forest is likely important for the species to forage away from the water, but also as a buffer against changes in water quality. Specifically, four out of the five sites where we observed *S. hudsonica* are sheltered ponds and lakes nearly surrounded by forest. Three of these are quite small kettle ponds that have lower alkalinity, dissolved ions, and pH in comparison to ponds where we did not observe *S. hudsonica*. These low concentrations not only highlight the need for pristine water conditions, but also the vulnerability of these waters to any changes to the surrounding land, such as by forest thinning or burning. Consequently, protecting forested buffer areas around small ponds will be of prime importance. In addition to these variables, larger substrate size and a higher proportion of emergent vegetation also appear to be important local-scale variables for *S. hudsonica* to thrive either because of its own habitat requirements or that of its prey. These are likely important for larval development and emergence because they might protect early instar larvae or serve as vegetation for emergence.

Other predictions we made based on literature on other congeners, did not prove true for *S. hudsonica*. For example, the congener *Somatochlora hineana* often dominates the dragonfly assemblage in habitats where it is found because it exploits habitats other dragonflies do not³⁰. Conversely, we found both exuviae and adults of *S. hudsonica* at sites with many other dragonfly species. We also presumed that fish presence might exert top-down control on *S. hudsonica* breeding habitat because dragonfly larvae often make up a significant portion of fish diets³³. However, we found *S. hudsonica* in two locations where fish are also present, Duck Lake (adults) and Delonde Creek (exuviae and adults).

Future monitoring efforts can be guided by the results we report in this study. The habitat scoring system we constructed in this study can be used as a way to prioritize new areas for *S.*

hudsonica reconnaissance. We showed that significantly higher suitability scores were indeed found in areas where *S. hudsonica* is present and where local habitat is suitable for the species. Thus, if we target small heavily forested ponds from 2500-3000 meters in elevation, we are likely to also find local conditions which favor presence of *S. hudsonica*.

Finding appropriate monitoring locations (i.e. where?) is no more important than monitoring at the right time of year (i.e. when?). Our findings support an earlier emergence period than previously reported for *S. hudsonica*. While Ann Cooper reported a flight period of mid-July through early August in the Colorado Front Range¹⁹, Dennis Paulson reported flight seasons for Yukon (June - August), British Columbia (May - August) and Montana (July - August) in Canada and the United States⁹. Our analysis of occurrence records shows earlier emergence at lower latitudes, and our field surveys support earlier flight times for the species. We first observed a mature adult male on June 28, 2017, which means it would have had to emerge at some point prior to that. The first *S. hudsonica* exuvia (of two) was found on June 30, 2017, and the peak emergence for *Somatochlora* sp. was estimated to be about July 5, 2017. Further corroborating this finding, we observed a decline in the encounter rate of *S. hudsonica* over the course of our monitoring throughout the summer. This implies that our study began after the peak in emergence. In future monitoring, we recommend moving the start date to early June or late May. Furthermore, our findings also recommend that adult surveys take place within the 10 am -2 pm timeframe under high sun conditions.

Curiously, the adult and exuvial surveys differed in their report of *S. hudsonica* occurrence, a finding which indicates the importance of studying a species throughout its life cycle. For example, peak exuvial discovery time was about 10 days earlier than peak adult observations, which could reflect the time it takes *Somatochlora* spp. to mature. Additionally, we collected an exuvia at one location (Barron SW) where no adults were observed. That could be explained by the rarity of *S. hudsonica* – adults were not observed at the site because they are uncommon in general - or it could be due to adult dispersal to more suitable habitats. It is also possible that the quality of the site for mating and oviposition may have changed over the (estimated) three years it takes for a larva to mature and emerge.

The more common trend was to find adults at locations with no *S. hudsonica* exuviae. While exuvial sampling provides the best evidence of breeding habitat, there are limitations with it as well. Exuvia sampling significantly underestimates species abundance. Our method of sampling once a week meant that we likely missed many exuviae, especially after storms and in unsheltered areas. Again, we may have missed emergences that happened before we accessed the sites. Variation among sites in exuvial density was extreme. We only collected

seven total dragonfly exuviae from Delonde Ponds, although many adults were observed, including teneral that, at other sites, were observed within inches of their molts. This discrepancy may be related to higher moose and elk grazing pressure that disturbs recent exuvial molts.

In sum, our analysis strongly indicates that *S. hudsonica* is imperiled by living on the edge of its distributional range. We showed that at the southern edge of its range, *S. hudsonica* can only be found at higher elevations. Thus, in the face of a warming climate, we can only expect that *S. hudsonica* would shift its distributions to higher elevations in order to maintain its thermophysiology. If so, an absolute barrier of tree line would preclude establishment of *S. hudsonica* at higher elevation. Such thermal restriction highlights the necessity of protecting small, snow-fed mountain ponds from other anthropogenic disturbances that could prevent them from providing adequate habitat. Such disturbances include deforestation by thinning and burning, livestock grazing, pollution from nearby roads and other point sources as well as more severe effects like dredging and filling. Given this finding, presence of *S. hudsonica* within its elevational range might be used to indicate high quality aquatic habitat along forest-aquatic ecotones within montane forests throughout the county. Conversely, absence of the species could hint at recreational or forestry related impacts to aquatic resources.

Despite the significant amount of knowledge gained from our joint collaboration on evaluating *S. hudsonica* habitat, many questions still remain unanswered with regard to the basic ecology of this imperiled species. To unravel these mysteries, we recommend a focused in-depth study earlier in the year at the Barron NE pond where we found numerous *S. hudsonica* specimens. Not only would this limit disturbance to potentially high suitability areas, but it would allow a different set of questions to be answered. Future studies might involve:

- (1) A concerted effort to find females to support captive rearing of *S. hudsonica* in the same manner as current, thriving *S. semicircularis* have been reared at the Butterfly Pavilion.
- (2) A more dedicated mark-recapture study to estimate population size at ponds. In 2017, we marked three male *S. hudsonica*, which we never saw or captured again, which highlighted the need for greater focus on this aspect of the study.
- (3) Determine fine scale habitat associations (vegetation diversity, emergence, substrate sizes at emergence site) for larvae in ponds.

Acknowledgements

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Species Conservation Plan for the Hudsonian Emerald (*Somatochlora hudsonica*
Hagen) on Boulder County Parks and Open Space

Prepared by:

Kristofor Voss, Ph.D.

Regis University

Katrina Loewy

Butterfly Pavilion

Species Description

The Hudsonian emerald, *Somatochlora hudsonica* (Hagen), is a dragonfly (order Odonata) in the Corduliidae family. *Somatochlora* is very diverse; containing the most species of any corduliid genus in North America, and the second most species of any anisopteran genus after *Gomphus* (Gomphidae) (Needham, Westfall, & May, 2014). Like all odonates, the Hudsonian emerald spends most of its life as an immature larva in aquatic habitats from which it emerges as the adult after hemimetabolous (incomplete) metamorphosis. *Somatochlora* larvae have heads twice as wide as they are long, that taper to a straight border with the thorax. *Somatochlora* larvae can be differentiated from other corduliids by presence of middorsal hooks in some species. When absent, the sides of the thorax are uniformly colored (Packauskas, 2005). Corduliids are known as emeralds because of the brilliant green eyes many species bear as adults (Cooper, 2014a; Packauskas, 2015). *S. hudsonica* is well-known for the white rings between each abdominal segment (Figure 1). That feature is diagnostic within Boulder County because no other ringed emeralds are found there (Cooper, 2014a). Elsewhere, different features must be used to distinguish *S. hudsonica* from other white-ringed emeralds (Paulson, 2009). *S. hudsonica* has a dark, metallic-green face with yellow sides (Figure 2) and a metallic-green thorax flanked on each side with a dull, yellow spot. Coloration in males and females are similar, but males have distinctive abdominal cerci that angle sharply inward and then curve outward to meet at a point (Paulson, 2009; Cooper, 2014a, see Figure 1). The total length of the individual is approximately 50-54 mm (Cooper, 2014a).



Figure 1: *S. hudsonica* male, dorsal view. Image by Nick Coon and Katrina Loewy



Figure 2: Marked S. hudsonica male, from the front. Lateral yellow spots are visible on the frons. Image by Katrina Loewy and Nick Coon

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 (Colorado Natural Heritage Program, 2015). For most dragonfly species in the plan, the State listed lack of information as a threat to their survival. Lack of knowledge certainly threatens the Hudsonian emerald, a dragonfly found in Boulder County and listed as a Tier 2 Species of Greatest Concern by Colorado Parks and Wildlife and as a sensitive species in Region 2 by the USDA Forest Service (Colorado Natural Heritage Program, 2015; Packauskas, 2005).

Distribution

The Hudsonian emerald is an uncommon species found throughout Canada and mountainous regions of Alaska, Montana, Wyoming, Colorado and Utah (Myrup & Baumann 2016; Needham, Westfall, & May, 2014; Packauskas, 2005; Paulson 2009). Within Colorado *S. hudsonica* has only been observed within Gilpin, Larimer, Park, and Boulder Counties. Because these counties lie on the southern periphery of the Hudsonian emerald's distribution, individuals tend to be locally restricted and rare. Consequently, while *S. hudsonica* is stable globally, the species is vulnerable to habitat degradation in areas where it occurs within the state (Colorado Natural Heritage Program, 1999).

Indeed, as of 2005 very few specimens had been collected and vouchered within Colorado, most of which were collected decades earlier (Packauskas 2005). Within Boulder County, confirmed sightings or collections occurred at Brainard Lake, Como Creek, ponds near the CU Boulder Mountain Research Station, Eldora Lakes, Rainbow Lakes, and Red Rock Lake (Abbot, 2017; Packauskas, 2005, Voss & Loewy, 2017). However, as of early 2017, *S. hudsonica* had not been officially documented in recent odonate surveys within Boulder County Parks and Open Space properties (Cooper 2014b, Cooper 2015, Cooper 2016).

Recent efforts during the summer of 2017 have bridged this knowledge gap. Voss & Loewy (2017) utilized a two-pronged modeling and field-based approach to estimate habitat suitability for *S. hudsonica* within the county. Two conceptually different habitat suitability approaches both predicted that BCPOS parcels in the montane regions of Western Boulder County would have the highest suitability for *S. hudsonica*.

Based on these models, prior occurrences of *S. hudsonica* within Boulder County and initial site reconnaissance, Voss & Loewy (2017) conducted surveys for *S. hudsonica* exuviae and adults at eight sites on BCPOS property: Barron NE (exuviae and adults, 40.0975 °N, 105.5144 °W), Barron SW (exuviae and adults, 40.0926 °N, 105.5212 °W), Caribou North (exuviae and adults, 40.0087 °N, 105.5422 °W), Delonde Ponds (exuviae and adults, 39.9899 °N, 105.5302 °W), Duck Lake (exuviae and adults, 40.0834 °N, 105.5129 °W), Giggey West (adults, 39.9499 °N, 105.4737 °W), Minnick-Thompson (adults, 40.0008 °N, 105.5022 °W), and Mud Lake (adults, 39.9777 °N, 105.5098 °W). Not only did these surveys successfully confirm presence of *S. hudsonica* at five of these sites (Barron NE, Barron SW, Caribou North, Delonde Ponds, Duck Lake), but they also validated the habitat modeling approach conducted by Voss & Loewy (2017). Sites where *S. hudsonica* was found had significantly higher predicted habitat suitability scores than areas where *S. hudsonica* was not found. Consequently, these maps could be used to find other Hudsonian emerald populations. These might include the following BCPOS areas: Steamboat Mountain, Heil Valley Ranch (Geer Canyon & Marrietta Canyon), El Dorado Springs (South Draw), Caribou Ranch, and Reynolds Ranch (Giggey Lake) (Boulder County Parks and Open Space, 2013).

Biology & Ecology

Very little is truly known about the specific biology of *S. hudsonica*. Most of what is known about its biology and ecological requirements comes from a decades old monograph describing the *Somatochlora* genus (Walker, 1925) and sporadic reports of species occurrences throughout subsequent decades. Packauskas (2005) summarized much of this literature relying mostly on studies of the Hudsonian emerald's congeners, especially Hine's emerald (*S. hineana*). Given that Hine's emerald does not belong to the same clade as the Hudsonian emerald (Packauskas 2005), much of the following might best be considered as a loose guideline for conservation until more is known. In the descriptions that follow, we indicate when we are generalizing from studies on congeners rather than studies focused on *S. hudsonica*.

Life Cycle

As with all dragonflies, the life cycle of *S. hudsonica* commences with the oviposition of fertilized eggs by females in aquatic habitat. Congeners can lay up to 500 eggs (*S. hineana*) that may overwinter before hatching (*S. forcipata* and *S. kennedyi*; Walker, 1925) or may hatch within a month (*S. filosa*). 25% of fertilized *S. semicircularis* eggs collected in July from females within Boulder County hatched within 40-53 days while the remainder remained viable 4-5 months later to overwinter (Voss & Loewy, 2017).

After hatching, larval dragonflies develop through successively larger instars (stages). While the precise number of larval instars is unknown for *S. hudsonica*, its congener, *S. kennedyi*, transitioned through 13-14 stages in the laboratory. Based on observations of Canadian populations of *S. hudsonica*, Walker estimated that the complete development would take two seasons. This means that if *S. hudsonica* eggs overwinter, the complete larval life cycle would take three years.

Upon completion of the last instar, the larva leaves the water, molts to the adult form, leaving the larval exuvia behind. Commencement of emergence in the literature varies by locality ranging from May in British Columbia (Paulson, 2009) to July in Montana (Paulson, 2009) and the Colorado Front Range (Cooper, 2014a). Although Cooper (2014a) reported the earliest flight time of *S. hudsonica* as mid-July, Voss & Loewy (2017) noted that the Hudsonian emerald tends to be found earlier at lower latitudes. Voss & Loewy (2017) not only estimated mid-June as the earliest adult occurrence date in Boulder County, but also found adults and exuvia in late June. The authors conclude that flight time of the Hudsonian emerald is likely earlier than reported (Voss & Loewy 2017). Using exuvial discovery date as a proxy for emergence in BCPOS properties, Voss & Loewy (2017) estimated peak emergence of *Somatochlora* (including both *S. hudsonica* and *S. semicircularis*) as early July, but this estimate may be biased by the higher proportion of *S. semicircularis* exuviae at the sites studied by the authors.

After emergence, *S. hudsonica* adults enter a pre-reproductive phase, the length of which is unknown, but for *S. hineana* could be as little as a week (Packauskas, 2005). Reproductive males rarely come to rest (Cooper, 2014a) as they exhibit stereotypical territorial patrolling behavior along the shore of water bodies (Cashatt & Vogt, 1990; Cooper, 2014a, Packauskas, 2005; Paulson 2009). Voss & Loewy (2017) observed similar behavior during adult surveys on BCPOS properties during summer 2017. Interestingly, Voss & Loewy (2017) observed far fewer females than males at BCPOS water bodies during their surveys. In several other dragonfly species, females only visit the water body to mate and lay eggs, spending the rest of their time at remote locations to forage (Merritt, Cummins, & Berg 2008). Females oviposit by tapping the end of their abdomen in the water at short intervals (Packauskas, 2005; Paulson, 2009; Walker, 1925), a behavior observed by Voss & Loewy (2017) at Duck Lake, Caribou North and Barron NE.

Habitat Requirements

Generally, the habitat of *S. hudsonica* adults is described as boggy-edged lakes, ponds or small/slow streams with abundant sedge growth (Cooper, 2004a; Dunkle, 2000; Packauskas, 2005; Paulson, 2009) with larvae found in mucky edges of woodland streams and bogs (Needham, Westfall, & May, 2004). This general habitat description coincided strongly with those locations where Voss & Loewy (2017) found Hudsonian emerald adults and exuviae on BCPOS lands. Notably, three of the five sites where these authors found *S. hudsonica* were small, precipitation-fed kettle ponds with abundant sedges surrounded by forest land (Caribou North, Barron NE, Barron SW) while the other two were larger lakes (Duck Lake) or pond complexes (Delonde Ponds) with abundant sedge marsh. Voss & Loewy (2017) also observed that sites where *S. hudsonica* was found had a higher proportion of emergent vegetation than those sites where *S. hudsonica* was not found.

A number of studies have demonstrated a quite narrow thermal niche for the Hudsonian emerald. Most species of *Somatochlora* are found in water with average temperatures of 16-20 °C (Walker, 1925), a finding corroborated by the high latitudes and elevations at which the species is found. Using species occurrence records, Voss & Loewy (2017) demonstrated that individuals at lower latitudes tended to be found only at higher elevations, thereby clarifying the general description of the species as a mountains rather than plains or foothills species (Cooper 2014a). Based on this relationship, Voss & Loewy (2017) concluded that the species is likely to be found within the elevational range of 2500 – 3000m. This result was further refined by site visits where Voss & Loewy (2017) found *S. hudsonica* to be present at an average elevation of 2800 m and absent at an average elevation of 2600 m. Together these findings are supported by Prather & Prather (2015) who indicate the species is found only above 2700 m in elevation.

Based on reports of habitat for the congener, *S. hineana*, Packauskas (2005) surmised that intact forest within 200m of the water body might be necessary for *S.*

hudsonica. Packauskas argues that intact forest might not only provide protection from the elements like thunderstorms and heat, but may also serve as mating areas. Indeed, within their surveys for *S. hudsonica* on BCPOS lands, Voss & Loewy (2017) showed that sites where *S. hudsonica* was found had higher percent forest, lower percent grassland, and lower percent barren than those sites where *S. hudsonica* was not found.

In addition to providing mating areas, highly forested ponds also tend to have good water quality which Packauskas posits may be important for supporting robust larval populations. Voss & Loewy (2017) confirmed this hypothesis by comparing water quality between sites where *S. hudsonica* was observed and sites where *S. hudsonica* was not observed. The authors found that water chemistry significantly differed in these sites. Notably, sites where *S. hudsonica* was found tended to have lower total dissolved solids, base cations, turbidity, pH, and some heavy metals than those sites where *S. hudsonica* was absent. Furthermore, the sites where Voss & Loewy (2017) observed *S. hudsonica* tended to be located farther from roads, a possible source of contaminants to water bodies.

Interspecific Relationships

Packauskas (2005) noted that in Colorado and Boulder County specifically, the distribution of *S. hudsonica* is quite localized, but that this observation could be due to both lack of effort in conducting dragonfly surveys and the narrow habitat requirements of the species. While Voss & Loewy (2017) found exuvia and adults in their surveys on BCPOS properties, the relative abundance of *S. hudsonica* in the odonate assemblage was no greater than 2% at those sites where the species was observed. Exuvial and adult surveys at these sites indicated that libellulids (*Leucorrhinia spp.*, *Sympetrum spp.*), aeshnids (*Aeshna spp.*, *Rhionaeshna spp.*), other corduliids (*Cordulia shurtleffii*, *Somatochlora semicircularis*) and damselflies were far more common. Although *S. hudsonica* is not an abundant member of the dragonfly assemblage throughout its range even in its preferred breeding habitat (Walker, 1925), boundary effects likely make *S. hudsonica* even less common than at higher latitudes. Whether this rarity has to do with competition from more robust regional dragonfly populations, narrow habitat requirements, or overall rarity remains an open question.

Like all odonates, *S. hudsonica* is a voracious predator during both its larval and adult life stages. No studies have thoroughly examined the diet of the species itself, but congener larvae (*S. kennedyi*, *S. forcipata*, *S. albicincta*) preyed upon protists, copepods, cladocerans, amphipods, simuliids, ephemeropterans and plecopterans in a size-dependent fashion (Packauskas, 2005; Walker, 1925). As adults, *Somatochlora spp.* are presumed to prey upon many dipteran species including midges, mosquitoes, deerflies, and even lepidopterans (Corbet, 2004; Packauskas, 2005) though definitive diet studies on *S. hudsonica* have not been performed.

Most dragonfly larvae die before they emerge as adults. Among the most generous estimates is that fewer than 10% survive to emergence (measured for *Plathemis lydia*, *Libellula luctuosa*, *Ladona deplanata*, *Epitheca cynosura*, *Epitheca semiquea*, and *Celithemis fasciata*) (Benke, 1976; Wissinger 1989). Long-lived *Cordulia aenea amurensis* experienced 99.8% mortality over five years spent as an aquatic juvenile (Ubukata, 1981). Most mortality is due to both cannibalistic and interspecific predation, most notably by fish or amphibians.

Possible Threats & Management Solutions

Given the habitat requirements of the species, its putative biology, and recent survey results on BCPOS lands, the following four stressors are most likely to have negative impacts on *S. hudsonica* populations within Boulder County. Each of these can be managed within those areas now known to harbor populations of the Hudsonian emerald as well as those predicted to possess the species.

Climate Change. Because of the thermal requirements of the species and its narrow elevational distribution within the county, climate change may be causing *S. hudsonica* to shift its range to progressively higher elevations. Such range shifts are more acutely experienced on the edge of a species geographical distribution. Although BCPOS can do little to stem the effects of global climate change and prevent such range shifts, ***BCPOS can protect high-quality habitats where the Hudsonian emerald is known or expected to occur.*** Protecting these habitats will ensure that refuges exist in the face of climate change. Because *S. hudsonica* will not be able to thrive above tree line, small sedge-bordered kettle ponds within the 2700-3000 elevation band are of high conservation value for the species.

Forestry Practices. *S. hudsonica* has been demonstrated to rely upon intact forest at the landscape scale, that is, within 0.5 km of water bodies where it is found. **BCPOS should work to curtail forest thinning and burning within a 0.5 km radius of known or expected populations.** Protection of forest around habitat has multiple benefits. First, keeping at least 90% forested land will ensure that putative mating refuges and foraging areas remain intact. This will ensure stable recruitment of new generations annually. Secondly, nearby forest will help constrain temperatures within aquatic resources to the range required for normal developmental progression. Finally, prevention of forest thinning and burning will help protect pristine water conditions found at these ponds.

Grazing Practices. Because *S. hudsonica* relies upon vegetated bog/marsh areas along the periphery of the water bodies it uses to breed and forage, **livestock grazing practices must be managed to prevent loss of such vegetation.** The wetland vegetation likely serves several purposes for Hudsonian emerald populations, including perching, emergence, and mating. Intensive grazing pressure not only removes vegetation, but it also disturbs emerging dragonflies during the vulnerable teneral phase immediately after emergence. Furthermore, extensive grazing and trampling negatively

impacts water quality by increasing nutrient loads and disturbing sediments. In particular, grazing might be limited during emergence times in late-June and early July to prevent such effects.

Other Impacts to Water Quality: *S. hudsonica* seems to have thriving populations only in aquatic habitats with pristine water quality. While keeping forest intact and minimizing grazing will surely have fall-on effects that protect water quality, **BCPOS should also minimize, to the extent possible, point-source effects that might contaminate high-quality water bodies where *S. hudsonica* has been found.** These sources include highway and road runoff, herbicides & pesticides for vegetation management, recreational impacts, and mining upstream of high-quality sites. Small, isolated precipitation-fed ponds like those where *S. hudsonica* has been observed on BCPOS lands are likely very sensitive to even small changes in pollution inputs, so vigilance about likely contamination sources is key. At this point it is also unknown whether these water quality relationships are directly affecting *S. hudsonica*, or indirectly via its prey

Other Management & Monitoring Recommendations. In addition to protecting high-quality habitat as described above, we also recommend the following to bolster the success of the aforementioned management strategies.

1. *Continue to find and record locations of *S. hudsonica* on BCPOS lands.* The only way this species can be adequately protected is by knowing locations of current populations. While the recent work of Voss & Loewy (2017) has substantively contributed to the catalogue of sites where *S. hudsonica* has been found, there are likely other, as of yet, undiscovered populations. This may require discussion with stakeholders and citizens who own conservation easements.
2. *Implement a monitoring plan to track the status of known populations and the effectiveness of management strategies.* While Voss & Loewy (2017) have established baseline data for the occurrence of *S. hudsonica* on BCPOS properties, the only way trends can be established is if known populations are tracked. Data collected on populations of *S. hudsonica* over a longer period of time will not only reveal population trends, but also insights about the biology and population dynamics of this understudied species. Because *S. hudsonica* is rare, using traditional mark-recapture techniques to estimate population size would be difficult to implement. Instead, transect surveys similar to those described by Voss & Loewy (2017) would at least serve as a relative indicator of population size over time.
3. *Implement monitoring protocols that match what is known about the biology of the species.* Currently published flight times for *S. hudsonica* in Boulder County seem to be later than actually observed on recent field visits (Voss & Loewy 2017). In order to adequately study microscale spatiotemporal emergence patterns over the course of the season, studies must take place earlier than July. Furthermore, protocols

should be standardized such that diurnal variability, interobserver reliability, and weather can be controlled in estimating relative population size.

4. *Partner with other agencies (e.g. US Forest Service) to understand the landscape scale population dynamics of S. hudsonica.* Understanding local population dynamics of this species of concern will require a landscape-scale approach that transcends agency boundaries. As a mobile species, dragonflies are able to move among habitat patches of varying quality. Understanding whether known sites of occurrence are breeding habitat (i.e. source populations) will require communication about those populations, where they occur, their proximity, and a more fundamental understanding of the dispersal capability of this species.
5. *Continue to fund basic conservation research on S. hudsonica.* While BCPOS has funded past work (Voss & Loewy 2017) to begin unraveling fundamental questions regarding the habitat requirements and distribution of *S. hudsonica* on its lands, much more work is needed. Specifically, an understanding of fine-scale habitat utilization and behavior, larval prey availability and use, larval secondary production, and continued efforts to study the life cycle of *S. hudsonica* and its congeners in the laboratory.

Acknowledgements

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Parks & Open Space

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PARKS & OPEN SPACE ADVISORY COMMITTEE

TO:	Parks & Open Space Advisory Committee
DATE/TIME:	Thursday, March 22, 2018, 6:30 p.m.
LOCATION:	Commissioners Hearing Room, 3 rd floor, Boulder County Courthouse, 1325 Pearl Street, Boulder, CO
AGENDA ITEM:	Homelessness on Boulder County Open Space
PRESENTER:	Jason Vroman, Lead Ranger; Sue Cullen, BCSO Parks Deputy
ACTION REQUESTED:	Information Only

Homelessness is a consistent issue on public lands across Boulder County. BCPOS has had our fair share of issues as well. This presentation will discuss what we have seen on Boulder County Parks and Open Space along with various ways we are addressing the issue.



Parks & Open Space

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PARKS & OPEN SPACE ADVISORY COMMITTEE

TO:	Parks & Open Space Advisory Committee
TIME/DATE:	Thursday, March 22, 6:30 p.m.
LOCATION:	Commissioners Hearing Room, 3 rd floor, Boulder County Courthouse, 1325 Pearl Street, Boulder, CO
AGENDA ITEM:	E-Bike Public Engagement Update
PRESENTER:	Tina Nielsen, Special Projects Manager
ACTION REQUESTED:	Information and Discussion

Background

This memo provides an update to the discussion at the January 25, 2018, POSAC meeting about public input on whether and where to allow e-bikes on county trails.

In December, 2017, staff proposed several updates of the current Rules and Regulations to POSAC. One of the proposed updates clarifies the definition of bicycles as “exclusively human powered vehicles.” Another update prohibits the use of e-bikes on all trails unless otherwise designated. These updates respond to a 2017 change in Colorado state law in which e-bikes were classified as bicycles instead of motorized vehicles. The state law provides local governments the authority to allow or prohibit the use of e-bikes on pedestrian and bike paths. These updates continue the status quo: motorized vehicles, including e-bikes, are prohibited on county open space trails, with exceptions for individuals with mobility disabilities. Based on the high public interest, it was evident that the time was right to have a community conversation about this topic.

E-bike Public Engagement to Date

Boulder County held three public open houses in February. Several local vendors provided different classes of e-bikes, giving people an option to demo them in advance of the open houses. Attendees at the demos and open houses filled out surveys. Staff also collected comments on the county e-bike web page.

Date	Location	Surveys/Comments	
		Demo	Non-demo
Tues. Feb. 6	Boulder	37	35
Sat. Feb. 10	Louisville	canceled	0
Tues. Feb 13	Longmont	25	13
Web page comment/survey	--	--	192
Phone/email	--	--	99
Total		62	339

To date we have received 401 survey responses and comments. The public comment period for this phase of the process concluded at the end of February. Attachments to this memo contain the open house information sheet and the two survey instruments.

Proposed Future Actions and Timeline

The staff team will analyze the surveys and comments and conduct an analysis of county trails looking at factor such as width, surface, and profile, as well as visitor use dimensions such as congestion and measures of conflict. After crafting a recommendation, the plan is to hold an open house in June to solicit input on the staff recommendation, followed by public hearings at POSAC and the BOCC in July.

March

- Analyze survey data, code comments
- Review peer agency actions
- Create trail analysis criteria

April

- Perform trail analysis
- Draft staff recommendation

May

- Referral to peer agencies

June

- Public open house
- Revise staff recommendation as needed based on public input

July

- Public hearing at POSAC
- Public hearing at BOCC

POSAC Action Requested

This item is for your information. We welcome your thoughts as we move forward with this process.

Attachments

- Open House Information Sheet
- E-bike Survey Open House
- E-bike Survey Demo



Parks & Open Space

5201 St. Vrain Road • Longmont, Colorado 80503
303.678.6200 • Fax: 303.678.6177 • www.BoulderCountyOpenSpace.org

WELCOME!

Thanks for attending our e-bike open house. Boulder County staff seeks your input on whether e-bikes should be allowed on **bike paths on Boulder County Open Space**, and if so, where e-bikes should be allowed. Staff members are available to answer your questions and discuss your thoughts. We are here to listen.

A few things to know

- Two large maps show **Boulder County Open Space trails** where bikes are allowed, one for the eastern half and one for the western half
- On the reverse side of these instructions you'll find a list of these same **Boulder County Open Space trails** that allow bikes
- Use the red and green dots on the maps to show where you think e-bikes should be allowed and not allowed (green for "in favor of e-bikes here" and red for "not in favor of e-bikes here")
- We are taking input for **Boulder County Open Space trails only**—NOT trails in cities, towns, or on Forest Service or other federal lands
- **Please fill out a survey and drop it in the box before you leave (only if you did not fill one out at the demo)**

Background

Motorized vehicles have never been allowed on Boulder County trails, with exceptions for people with mobility impairments. You can find more details on our web page:

<https://www.bouldercounty.org/open-space/parks-and-trails/accessibility/>

Last year the State Legislature passed bill 17-1151, changing the definition of electric assist bicycles: https://leg.colorado.gov/sites/default/files/documents/2017A/bills/2017a_1151_signed.pdf

(58) "Motor vehicle" means any self-propelled vehicle that is designed primarily for travel on the public highways and that is generally and commonly used to transport persons and property over the public highways or a low-speed electric vehicle; **except that the term does not include ELECTRICAL ASSISTED BICYCLES**, low-power scooters, wheelchairs, or vehicles moved solely by human power. (Emphasis added.)

The bill gives local jurisdictions authority to prohibit electric bikes. In the absence of any prohibition, the state law is the default. E-bikes are treated the same as bikes in state statute **§42-4-1412** <https://www.bikelaw.com/2017/08/colorado-electric-bicycle-laws/>.

Next Steps

Following the public input gathering phase in February, staff will compile and review comments and other research. Staff will formulate a recommendation and schedule further dates for public input. Details will be posted at www.BoulderCountyOpenSpace.org/ebike. and emailed to everyone who posted a comment.

Boulder County Open Space Trails Allowing Bikes

Foothills & Mountains

Bald Mountain

- Pines to Peaks Loop

Betasso Preserve

- Benjamin Loop
- Betasso Link Trail
- Bummers Rock Connector
- Canyon Loop Trail
- Fourmile Link Trail
- Loop Link

Hall Ranch

- Antelope Trail
- Bitterbrush Trail
- Nelson Loop

Heil Valley Ranch

- Picture Rock Trail
- Ponderosa Loop
- Wapiti Trail
- Wild Turkey Trail
- Overland Loop

Mud Lake

- Caribou Link Trail
- Kinnickinnick Loop
- Tungsten Loop

Ron Stewart Preserve at Rabbit Mountain

- Eagle Wind Trail
- Indian Mesa
- Little Thompson Overlook

Walker Ranch

- Meyers Homestead
- Walker Ranch Link
- Walker Ranch Loop & Access

Flat Trails on the Plains

Agricultural Heritage Center

- McIntosh Connector

Boulder Canyon Trail

Carolyn Homberg Preserve at Rock Creek Farm

- Cradleboard Trail
- Lac Amora Link Trail
- Mary Miller Trail

Fairgrounds

- Cattail Pond Trail

Lagerman Agricultural Preserve

- Lagerman Trail
- Open Sky Trail

Legion Park

- Legion Loop

Niwot/Gunbarrel Area

- Cottontail Trail
- Homestead Trail
- Heatherwood Notch Trail
- Heatherwood-Walden Link Trail
- Niwot Trails

Pella Crossing

- Braly Trails
- Marlatt Trails

Walden Ponds

- Walden Ponds Trail

Other Trails on the Plains

- Harney-Lastoka Trail
- North Rim Trail (Lake Valley Estates)

Regional Trails

Note: Regional Trails may include portions of Flat Trails on the Plains

Coal Creek Trail

- Anthem Connection
- Coal Creek Trail
- Coalton Trailhead
- Mayhoffer Singletree Trail
- Meadowlark Trail
- Ruth Roberts
- Ruth Roberts Connector
- Flagg Park
- Imel/NW Parkway

Rock Creek Trail

- Rock Creek Trail

LoBo Trail

- LoBo Trail
- Gunbarrel Estates
- Twin Lakes East
- Twin Lakes West
- Twin Lakes Trail
- Willows Trail (Twin Lakes)
- Niwot Trail System
- 95th Street

St. Vrain Greenway

Callahan Trail

US 36 Bikeway—e-bikes allowed since it's located in CDOT right-of-way



Welcome! We'd like your help.

Boulder County Parks and Open Space is conducting this survey to gain a better understanding of your opinion related to the use of e-bikes on trails.

E-Bike Definition

E-bikes are bicycles with an integrated electric motor that does not exceed 750 watts of power (1 horsepower). E-bikes are separated into three classes.

Stop! If you already completed a survey during the e-bike demo earlier today, please accept our thanks and do not complete a duplicate survey.

1. Which activities do you typically participate in when you visit open space? (check all that apply)

- | | | | |
|-------------------------------|---|--|--|
| <input type="checkbox"/> Hike | <input type="checkbox"/> Walk the Dog | <input type="checkbox"/> Ride a horse | <input type="checkbox"/> Special event |
| <input type="checkbox"/> Bike | <input type="checkbox"/> Fish | <input type="checkbox"/> Picnic | <input type="checkbox"/> View wildlife |
| <input type="checkbox"/> Run | <input type="checkbox"/> Family gathering | <input type="checkbox"/> Photography/Art | <input type="checkbox"/> Other – describe: |

2. Which activity listed above (in Question 1) is your most frequent activity?

(write only one activity) _____

3. Have you ever ridden an e-bike?

- Yes
 No

4. Thinking about Boulder County Parks and Open Space properties, please indicate your level of support or opposition for allowing Class 1 e-bikes on the three types of trails listed.

Class 1 e-bikes provide electrical assistance only while the rider is pedaling. Electrical assistance stops when the bike reaches 20 mph.

	Strongly Oppose ▼	Oppose ▼	Neutral ▼	Support ▼	Strongly Support ▼	Not sure ▼
Foothills and mountain trails (e.g. Betasso Preserve, Hall Ranch, Heil Valley Ranch)	<input type="checkbox"/>					
Flat trails in the plains (e.g. Pella Crossing, Lagerman Agricultural Preserve)	<input type="checkbox"/>					
Regional Trails (e.g. LoBo Trail, Coal Creek Trail, Rock Creek Trail)	<input type="checkbox"/>					

5. Please briefly explain why you answered that way:

More questions on reverse side

6. Thinking about Boulder County Parks and Open Space properties, please indicate your level of support or opposition for allowing Class 2 e-bikes on the three types of trails listed.

Class 2 e-bikes provide electrical assistance regardless if the rider is pedaling or not. Electrical assistance stops when the bike reaches 20 mph.

	Strongly Oppose ▼	Oppose ▼	Neutral ▼	Support ▼	Strongly Support ▼	Not sure ▼
Foothills and mountain trails (e.g. Betasso Preserve, Hall Ranch, Heil Valley Ranch)	<input type="checkbox"/>					
Flat trails in the plains (e.g. Pella Crossing, Lagerman Agricultural Preserve)	<input type="checkbox"/>					
Regional Trails (e.g. LoBo Trail, Coal Creek Trail, Rock Creek Trail)	<input type="checkbox"/>					

7. Please briefly explain why you answered that way:

8. Where do you live? (check only one)

- | | | | |
|-------------------------------------|-------------------------------------|------------------------------------|---|
| <input type="checkbox"/> Boulder | <input type="checkbox"/> Gold Hill | <input type="checkbox"/> Lyons | <input type="checkbox"/> Unincorporated Boulder County |
| <input type="checkbox"/> Broomfield | <input type="checkbox"/> Lafayette | <input type="checkbox"/> Nederland | <input type="checkbox"/> Ward |
| <input type="checkbox"/> Denver | <input type="checkbox"/> Longmont | <input type="checkbox"/> Niwot | <input type="checkbox"/> Outside Colorado |
| <input type="checkbox"/> Erie | <input type="checkbox"/> Louisville | <input type="checkbox"/> Superior | <input type="checkbox"/> None of these, but in Colorado |

9. If there is anything else you would like to tell us, please use the space below:

For more information or to submit comments online, please visit www.BoulderCountyOpenSpace.org/ebike or contact Tina Nielsen, Special Projects Manager at 303-678-6279 or tnielsen@bouldercounty.org.

If found, please return survey to: Boulder County Parks and Open Space, 5201 Saint Vrain Road, Longmont CO 80503



Welcome! We'd like your help.

Boulder County Parks and Open Space is conducting this survey to gain a better understanding of your opinion related to the use of e-bikes on trails.

E-Bike Definition

E-bikes are bicycles with an integrated electric motor that does not exceed 750 watts of power (1 horsepower). E-bikes are separated into three classes.

1. Which activities do you typically participate in when you visit open space? (check all that apply)

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|-------------------------------|---|--|--|
| <input type="checkbox"/> Hike | <input type="checkbox"/> Walk the Dog | <input type="checkbox"/> Ride a horse | <input type="checkbox"/> Special event |
| <input type="checkbox"/> Bike | <input type="checkbox"/> Fish | <input type="checkbox"/> Picnic | <input type="checkbox"/> View wildlife |
| <input type="checkbox"/> Run | <input type="checkbox"/> Family gathering | <input type="checkbox"/> Photography/Art | <input type="checkbox"/> Other – describe: |

2. Which activity listed above (in Question 1) is your most frequent activity?

(write only one activity) _____

3. Have you ridden an e-bike before today?

- Yes
 No

4. Thinking about Boulder County Parks and Open Space properties, please indicate your level of support or opposition for allowing Class 1 e-bikes on the three types of trails listed.

Class 1 e-bikes provide electrical assistance only while the rider is pedaling. Electrical assistance stops when the bike reaches 20 mph.

	Strongly Oppose ▼	Oppose ▼	Neutral ▼	Support ▼	Strongly Support ▼	Not sure ▼
Foothills and mountain trails (e.g. Betasso Preserve, Hall Ranch, Heil Valley Ranch)	<input type="checkbox"/>					
Flat trails in the plains (e.g. Pella Crossing, Lagerman Agricultural Preserve)	<input type="checkbox"/>					
Regional Trails (e.g. LoBo Trail, Coal Creek Trail, Rock Creek Trail)	<input type="checkbox"/>					

5. Thinking about Boulder County Parks and Open Space properties, please indicate your level of support or opposition for allowing Class 2 e-bikes on the three types of trails listed.

Class 2 e-bikes provide electrical assistance regardless if the rider is pedaling or not. Electrical assistance stops when the bike reaches 20 mph.

	Strongly Oppose ▼	Oppose ▼	Neutral ▼	Support ▼	Strongly Support ▼	Not sure ▼
Foothills and mountain trails (e.g. Betasso Preserve, Hall Ranch, Heil Valley Ranch)	<input type="checkbox"/>					
Flat trails in the plains (e.g. Pella Crossing, Lagerman Agricultural Preserve)	<input type="checkbox"/>					
Regional Trails (e.g. LoBo Trail, Coal Creek Trail, Rock Creek Trail)	<input type="checkbox"/>					

Complete reverse side after your test ride

Complete these questions after your test ride

1. Thinking about Boulder County Parks and Open Space properties, please indicate your level of support or opposition for allowing Class 1 e-bikes on the three types of trails listed.

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	Strongly Oppose ▼	Oppose ▼	Neutral ▼	Support ▼	Strongly Support ▼	Not sure ▼
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Regional Trails (e.g. LoBo Trail, Coal Creek Trail, Rock Creek Trail)	<input type="checkbox"/>					

2. Please briefly explain why you answered that way:

3. Thinking about Boulder County Parks and Open Space properties, please indicate your level of support or opposition for allowing Class 2 e-bikes on the three types of trails listed.

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	Strongly Oppose ▼	Oppose ▼	Neutral ▼	Support ▼	Strongly Support ▼	Not sure ▼
Foothills and mountain trails (e.g. Betasso Preserve, Hall Ranch, Heil Valley Ranch)	<input type="checkbox"/>					
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Regional Trails (e.g. LoBo Trail, Coal Creek Trail, Rock Creek Trail)	<input type="checkbox"/>					

4. Please briefly explain why you answered that way:

5. Where do you live? (check only one)

- | | | | |
|-------------------------------------|-------------------------------------|------------------------------------|---|
| <input type="checkbox"/> Boulder | <input type="checkbox"/> Gold Hill | <input type="checkbox"/> Lyons | <input type="checkbox"/> Unincorporated Boulder County |
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