Surveys and Monitoring for the Hiawatha National Forest: FY 2018 Report

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Cover: Large boulder with walking fern, Hiawatha National Forest, July 2018 (photo by Cuthrell).

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Niagara Habitat Monitoring – for rare snails, ferns and placement of data loggers (East Unit)

Vegetation monitoring, as outlined in Alternative 2 of the Niagara EIS, was initiated to develop the methodology needed to understand the changes that may occur in karst feature habitat due to vegetation management. Specifically, this monitoring was designed to address microhabitat conditions within karst feature habitat and how those conditions may be affected by vegetation management with respect to changes in light intensity, ground temperature, relative humidity, and moss cover between treated and untreated sites.

After reviewing the monitoring plan sites were selected for sampling with the assistance of HNF staff. Sampling plots were circular and 1/10 of an acre (11.3 m radius; James and Shugart 1970). Sampling included the collection of overall plot level and three, 1 m^2 plots along the cliff/boulder face where rare ferns typically would be growing or rare land snails were likely to occur (Figure 1). Measurements collected at the overall plot level focused on forest structure and species composition. Tree density and composition was measured in two categories: tree (dbh ≥ 3.5 inches) and subcanopy (dbh < 3.5 inches). Other overall plot level measurements included percent canopy closure, plant species lists and coarse woody debris (CWD) qualitative assessment. Percent canopy closure was estimated along the cardinal directions from the plot center. Ocular tube readings of canopy conditions were taken at paced intervals (~1 m) five times in each cardinal direction. The ratio of hits to misses in the ocular tube gave the percentage canopy cover for that plot.

Figure 1. Option 2 Site 7, vegetation plot C. Left photo on 23 July 2014; right photo on 7 August 2017.

To address the changes that may occur after the different forest treatments, during the summer of 2018 (July 23-24) we conducted vegetation sampling at the 8 Reference sites. In conjunction with the vegetation sampling, we placed data loggers at the same 8 Reference sites. Two data loggers were placed at each site at the plot center. One data logger placed at the top of the cliff or boulder recorded temperature and light intensity while a second data logger placed at the base recorded both temperature and relative humidity. All data loggers were placed in the field during July (11-12) and all were collected on 3 October 2018. Data has been offloaded from the devices and are currently being summarized for preliminary analysis.

We continue to compile temperature, humidity, and light intensity data gathered by data loggers during 2012 through 2018 into a database to facilitate future analyses. Because the data loggers export information in different formats depending on type (i.e., temperature and relative humidity vs. temperature and light intensity), substantial data manipulation is necessary to produce a consistent format for data summarization and analysis. In addition, all the vegetation monitoring data from 2012-2018 has now been entered into a large excel database and we have begun analysis (Appendix I).

Raptor Nest Checks and Productivity Surveys (East Unit)

Both the Red-shouldered Hawk (*Buteo lineatus*, state threatened) and Northern Goshawk (*Accipiter gentilis*, special concern) are Regional Forester Sensitive Species (RFSS) with known nesting occurrences within the east and west units of the Hiawatha National Forest (HNF). During the 2018 surveys a total of 60 nests or old nesting territories (East Unit,) were checked by MNFI staff for breeding use, with a subset of those (active or possibly active nests) visited a second time for nest productivity.

In the East Unit, we visited 60 nests to check for breeding use. Initial nest checks and conspecific call broadcasts were conducted during the span of May 4 – May 16. During the first visit 15 active or potentially active (i.e., decorated nest but adult not observed) Red-shouldered Hawk nests and 3 Northern Goshawk nests were discovered. In addition, staff from HNF found 7 active nests. MNFI staff revisited all 23 active and potentially active nests in June to assess nest success and productivity. Productivity surveys during 2018 were completed on June 18-21 using a telescoping fiberglass pole and video camera (GoPro Hero) to inspect nests. One of the three active Northern Goshawk nests found during the first round of surveys was successful, with a total of 1 chick fledged. We observed 67% (14/21) of the Red-shouldered Hawk nests to be successful and counted 32 chicks total (1.52 young per active nest, 2.29 young per successful nest) (Table 1).

Overall Red-shouldered Hawk nest success appeared to be in line with previous years (Figure 2), but down from 2017, with a total number of 32 chicks produced (1.52 young per active nest, 2.29 young per successful nest) (Table 1). The trend appears to be stable for the HNF East Unit since 2006 (Appendix II).

Table 1. 2018 Season Summary of nesting raptors in the Hiawatha National Forest.

Raptor Species	Active Nests	Successful Nests	Number of young	young/ active	young/ successful	% active nests successful
RSHA						
East	21	14	32	1.52	2.29	67 %
West						
NOGO						
East	3	1	1	0.33	1.00	33 %
West						

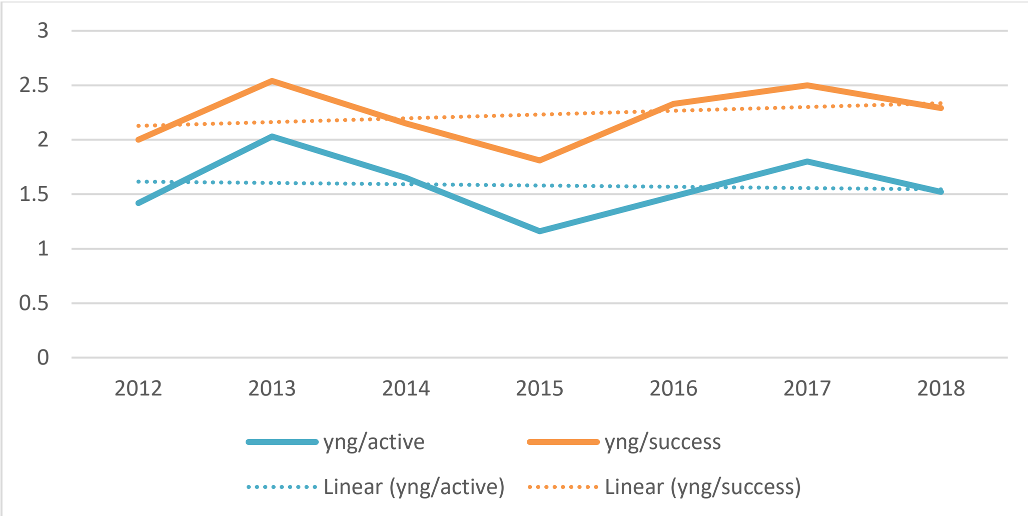

Figure 2. RSHA productivity 2012-2018 on the Hiawatha National Forest, East Unit.

Recommendations for Future Work

The raptor nest monitoring data set is approaching two decades and therefore we recommend continuing this level of field work in 2019. We also recommend continuing to push forward with publishing the results of the data set in a peer reviewed journal, such as the Journal of Raptor Research. This may help determine, or better define, the overall goal or objective of the monitoring program.

Also, if a goal is to find additional Northern Goshawk nesting territories within the HNF, we recommend doing surveys for Northern Goshawks during the courtship phase, which for northern Michigan, is likely from 1 March through 7 April. Recent studies (Roberson et al. 2005) suggest this may be the best time to survey for this species. In addition to confining our searches and call playbacks to old nesting sites, we could do some wider encompassing searches in those nesting territories. Alternatively, surveys could be conducted during the fledgling-dependency phases (approximately 25 June – 20 July).

Finally, it has been discussed briefly to do some level of species distribution modeling for defining nesting habitat for Red-shouldered hawks. There is currently a Landscape Capability for Red-shouldered Hawk, Version 3.0, Northeast U.S., produced by Kevin McGarigal (Principal Investigator), Bill DeLuca (Originator), North Atlantic Landscape Conservation Cooperative (funder).

This model, which includes Virginia and states to the north and everything east of Kentucky and Ohio. A similar model could be constructed for Michigan. This dataset depicts the potential capability of the landscape throughout the Northeastern United States to provide habitat for Red-shouldered Hawk, during the breeding season, based on environmental conditions existing in approximately 2010. Landscape capability integrates factors influencing climate suitability, habitat capability, and other biogeographic factors affecting the species' prevalence in the area. All locations are scored on a scale from 0 to 1, with a value of 0 indicating no capacity to support the species and 1 indicating optimal conditions for the species.

Rare Plant Surveys (East and West Units)

In winter 2018, MNFI and Hiawatha NF staff identified and prioritized element occurrences of state-listed plant species on HNF lands for resurvey, focusing on populations of declining orchid species such as the state threatened calypso (*Calypso bulbosa*) state endangered round-leaved orchis (*Amerorchis rotundifolia*), state special concern Ram's head lady's slipper (*Cypripedium arietinum*). When additional surveys allowed, other rare plant species were targeted including the following state threatened species, Lapland buttercup (*Coptidium lapponicum*), New England sedge (*Carex novae-anglica*), and the following special concern species, green spleenwort (*Asplenium viride*), clubmoss (*Spinulum canadense*), Wiegand's sedge (*Carex wiegandii*), and Alga pondweed (*Potamogeton confervoides*).

In late May - August 2018, meander surveys for rare plant species were conducted in habitats previously determined to support populations of target species. Population data and spatial locations were recorded using the BackCountry Navigator Pro GPS Application (CritterMap Software LLC) for Android. To facilitate detection of population trends, a census approach was used for calypso. All flowering and sterile individuals (leaves) of calypso were recorded and marked with GPS. For all other rare species documented, spatial coordinates and more general estimates of populations were recorded. Following field surveys, element occurrence ranks were updated and new element occurrences were created for newly documented populations (Table 3).

Figure 3. Calypso or fairy orchid (*Calypso bulbosa*) at Search Bay North, EOID 3639, 20 June 2018.

Table 2. Rare plant element occurrences on HNF in 2018, and those in need of further survey.

Species	EOID	State Status	Old Rank	New Rank	Survey Type
Amerorchis rotundifolia	2159	E	B	B	Qualitative meander
Amerorchis rotundifolia	8929	E	CD	?	Qualitative meander
Amerorchis rotundifolia	21340	E	E	E	***Did not survey***
Amerorchis rotundifolia	21341	E	E	E	***Did not survey***
Calypso bulbosa	3639	T	C	C	Quantitative census
Calypso bulbosa	21343	T	H	H	Quantitative census
Calypso bulbosa	13006	T	CD	CD	Quantitative census
Calypso bulbosa	17	T	D	D	Quantitative census
Calypso bulbosa	1167	T	F	F	***Did not survey***
Calypso bulbosa	7091	T	AB	?	Quantitative census
Calypso bulbosa	12318*	T	B	?	Quantitative census
Calypso bulbosa	390*	T	C	?	Quantitative census
Calypso bulbosa	4537	T	F?	F?	***Did not survey***
Calypso bulbosa	10964	T	E	?	***Did not survey***
Calypso bulbosa	1922	T	B	?	***Did not survey***
Calypso bulbosa	2720	T	F	F	Quantitative census
Asplenium viride	6554	SC	B	?	Qualitative meander
Cypripedium arietinum	20645	SC	CD	CD	Qualitative meander
Cypripedium arietinum	19913	SC	D	D	***Did not survey***
Cypripedium arietinum	19665	SC	C	C	Qualitative meander
Cypripedium arietinum	12398	SC	CD	?	***Did not survey***
Cypripedium arietinum	11482	SC	H	H	***Did not survey***
Cypripedium arietinum	4470	SC	F	D	Qualitative meander
Cypripedium arietinum	3560	SC	E	?	***Did not survey***
Coptidium lapponicum	5473	T	A	A	Qualitative meander
Spinulum canadense	21371	SC	E	?	Qualitative meander
Carex novae-anglica	4459	T	B	B	Qualitative meander
Carex wiegandii	6963	SC	A	A	Qualitative meander
Potamogeton confervoides	NEW	SC		E	Qualitative meander
Vaccinium cespitosum	many	see	section	below	Qualitative meander

* need to merge these EOs into one

Recommendations for Future Work

We recommend continued surveys of previously documented populations of climate-sensitive and declining species, especially *Calypso bulbosa* and *Amerorchis rotundifolia* (sites not visited in past few years, see ***did not survey designation*** under survey type in table 2) but also *Galium kamtschaticum* and species of boreal fens such as *Carex scirpoidea*, *Empetrum nigrum*, *Erigeron hyssopifolius*, and *Pinguicula vulgaris*. Likewise, records for green spleenwort and walking fern that have not been visited in recent years should also be a priority for future survey.

Dwarf bilberry and Northern blue surveys (West Unit)

Five reported dwarf bilberry (*Vaccinium cespitosum*) locations were surveyed during 2018. Two locations, based on Don Henson surveys in 1980s without MNFI data forms or vouchers, were not found. Of these the record north of Slowfoot and Dam Lakes in Schoolcraft County does not appear to support appropriate habitat. The mapped location is in a large peatland (poor conifer swamp) with scattered sand stringers and islands. The islands could provide habitat but it would be atypical compared to known sites. The second site, northwest of Pauquette Lake, contains appropriate habitat but the species was not found during surveys in 2017 and 2018.

The Evelyn site (Hickey Creek north), about 2.5 miles northwest of Shingleton, includes a number of small meta-population elements that persist under a full canopy of black spruce. The population also includes larger clones in old woods roads and associated open area. These meta-populations may be large enough to support northern blue butterfly. No northern blues were observed during 2018 surveys, leaving the lone individual sited in 2017 as the only record for the butterfly in the Evelyn population.

The Hickey Creek Truck Trail site was resurveyed in 2018 after confirmation of the site in 2017. Two additional meta-population areas for dwarf bilberry were located to the north of the original Don

Figure 4. Will MacKinnon standing near newly discovered patch of dwarf bilberry, June 2018, Hickey Creek Truck Trail.

Henson record. Fourteen clonal groups (waypoints) were recorded in the two clusters. The habitat of the new observations appears to more typical dwarf bilberry habitat than the large clone occurring along Hickey Creek Truck Trail. Some of the clones appear large enough to support northern blue butterflies, but no butterflies were observed in 2018. Plant and butterfly surveys were conducted on June 16, June 26 and July 2, 2018.

The Prairie Creek and Shingleton populations occurring within a mile of the forest boundary were surveyed. These populations (EOs) have been combined due to a large number of plant locations found between the two records. Due to the large number of plants and butterflies observed an afternoon was spent north of M-28 to further assess the extent of the population.

The original Shingleton population occurs in a small, closing clearing just south of the railroad track on state forest land. Surveys into the closed canopy forest surrounding this site revealed a large number of small dwarf bilberry clones persisting in small canopy gaps throughout the forest. The original Prairie Creek record occurs along the edge of extensive open area of northern wet meadow. In this area, approximately thirty (30) large clones of dwarf bilberry, and most were associated with northern blue butterfly. Over two hundred (200) northern blue butterflies were counted during the survey. Within the state forest, in the prairie Creek opening, along the railroad tracks and along highway M-28 eighty-eight (88) *Vaccinium cespitosum* waypoints were recorded.

This complex is the core of the dwarf bilberry and northern blue butterfly populations in this area. The Prairie Creek opening was present at the time of the original GLO surveys. The mapped opening follows boundaries of modern features but the presence of a large open area extending through extensive wetlands and into the uplands is clearly noted in the survey notes. It is highly probable that this area has supported bilberry and northern blue butterfly populations since long before European settlement.

Statewide Bumble Bee Surveys (East and West Units)

Museum work: During year one, bumble bee specimens from the Albert J. Cook Arthropod Research Collection (ARC) at Michigan State University were viewed, identifications confirmed/verified, and collection label information was tabulated into a collection data base. Important fields included locality, date, and any additional collection information including technique or plants collected from. A total of 4,164 bumble bees were inspected from the collection and label information was tabulated with locality information digitized. All of the *Bombus* species (including *B. affinis, B. terricola, B. auricomus,* and *B. pensylvanicus*) are available on the IDigBio web site (https://www.idigbio.org/portal/search). **All pertinent collection records for these species are currently being entered into the MNFI Conservation database for these bumble bee species, including those associated with the Hiawatha National Forest (Table 3).** In addition, we acquired bumble bee collections from Dr. Thomas Wood in the Department of Entomology at Michigan State University, which include personal collections, verified iNaturalist specimen, and specimen from the University of Michigan insect collection. The identity of each specimen has been confirmed by experts, including MNFI Zoologists and Dr. Tom Wood. In total, our non-MNFI data set includes 9,388 bumble bees. We are currently planning to visit the University of Michigan insect collection to gather data on additional specimen that may not be included in our current data sets, and project that this work will occur during the winter through early spring 2019. Furthermore, we are beginning to run the *Bombus* through the S-rank calculator, version 3.1 (NatureServe 2012). The rank calculator is a spreadsheet into which the biologist inputs information on rarity, trends, and threats, each of which has several additional subcategories. The calculator then performs a series of algorithms based on pre-defined or user-defined parameter weights to generate an S-rank (Badra et al. 2014).

Field based research: In 2016-2018, 150 sites across Michigan were inventoried for bumble bees from July through September, with the majority in the Upper Peninsula of Michigan, including many within the Hiawatha National Forest. A total of 1,309 individual bumble bees were collected, processed, identified, and labeled with collection and identification tags. **A total of 172 voucher bumble bees were collected from the Hiawatha National Forest (Table 3).** These specimens are now stored in the MNFI general collection for future reference. During our state-wide sampling, we collected 44 *B. terricola*, 13 *B. pensylvanicus*, two *B. auricomus*, and zero *B. affinis*. *Bombus terricola* was collected at a total of 33 different sites, including several within the Hiawatha National Forest **(Figure 5, 6)**, while *B. pensylvanicus* was collected at just two sites in Newaygo County. Interestingly, prior to our collections, the last recorded *B. pensylvanicus* specimen was collected over 20 years ago in 1997. Unfortunately, we did not find any *B. affinis* during our surveys throughout the state. Additionally, we were unable to find several other species (*B. ashtoni, B. feradale, B. insularis*) that we were hoping to collect during our surveys, indicating that these species are likely declining in population numbers as well. Nearly all of the sites we visited in 2016-2018 (147 out of 150) were occupied by at least one bumble bee, with a range of 1 to 43 bumble bees collected. We found that a few common bumble bee species represented the majority of our *Bombus* collections, including *B. impatiens* (n= 417), *B. vagans* (n=229), and *B. griseocollis* (n=187). Overall, our findings are consistent with those of other researchers assessing bumble bee distributions in the Midwest region of the United States.

Bee surveys were not conducted when the temperature was below 15° C (60° F), during rain, or when winds exceeded 25 km/h (15 mph). During 2017 and 2018, we eliminated the systematic circular plot survey technique (Hale 1994) because of the low number of bees we observed during 2016. For this year of the project, we built on the museum records for both *B. affinis* and *B. terricola* records from the Upper Peninsula. We visited the general area of all the records for both *affinis* and *terricola*. Most records were rather vague or general in location, so we delineated polygons and then visited the general area and focused our survey efforts on patches of dense flowering resources. This approach proved better at covering sites more quickly and increasing our likelihood of encountering the target rare species. This was the same approach that was used in the latter half of the 2016 field season.

At each site visit we recorded a latitude and longitude with handheld GPS units and took photos of representative habitats. Survey start and end times were recorded, as well as start and end temperature, relative humidity, wind speed, and percent cloud cover. For each flowering species in the area surveyed, DAFOR ranks were recorded. Attempts were not made to capture all bumble bees seen at the site but to collect representatives of different species. All collected bees were held in small plastic or glass vials, placed into ice coolers, brought back to the lab, placed into a freezer, and vouchered. A total of 150 sites were visited and sampled with this method from 2016 through 2018, many of which were on the Hiawatha National Forest.

Table 3: Element occurrence IDs associated with *Bombus terricola* collected within the Hiawatha National Forest. No individuals of *B. auricomus*, *B. affinis*, or *B. pensylvanicus* were found in historic or current collections.

EO ID	Historic/Recent	FIRSTOBS	LASTOBS
22205	Historic	1911-06-23	1911-06-25
22454	Historic	1921-08-25	1921-08-25
22468	Historic	1925-09-14	1925-09-14
22473	Historic	1927-09-02	1927-09-02
22456	Historic	1923-04-18	1954-08-31
22623	Historic	1922-07-26	1955-07-13
22210	Historic	1964-05-31	1964-05-31
22211	Historic	1964-05-31	1964-05-31
22275	Historic	1964-07-22	1964-07-22
22213	Historic	1973-06-12	1973-06-12
22630	Historic	1977-06-12	1977-06-12
22208	Historic	1933-06-17	1986-08-01
22207	Historic	1916-08-01	1993-08-16
22216	Recent	2014-07-10	2014-07-10
21525	Recent	2017-08-07	2017-08-07
21529	Recent	2017-08-07	2017-08-07
21533	Recent	2017-08-08	2017-08-08
22169	Recent	2017-08-08	2017-08-08
22177	Recent	2018-08-01	2018-08-01
22178	Recent	2018-08-01	2018-08-01
22179	Recent	2018-08-01	2018-08-01
22180	Recent	2018-08-01	2018-08-01
22181	Recent	2018-08-02	2018-08-02
22182	Recent	2018-08-02	2018-08-02
22183	Recent	2018-08-02	2018-08-02
22184	Recent	2018-08-03	2018-08-03
22185	Recent	2018-08-03	2018-08-03
22186	Recent	2018-08-03	2018-08-03
22187	Recent	2018-08-06	2018-08-06

Table 4: Total number of Bumble bees of each species collected in the Hiawatha National Forest. Includes both historic and current records, as well as those individuals caught by MNFI scientists.

Bumble bee species	Total Collected	Historic (>20yrs)	Current (< 20yrs)	MNFI collected
Bombus bimaculatus	4	3	1	0
Bombus borealis	34	8	26	19
Bombus fervidus	2	2	0	0
Bombus griseocollis	35	1	34	30
Bombus impatiens	19	0	19	13
Bombus perplexus	17	1	16	13
Bombus ternarius	69	16	53	26
Bombus terricola	**97**	**76**	**21**	**19**
Bombus vagans	76	8	68	52
				172 total

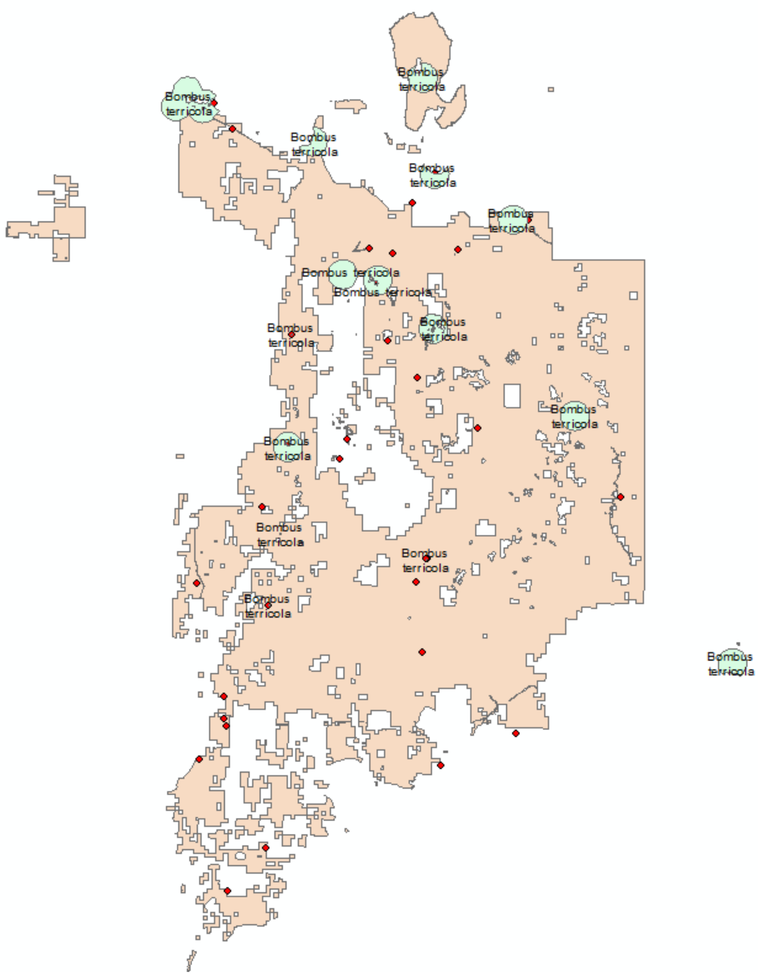

Figure 5. *Bombus terricola* element occurrences locations with the Hiawatha National Forest (West Unit). Green circles are historic EOs, while current EOs are labeled. Red dots indicate non-*terricola* Bombus collections.

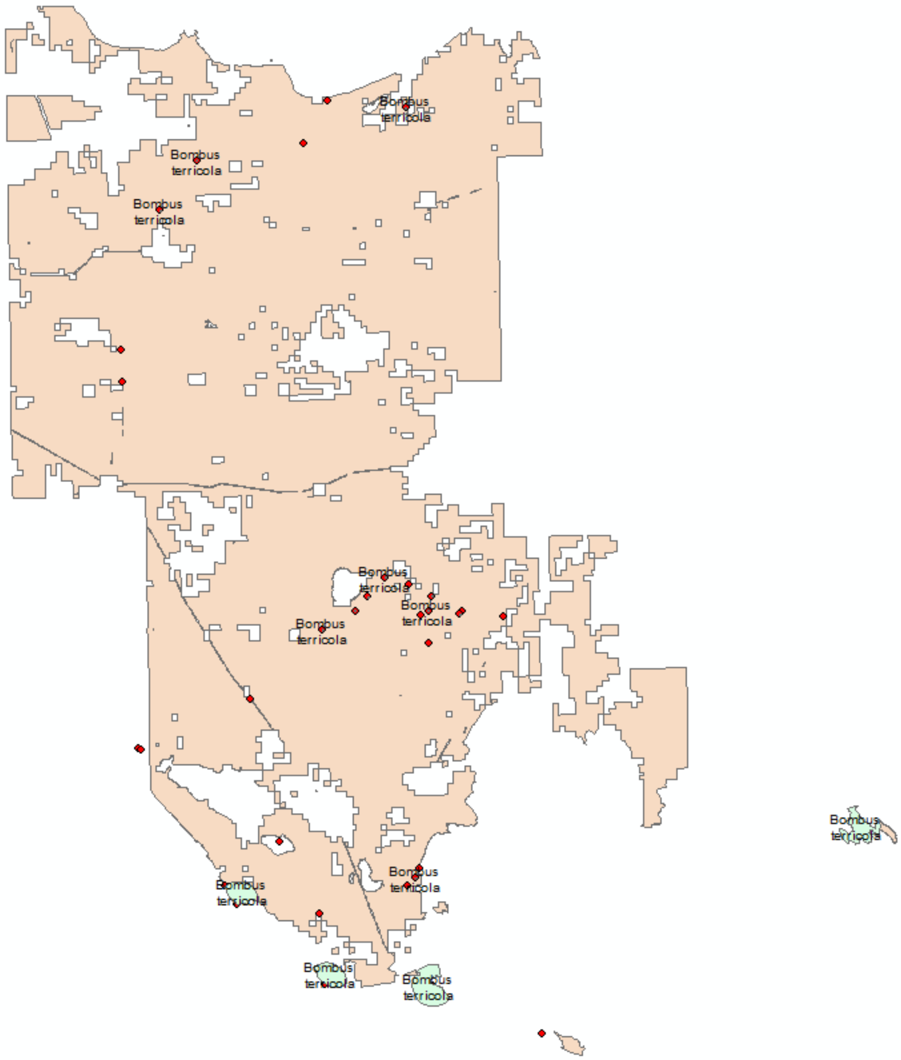

Figure 6: *Bombus terricola* element occurrences locations with the Hiawatha National Forest (East Unit). Green circles are historic EOs, while current EOs are labeled. Red dots indicate non-*terricola* Bombus collections.

Reconcile databases – MNFI/NRIS (East and West Units)

MNFI continues to update the Biotics Database after every field season and we have been making changes to web-based subscription access. This year a total of 24 Element Occurrences from the Hiawatha National Forest were transcribed or added to the MNFI Biotics Database and an additional 24 records were updated (Appendix 1). Over the past four years a total of 267 Element Occurrences have either been updated (sometimes the same EOs multiple years) or newly added to the database. Before the next field season we plan to update or newly transcribe several raptor nesting records on the Hiawatha National Forest. As for data we have received from the HNF, most of this data are animal records and exclusively from the East Unit. ***We would appreciate receiving additional plant and records from both Units.*** We are also currently reviewing access requirements/rates with several agencies and groups of data users and have provided the Hiawatha National Forest access at the full shape file level because of your level of financial support to our program.

This data base access is being provided as a direct result of our great working relationship we have established over the past several years and we look forward to continued collaboration on this and future projects!

Mussel Surveys (West Unit)

Mussel surveys were performed at thirteen lake sites and six stream sites in 2018 within the west unit of Hiawatha National Forest. These surveys are part of a continuing effort to document native mussel occurrences and community composition in the Upper Peninsula before the introduction of zebra mussels to these waterbodies. Native freshwater mussels (Unionidae) can be severely impacted by zebra mussels, sometimes resulting in a complete loss of the native mussel community from a lake or river reach. Though introductions of zebra mussel (*Dreissena polymorpha*) to inland lakes in the Upper Peninsula are likely to increase, relatively few occurrences are currently documented. These surveys also aim to document locations of rare and listed mussel species. Recent genetics and morphological work has enabled more accurate identification of two very similar mussel species, giant floater (*Pyganodon grandis*) and lake floater (*Pyganodon lacustris*) (Zanatta pers. com. 2018), both of which potentially occur in Hiawatha NF. Lake floater is a species of special concern. These surveys have identified occurrences of Pyganodon that can now be studied further to determine identification to species.

Unionid mussel surveys were performed to determine the presence/absence and abundance of each species at each site. A measured search area was used to standardize sampling effort among sites and allow unionid density estimates to be made. Typically, around $128m^2$ area provides a good compromise between amount of search effort per site and the number of sites to be completed within the timeline of the project. In lakes, a transect line or tape was used to delineate the search area. In streams, the search area spanned the width of the steam, when possible, and the length of reach surveyed was measured to determine the search area. Only wadable habitats were surveyed, i.e. waist deep (approximately 70cm) and shallower. Survey of deeper habitats is possible with the use of dive equipment, but this was outside the scope of this survey. Boat ramps or access points are likely points of entry into lakes for zebra mussels. Zebra mussels and other aquatic invasive species are often inadvertently transported on boats, trailers, and recreation/fishing gear. Sample sites were located adjacent to boat access points, when present, to maximize chances of detecting zebra mussels. Latitude and longitude of each site was recorded with a hand-held GPS unit.

Live unionids and shells were located with a combination of visual and tactile means. Glass bottom buckets were used to facilitate visual searches. Occasional tactile searches through the substrate were made to help ensure that buried unionids were not overlooked. Live individuals were identified to species and planted back into the substrate anterior end down (siphon end up) in the immediate vicinity of where they were found. Shells were also identified to species. Presence of zebra mussels and Asian clams (*Corbicula fluminea*) were noted if found.

Habitat data were taken to describe and document conditions at the time of the surveys. The substrate within each transect was characterized by estimating percent composition of each of the following six particle size classes (diameter); boulder (>256mm), cobble (256-64mm), pebble (64-16mm), gravel (16-2mm), sand (2-0.0625mm), silt/clay (<0.0625) (Hynes 1970). Woody debris, aquatic vegetation, exposed solid clay substrate, and erosion were noted when observed. Conductivity and pH were recorded with an Oakton handheld meter. Total alkalinity and hardness (calcium and magnesium) were measured with LaMotte kits.

A total of seven native mussel species were documented. Live native mussels were found at seven of the thirteen lakes, and three of the six stream survey sites. Individuals identified as *Pyganodon sp.* in this study are either *Pyganodon grandis* (giant floater) or *Pyganodon lacustris* (lake floater). *Pyganodon sp.* were found at nine sites. Additional genetics and/or morphological study are needed to confirm the species at these sites, as well as sites surveyed in previous years. The state threatened slippershell (*Alasmidonta viridis*) (Figure 7) and species of special concern creek heelsplitter (*Lasmigona compressa*) were found at Site 18 in the Indian River upstream of Bar Lake (Figure 8). One shell of the special concern fluted-shell (*Lasmigona costata*) was found in Bar Lake at Site 17 (Figure 9).

Figure 7. The state threatened slippershell (*Alasmidonta viridis*), from Site 18 in the Indian River at the inlet to Bar Lake.

Figure 8. Creek heelsplitter (*Lasmigona compressa*), a species of special concern from Site 18 in the Indian River upstream of Bar Lake.

Figure 9. A shell of the special concern fluted-shell (*Lasmigona costata*) found in Bar Lake at Site 17.

Locations of mussel survey sites are given in Table 5, and the numbers of individuals of each species found are given in Table 6. An additional lake site had mussel shells present but none live. The site with the highest mussel species richness and abundance was Site 18 in the Indian River just upstream of the inlet to Bar Lake (0.48 indvs./m^2). *Pyganodon sp.* and fatmucket (*Lampsilis siliquoidea*) were the most abundant and frequently found mussel species. No zebra mussels or Asian clams were detected at any of the sites surveyed. A total of ten species of aquatic snails were found incidentally while performing mussel surveys (Appendix III). No listed or special concern snail species were found. The area surveyed at each site is a small fraction of the available habitat in each lake. Surveying additional sites in the lakes surveyed in 2018 could reveal additional populations.

Physical and chemical habitat measures are provided in (Appendix IV and V). Total alkalinity and hardness (calcium and magnesium) were particularly low (<20mg/l) at West Branch, Ramsey, Mowe, and McComb Lakes (Sites 2, 6, 10, and 12). Conductively of the water in these lakes was also very low (<20µS). No unionid mussels were found at these sites, and no unionid mussels, fingernail clams, or snails were found at two of the four sites. One possible explanation for this, is a lack of available calcium for shell production. These were the only sites with <28mg/L calcium concentration, a level that has been identified as a threshold for survival of zebra mussels (Hollandsworth et al. 2011, Cohen and Weinstein 2001, Hincks and Mackie 1997). Exceptionally low alkalinity and hardness at these four sites may be a limiting factor for native unionid mussels.

Table 5. Locations of mussel survey sites in Hiawatha National Forest, Summer 2018.

Site #	Waterbody	Access	Latitude (N)	Longitude (W)
1	SW Br Fishdam River	2226(2231)	45.97265	-86.62085
2	West Branch Lake	2206	45.97565	-86.60769
3	Sturgeon River	H-13	45.94987	-86.70585
4	Van Winkle Lake	N3	46.05404	-86.57005
5	Camp 7 Lake	Camp 7 Rd.	46.05555	-86.55113
6	Ramsey Lake	2233	45.98689	-86.75985
7	Indian River	Indian River campground site 5	46.15392	-86.40524
8	Crooked Lake	Two-track off M-94	46.21440	-86.42554
9	Big Boot Lake	Two-track off M-94	46.26667	-86.45133
10	Mowe Lake	2693	46.14474	-86.57740
11	Hugaboom Lake	440	46.15105	-86.60806
12	McComb Lake	Two-track off 2269	46.19092	-86.65238
13	Red Lake	2451	46.19785	-86.56826
14	Blue Joe Lake	Two-track off 2257	46.19964	-86.57396
15	Cookson Lake	2451	46.19572	-86.56150
16	Indian River	Two-track off 2269 near Bar Lake inlet	46.23301	-86.65373
17	Bar Lake	Two-track off 2269 near Sturgeon River inlet	46.23303	-86.65304
18	Indian River	Marten Run Trail	46.18953	-86.57033
19	Delias Run	At confluence of Indian River	46.18278	-86.44016

Table 6. Numbers of unionid mussels (#), relative abundance (RA), and density (D, indvs./m^2) recorded at each survey site, Summer 2018. Presence/absence of aquatic snails, fingernail clams, and non-native bivalves noted.

		1	2	3	4			5	6	7	8		
Common Name	Species	#	#	#	#	RA	D	#	#	#	#	RA	D
Slippershell (T)	*Alasmidonta viridis*												
Cylindrical papershell	*Anodontoides ferussacianus*												
Spike	*Eurynia dilatata*												
Fatmucket	*Lampsilis siliquoidea*												
Creek heelsplitter (SC)	*Lasmigona compressa*												
Fluted-shell (SC)	*Lasmigona costata*												
Lake/giant floater	*Pyganodon sp.*				1	1.00	0.01				1	1.00	0.00
Strange floater	*Strophitus undulatus*												
	Total # indvs. and density	0	0	0	1		0.01	0	0	0	1		0.00
	# species live	0	0	0	1			1	0	0	1		
	# species live or shell	0	0	0	1			1	0	0	1		
	Area searched (m^2)	126	30	120	162			152	20	84	330		
Asian clam	*Corbicula fluminea*												
Zebra mussel	*Dreissena polymorpha*												

		9			10	11			12	13	14		
Common Name	Species	#	RA	D	#	#	RA	D	#	#	#	RA	D
Slippershell (T)	*Alasmidonta viridis*												
Cylindrical papershell	*Anodontoides ferussacianus*												
Spike	*Eurynia dilatata*												
Fatmucket	*Lampsilis siliquoidea*	S(3)				2	0.40	0.02					
Creek heelsplitter (SC)	*Lasmigona compressa*												
Fluted-shell (SC)	*Lasmigona costata*												
Lake/giant floater	*Pyganodon sp.*	2	1.00	0.01		3	0.60	0.02		S(2)	1	1.00	0.01
Strange floater	*Strophitus undulatus*												
	Total # indvs. and density	2		0.01	0	5		0.04	0	0	1		0.01
	# species live	1			0	2			0	0	1		
	# species live or shell	2			0	2			0	1	1		
	Area searched (m^2)	232			260	124			160	128	160		
Asian clam	*Corbicula fluminea*												
Zebra mussel	*Dreissena polymorpha*												

		15			16			17		
Common Name	Species	#	RA	D	#	RA	D	#	RA	D
Slippershell (T)	*Alasmidonta viridis*									
Cylindrical papershell	*Anodontoides ferussacianus*				2	0.09	0.02	2	0.02	0.01
Spike	*Eurynia dilatata*				16	0.70	0.17			
Fatmucket	*Lampsilis siliquoidea*	35	0.78	0.16	3	0.13	0.03	3	0.03	0.01
Creek heelsplitter (SC)	*Lasmigona compressa*									
Fluted-shell (SC)	*Lasmigona costata*							S(1)		
Lake/giant floater	*Pyganodon sp.*	10	0.22	0.05				82	0.94	0.33
Strange floater	*Strophitus undulatus*				2	0.09	0.02			
	Total # indvs. and density	45		0.20	23		0.25	87		0.35
	# species live	3			3			3		
	# species live or shell	3			3			4		
	Area searched (m^2)	220			93			250		
Asian clam	*Corbicula fluminea*									
Zebra mussel	*Dreissena polymorpha*									

		18				19		
Common Name	Species	#	RA	D		#	RA	D
Slippershell (T)	*Alasmidonta viridis*	1	0.01	0.01				
Cylindrical papershell	*Anodontoides ferussacianus*	3	0.04	0.02				
Spike	*Eurynia dilatata*	43	0.62	0.30				
Fatmucket	*Lampsilis siliquoidea*	18	0.26	0.13		1	1.00	0.01
Creek heelsplitter (SC)	*Lasmigona compressa*	2	0.03	0.01				
Fluted-shell (SC)	*Lasmigona costata*							
Lake/giant floater	*Pyganodon sp.*	1	0.01	0.01				
Strange floater	*Strophitus undulatus*	1	0.01	0.01				
	Total # indvs. and density	69		0.48		1		0.01
	# species live	7				1		
	# species live or shell	7				1		
	Area searched (m^2)	144				128		
Asian clam	*Corbicula fluminea*							
Zebra mussel	*Dreissena polymorpha*							

Niagara Habitat Monitoring Analysis

Environmental Variables

For each year (2012-2016), we compared mean elevated temperature, surface temperature, humidity, average light intensity, and maximum light intensity among the five treatment categories (reference, control, option 1, option 2, and option 3). Comparisons were made using a mixed model (PROC MIXED, SAS Institute, Cary, NC) consisting of treatment as a fixed effect and day and hour as random effects. We used a repeated measures component to account for sampling occurring at 30-min intervals at the same locations. Three commonly used covariance structures were evaluated for each variable: variance components, autoregressive order 1, and compound symmetric (Littell et al. 1996, Kincaid 2005). We selected the best-approximating model using Akaike's Information Criterion (AIC). We log transformed ($\log_e[x]$) light intensity data and arcsine-square root ($\arcsin\sqrt{x}$) transformed relative humidity.

Vegetation Information

Data from vegetation sampling were compared among the following treatment categories: reference, control, pre-harvest (options 1, 2, and 3 combined), post-harvest option 1, and post-harvest option 2. Mean basal area (ft^2/acre), percent canopy closure, and subcanopy densities of balsam fir (*Abies balsamea*), ironwood (*Ostrya virginiana*), and sugar maple (*Acer saccharum*) were compared using a mixed model with treatment as a fixed effect and year and site as random effects. We compared percent cover of rock and moss estimated using a mixed model consisting of treatment as a fixed effect and year, site, and plot as random effects. Percent canopy closure and percent cover variables were arcsine-square root ($\arcsin\sqrt{x}$) transformed and subcanopy densities were log transformed ($\log_e[x+1]$) prior to analysis.

Multivariate Analyses

We used nonmetric multidimensional scaling (NMS) to explore possible patterns among our treatments in environmental and vegetation variables. Stands were assigned to the following treatment categories: reference, control, pre-harvest (options 1, 2, and 3 combined), post-harvest option 1, and post-harvest option 2. Prior to analysis, we conducted a Pearson correlation matrix (PROC CORR, SAS Institute, Cary, NC) to examine potential collinearity among our variables. Variables were removed when $r > 0.60$, leaving a final set of 22 variables for analysis (Table 7). We performed NMS using the Bray-Curtis distance measure, 250 runs on the original data matrix, and a maximum of 500 iterations. A final solution was achieved when an instability value of 0. 0000001 was obtained or after 500 iterations. A Monte-Carlo permutation procedure (McCune and Grace 2002) was conducted with 250 randomized runs to evaluate if axes produced by NMS explained more variation than by chance alone.

We conducted multi-response permutation procedures (MRPP) to test for differences in the environmental and vegetation variables among the treatment categories. Bray-Curtis distance measures and natural weighting ($n_i/\Sigma n_i$; Mielke 1984) were used in the MRPP analysis. We tested for differences among all five categories and then completed pair-wise MRPP comparisons of all possible pairs of the treatment categories. Multivariate analyses were completed using PC-ORD v.6.08 (McCune and Mefford 2011).

Table 7. Final set of variables used in multivariate analyses.

Variable Type	Vegetation Stratum	Variable Description
Environmental	---	Surface temperature (°C)
		Relative humidity
		Mean light intensity (lum/ft^2)
Vegetation	Canopy	Basal area (ft^2/acre)
		Percent canopy closure
		American basswood density
		American beech density
		Aspen density
		Paper birch density
		Sugar maple density
		Snag density
	Subcanopy	American beech density
		Ironwood density
		Balsam fir density
		Sugar maple density
		Snag density
		Shrub density
	Ground cover	Bare soil percent cover
		Bedrock percent cover
		Coarse woody debris percent cover
		Moss percent cover
		Total number of plant taxa

Results

Environmental Variables

Elevated temperature was consistently lower at control sites compared to the other treatment types, but patterns among the other treatments varied by year (Figure 10). Patterns in surface temperature were consistent across years, with reference and control being similar in most years and lower compared to options 1, 2, and 3 (Figure 11). We observed variation in relative humidity among the treatment types both within and among years, with no consistent pattern evident even when considering the timing of the option 1 and 2 harvests (Figure 12). The patterns in light intensity (lum/ft^2) were nearly identical whether comparing average hourly or maximum hourly values (Figures 13 and 14). Light intensity varied considerably both within and among years. Reference and control sites had lower mean light intensity than options 1, 2, and 3 sites in most years, except for 2014 when intensity at option 1 sites was lower than reference and control samples and in 2016 when intensity was similar among reference, control, and option 1 stands.

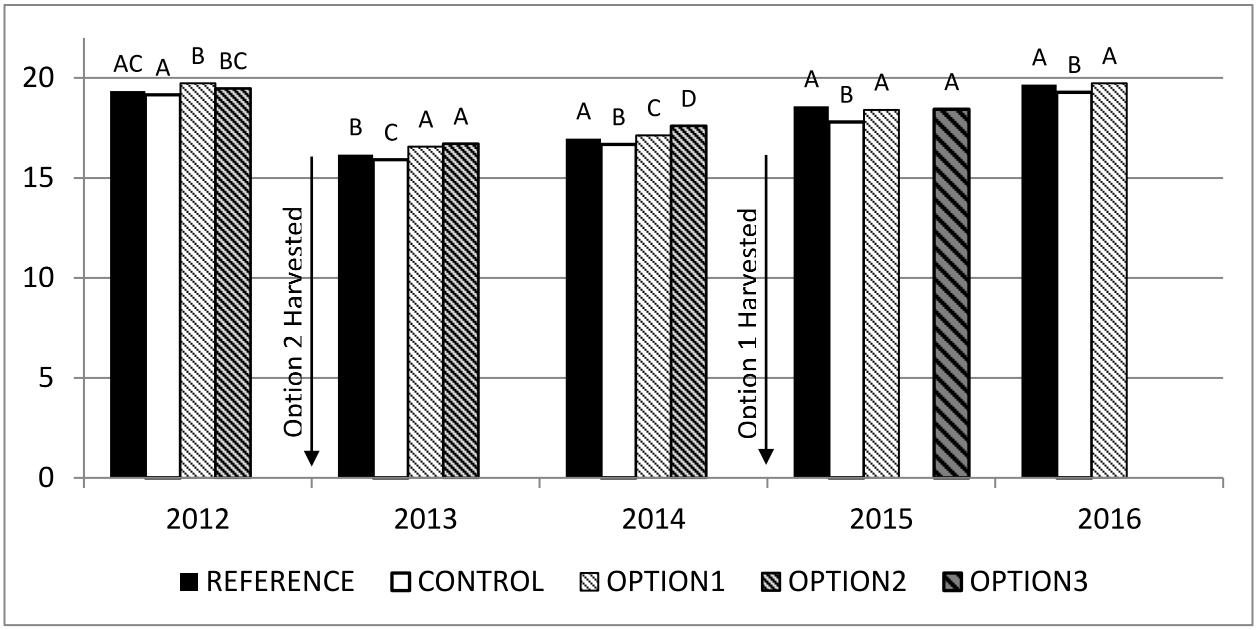

Figure 10. Mean hourly elevated temperature (°C) from mid-July through August by treatment and year in the Hiawatha National Forest. Within a given year, treatments having the same label were not significantly different.

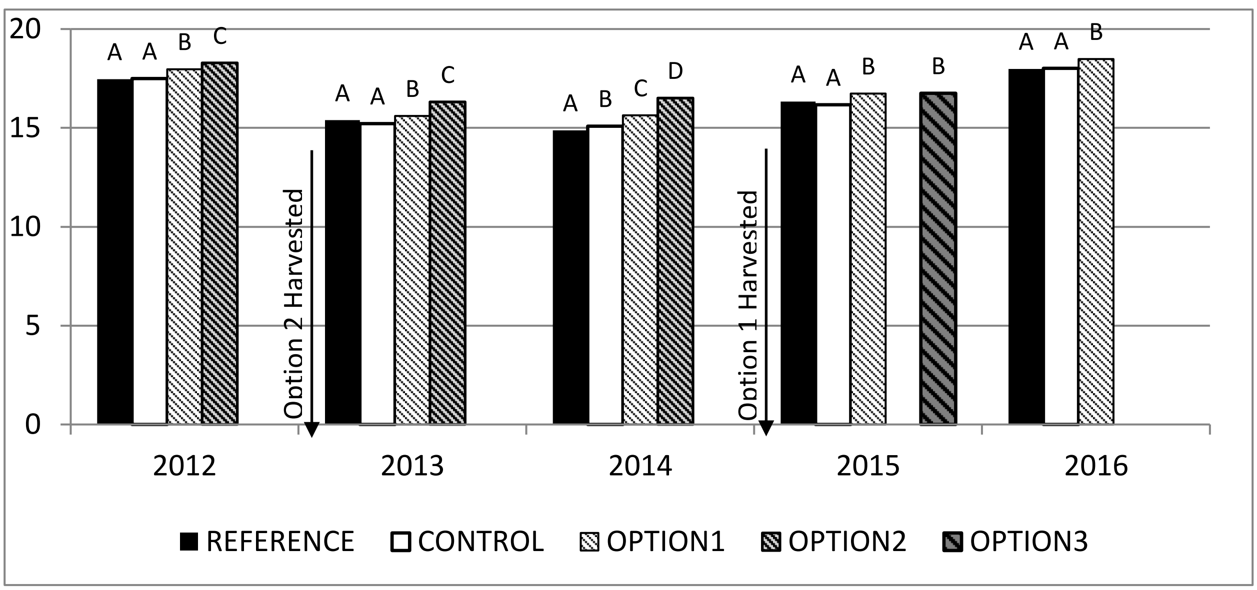

Figure 11. Mean hourly surface temperature (°C) from mid-July through August by treatment and year in the Hiawatha National Forest. Within a given year, treatments having the same label were not significantly different.

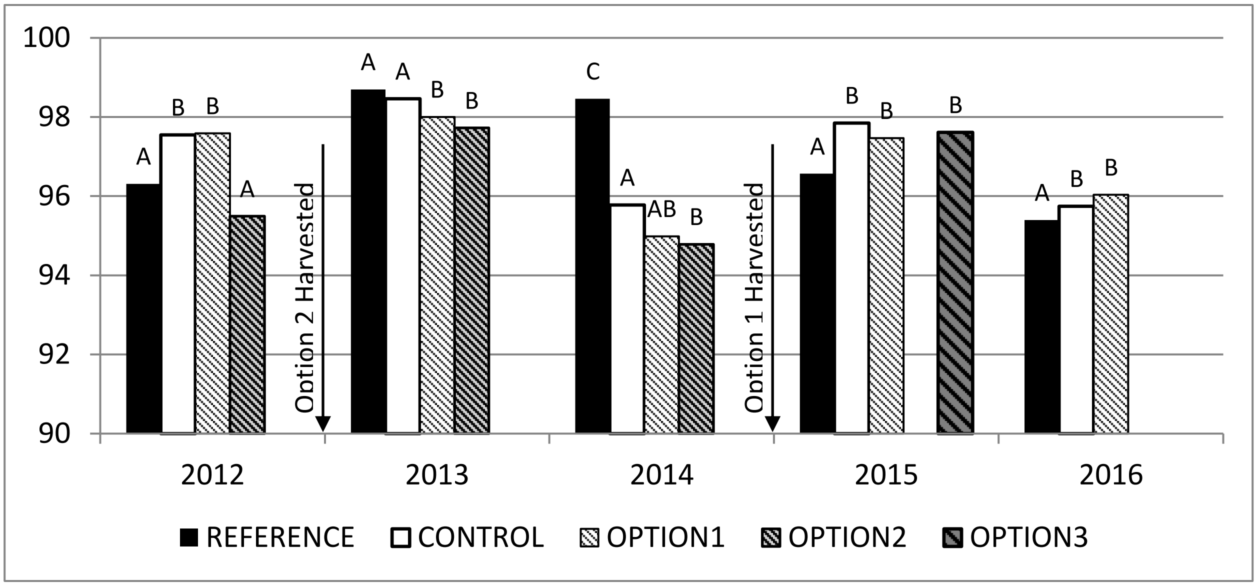

Figure 12. Mean hourly percent humidity from mid-July through August by treatment and year in the Hiawatha National Forest. Within a given year, treatments having the same label were not significantly different.

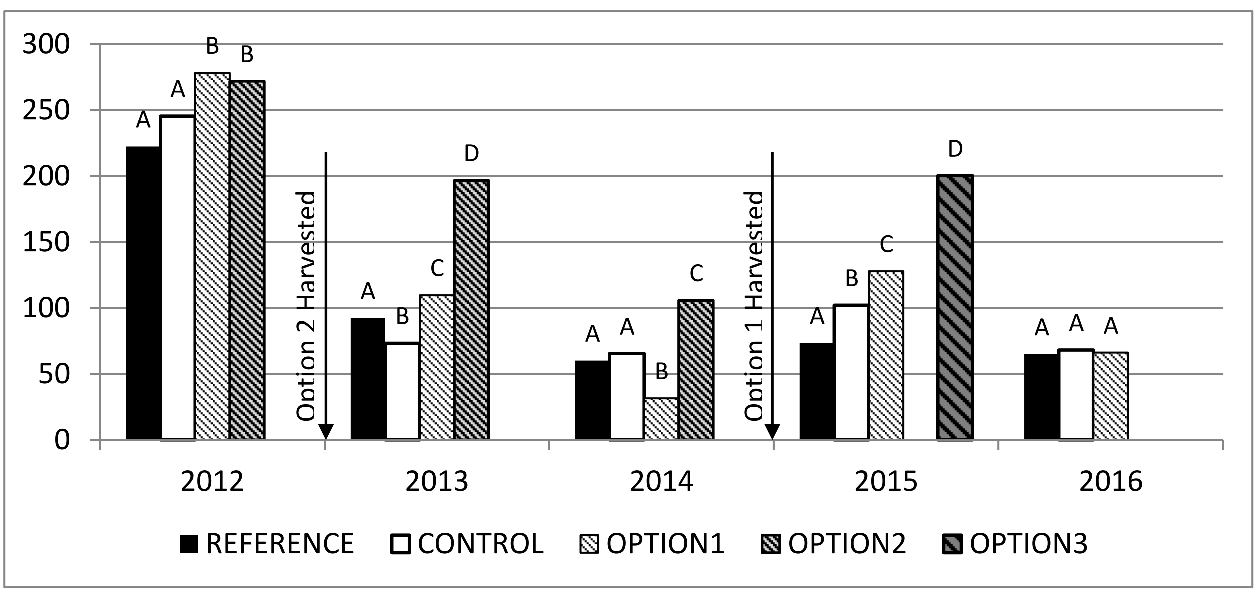

Figure 13. Mean hourly average light intensity (lum/ft^2) from mid-July through August by treatment and year in the Hiawatha National Forest. Within a given year, treatments having the same label were not significantly different.

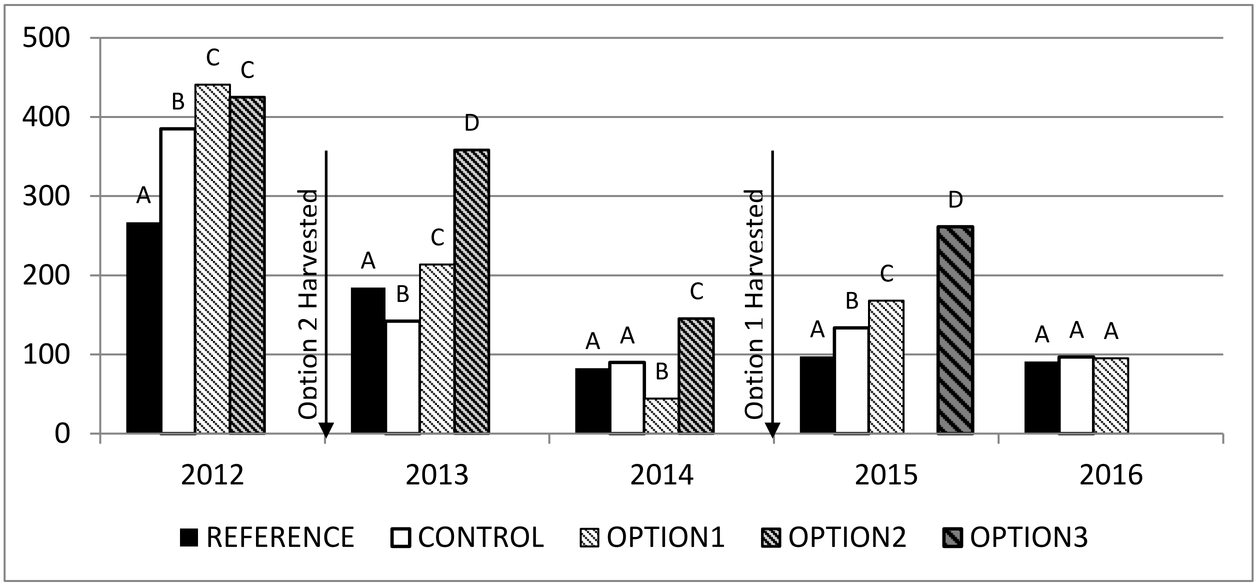

Figure 14. Mean hourly maximum light intensity (lum/ft^2) from mid-July through August by treatment and year in the Hiawatha National Forest. Within a given year, treatments having the same label were not significantly different.

Vegetation Information

Average basal area was significantly lower in post-harvest option 2 sites compared to all other treatments (Figure 15). We found no difference in basal area among reference, control, pre-harvest option 1, and post-harvest option 1 samples. We observed the same pattern in percent canopy closure, with post-harvest option 2 being significantly lower than all other treatments, including pre-harvest option 2 (Figure 15). No consistent patterns emerged in subcanopy densities for the three most common species (balsam fir, ironwood, and sugar maple), with densities varying across years and treatments (Figure 16). Similarly, we found no significant difference in percent cover of bedrock and moss among the treatment types or before and after harvest within treatment (options 1 and 2; Figure 17).

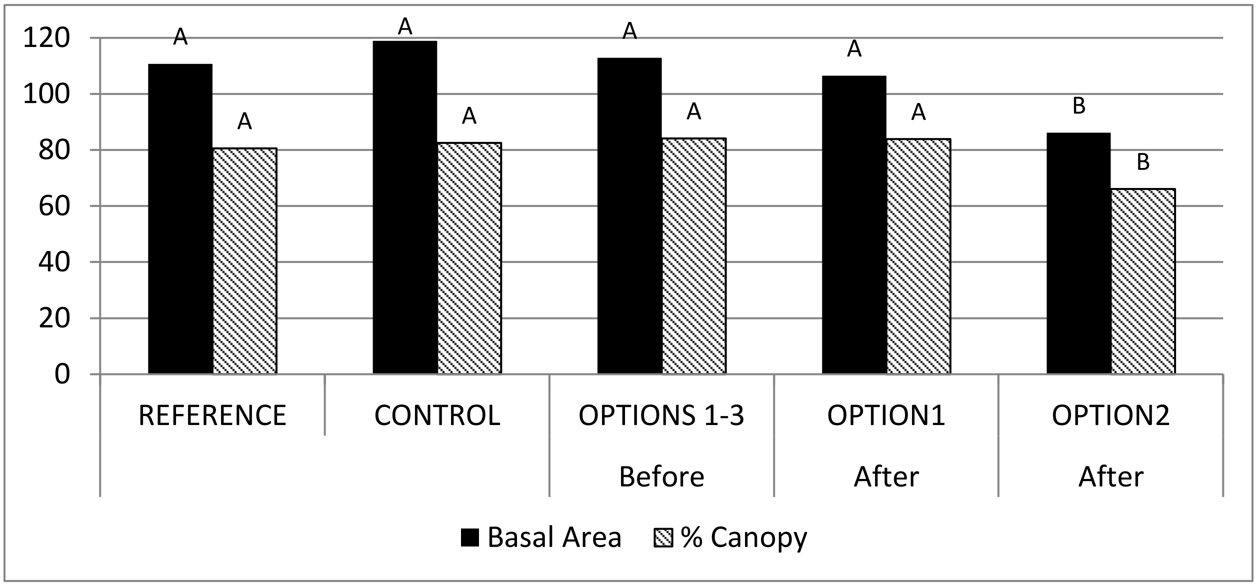

Figure 15. Mean basal area (ft^2/acre) and percent canopy cover by treatment and before and after harvest in the Hiawatha National Forest. For a given variable, means having the same label were not significantly different.

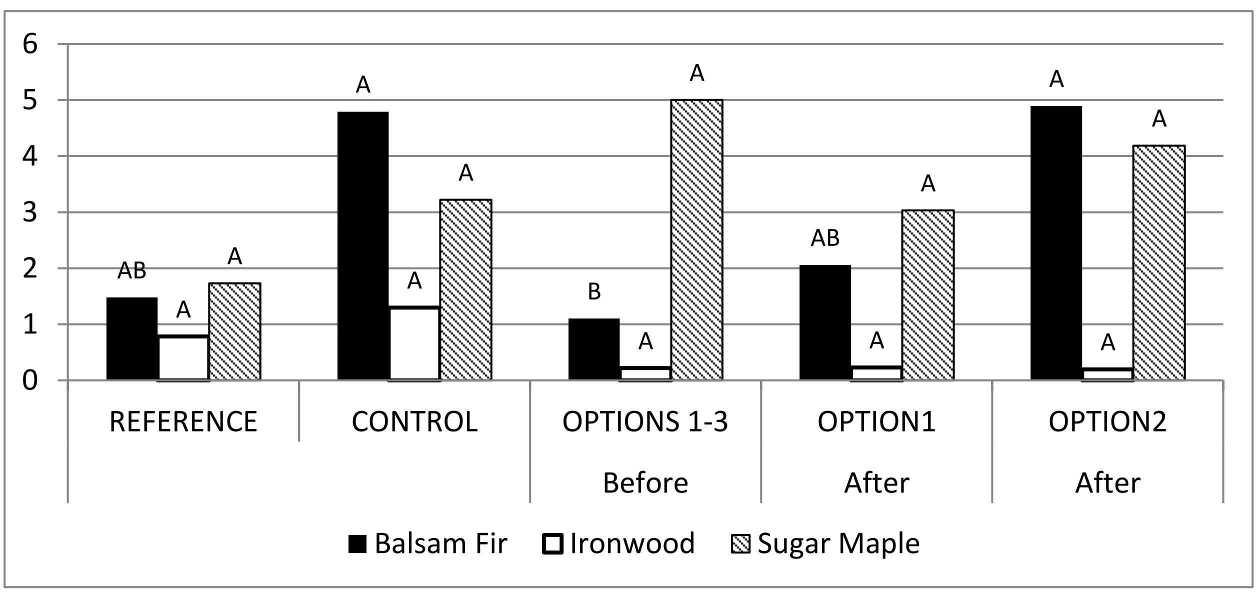

Figure 16. Mean subcanopy density (number/0.1 acre, 11.3-m radius plot) for the three most common species by treatment and before and after harvest in the Hiawatha National Forest. For a given species, means having the same label were not significantly different.

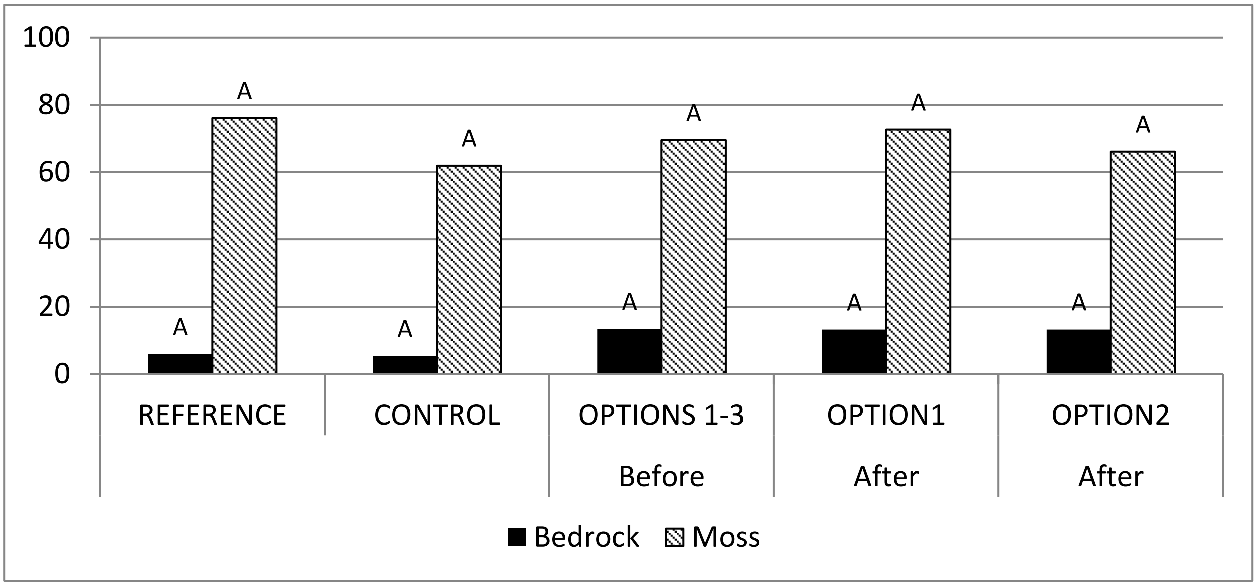

Figure 17. Mean percent cover of bedrock and moss by treatment and before and after harvest in the Hiawatha National Forest. For a given variable, means having the same label were not significantly different.

Multivariate Analyses

Initial NMS analysis suggested the data were best represented by three dimensions and a solution with equal or less stress was not likely to occur by chance alone (P = 0.008). After rerunning NMS with only three dimensions, 77.8% of the variation in the original distance matrix was explained (final stress of 17.08). There was some clustering of sites according to treatment type along the first dimension but no discernable separation along the second or third dimensions (Figure 18). The first axis was negatively correlated with snag (r = -0.648) and sugar maple (r = -0.715) density in the canopy and balsam fir density in the subcanopy (r = -0.609), and positively associated with mean light intensity (r = 0.547) and percent cover of bedrock (r = 0.592). Reference and control stands were largely on the negative end of the first axis, indicating they tended to have greater densities of snags and sugar maple in the canopy, greater balsam fir densities in the subcanopy, lower light intensity, and lower percent cover of bedrock compared to the managed stands (options 1-3).

Results of MRPP analyses were consistent with the patterns observed in the NMS ordination. Environmental and vegetation variables differed among the five treatment categories (T = -9.83, A = 0.10, P < 0.001). Pair-wise MRPP comparisons indicated that reference and control sites were similar (T = -0.13, A < 0.01, P = 0.411) but all other treatment combinations differed ($P \leq$ 0.016).

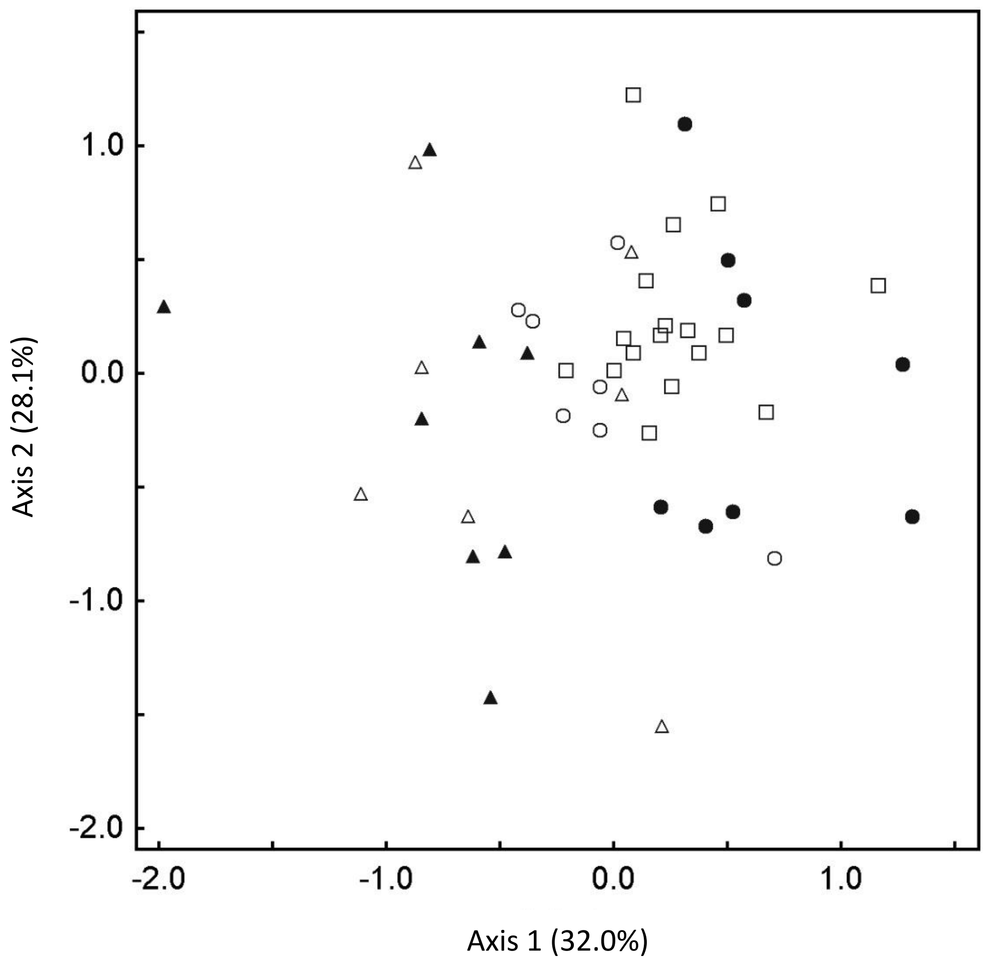

Figure 18. Nonmetric multidimensional scaling plot for environmental and vegetation data collected at stands within Hiawatha National Forest. Treatment types are coded as follows: shaded triangle = reference; open triangle = control; options 1, 2, and 3 pre-harvest = open square; option 1 post-harvest = open circle; and option 2 post-harvest = shaded circle.

Recommendations for Future Work

We have nearly completed entering data gathered with data loggers and during vegetation sampling in 2017 and 2018 and will finish quality control work in 2019. We recommend periodically repeating the analyses conducted for this report as new information is collected. Final analyses will be completed once finishing the last round of sampling in option 3 stands (i.e., 5 years after harvest).

Hine's emerald dragonfly surveys (East Unit)

In late July early August 2018, meander surveys for Hine's emerald dragonflies were conducted in habitats previously determined to support populations. Population data and spatial locations were recorded using the BackCountry Navigator Pro GPS Application (CritterMap Software LLC) for Android. All adults observed were recorded and marked with GPS. Following field surveys, element occurrence ranks were updated (Table 3).

Table 8. Hine's emerald dragonfly element occurrences visited on HNF in 2018.

Species	EOID	State Status	Old Rank	New Rank	Survey Type
Somatochlora hineana	5982	E	CD	F	Qualitative meander
Somatochlora hineana	9122	E	D	F	Qualitative meander
Somatochlora hineana	1909	E	AB	AB	*Qualitative meander*

Recommendations for Future Work

We recommend revisiting known occurrences on the HNF focusing on those occurrences that have not been visited in recent years. In addition, there are additional northern fen EOs that should be visited to determine if Hine's emerald dragonfly occurs within any of these fens.

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Figure 3. Calypso or fairy orchid (*Calypso bulbosa*) at Search Bay North, EOID 3639, 20 June 2018.

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Appendix 1

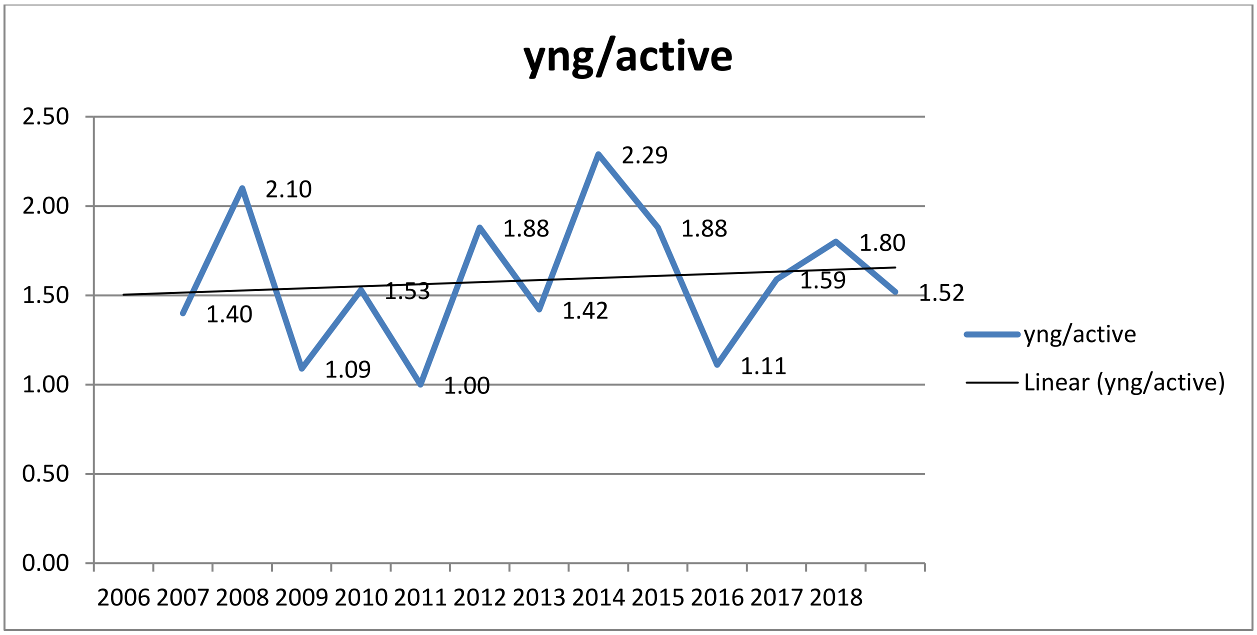
Element Occurrence Records either updated or newly transcribed into the MNFI Biotics Conservation Data base.

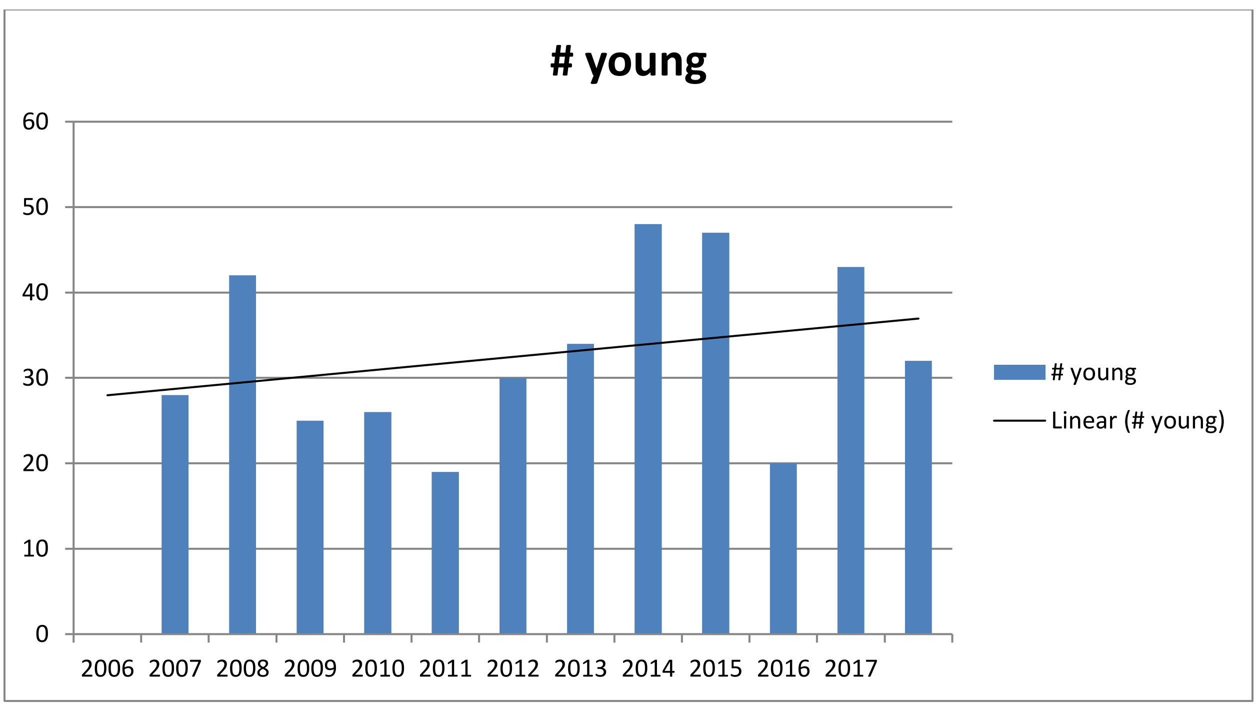
EO_ID	SCIENTIFIC_NAME	COMMON_NAME	REC_LAST_MOD_DATE	REC_LAST_ MOD_USER
1806	Asplenium viride	Green spleenwort	12/21/2018 14:31	dlc
3132	Iris lacustris	Dwarf lake iris	03/07/2018 15:34	dje
4462	Vaccinium cespitosum	Dwarf bilberry	03/07/2018 15:36	dje
6958	Calypso bulbosa	Calypso or fairy-slipper	01/13/2018 17:07	hde
7447	Asplenium viride	Green spleenwort	01/24/2018 12:39	hde
8678	Nycticorax nycticorax	Black-crowned night-heron	04/10/2018 11:39	dje
9332	Asplenium viride	Green spleenwort	12/06/2018 17:03	dlc
9764	Buteo lineatus	Red-shouldered hawk	01/25/2018 12:57	dje
10006	Vaccinium cespitosum	Dwarf bilberry	03/07/2018 15:37	dje
13207	Tetraneuris herbacea	Lakeside daisy	10/10/2018 11:11	dje
13862	Buteo lineatus	Red-shouldered hawk	10/30/2018 11:20	kea
13862	Buteo lineatus	Red-shouldered hawk	10/30/2018 11:20	kea
13884	Buteo lineatus	Red-shouldered hawk	10/30/2018 10:39	kea
13884	Buteo lineatus	Red-shouldered hawk	10/30/2018 10:39	kea
16783	Buteo lineatus	Red-shouldered hawk	10/26/2018 15:41	kea
16787	Accipiter gentilis	Northern goshawk	10/30/2018 11:26	kea
18252	Buteo lineatus	Red-shouldered hawk	01/25/2018 12:18	dje
18639	Buteo lineatus	Red-shouldered hawk	01/24/2018 12:58	hde
18666	Buteo lineatus	Red-shouldered hawk	01/25/2018 12:13	dje
19943	Buteo lineatus	Red-shouldered hawk	10/26/2018 15:01	kea
19943	Buteo lineatus	Red-shouldered hawk	10/26/2018 15:01	kea
19943	Buteo lineatus	Red-shouldered hawk	10/26/2018 15:01	kea
19944	Buteo lineatus	Red-shouldered hawk	01/25/2018 12:08	dje
19946	Buteo lineatus	Red-shouldered hawk	01/25/2018 11:32	dje
20068	Picoides arcticus	Black-backed woodpecker	04/16/2018 9:26	dlc
20725	Buteo lineatus	Red-shouldered hawk	01/25/2018 11:30	dje
20728	Buteo lineatus	Red-shouldered hawk	10/26/2018 14:44	kea
20728	Buteo lineatus	Red-shouldered hawk	10/26/2018 14:44	kea
20730	Accipiter gentilis	Northern goshawk	02/15/2018 10:32	dje
20732	Accipiter gentilis	Northern goshawk	02/15/2018 10:33	dje
20799	Buteo lineatus	Red-shouldered hawk	01/25/2018 9:56	dje
20804	Buteo lineatus	Red-shouldered hawk	01/25/2018 9:43	dje
20805	Buteo lineatus	Red-shouldered hawk	01/25/2018 9:28	dje
20806	Buteo lineatus	Red-shouldered hawk	01/25/2018 9:22	dje
20807	Buteo lineatus	Red-shouldered hawk	01/25/2018 9:18	dje
20809	Buteo lineatus	Red-shouldered hawk	01/25/2018 8:58	dje
20811	Accipiter gentilis	Northern goshawk	02/15/2018 10:35	dje

20812	Accipiter gentilis	Northern goshawk	02/15/2018 10:36	dje
21327	Botaurus lentiginosus	American bittern	03/07/2018 15:39	dje
21369	Carex billingsii	Three-seed sedge	03/07/2018 15:42	dje
21370	Potamogeton confervoides	Alga pondweed	03/07/2018 15:43	Dje
21371	Spinulum canadense	Clubmoss	03/07/2018 15:45	dje
21471	Botaurus lentiginosus	American bittern	02/19/2018 13:55	mjm
21525	Bombus terricola	Yellow banded bumble bee	03/05/2018 14:18	dje
21529	Bombus terricola	Yellow banded bumble bee	12/04/2018 14:02	lmr
21533	Bombus terricola	Yellow banded bumble bee	03/05/2018 14:11	dje
21770	Accipiter gentilis	Northern goshawk	10/30/2018 10:53	kea
21775	Buteo lineatus	Red-shouldered hawk	10/23/2018 16:12	kea

Appendix II.

Red-shouldered Hawk productivity on the East Unit of the Hiawatha National Forest, 2006-2018.





Appendix III.

Aquatic snail species and other incidental finds at each mussel survey site, Summer 2018.

Common Name	Species/Taxa	1	2	3	4	5	6	7	8	9	10
Snails	Gastropoda			X	X	X			X	X	X
Pointed campeloma	*Campeloma decisum*					x			x	x	x
Liver elimia	*Elimia livescens*			x							
	Gyraulus sp.										
Two-ridge rams-horn	*Helisoma anceps*					x					
Swamp lymnaea	*Lymnaea stagnicola*										
Tadpole physa	*Physella gyrina*					x			x		
Marsh rams-horn	*Planorbella trivolvis*				x	x			x		
Bell-mouth ram's horn	*Planorbella campanulata*								x	x	
Marsh pondsnail	*Stagnicola elodes*								x		
	Hydrobiid sp.										
Fingernail clams	Sphaeriidae				X	X		X		X	X
Crayfish	Decapoda										
Fish									X		
Northern redbelly dace	*Chrosomus eos*										
Johnny darter	*Etheostoma nigrum*										
Logperch	*Percina caprodes*										
Freshwater sponge	*Spongilla sp.*			X	X						

Common Name	Species/Taxa	11	12	13	14	15	16	17	18	19
Snails	Gastropoda	X	X	X	X	X	X	X	X	
Pointed campeloma	*Campeloma decisum*	x	x	x	x	x	x		x	
Liver elimia	*Elimia livescens*						x		x	
	Gyraulus sp.			x				x		
Two-ridge rams-horn	*Helisoma anceps*	x			x	x	x			
Swamp lymnaea	*Lymnaea stagnicola*	x					x	x		
Tadpole physa	*Physella gyrina*	x		x	x					
Marsh rams-horn	*Planorbella trivolvis*			x	x		x	x	x	
Bell-mouth ram's horn	*Planorbella campanulata*	x				x		x		
Marsh pondsnail	*Stagnicola elodes*	x								
	Hydrobiid sp.			x						
Fingernail clams	Sphaeriidae	X		X	X	X	X	X	X	X
Crayfish	Decapoda			X			X		X	
Fish						X			X	
Northern redbelly dace	*Chrosomus eos*					x				
Johnny darter	*Etheostoma nigrum*								x	
Logperch	*Percina caprodes*					x				
Freshwater sponge	*Spongilla sp.*				X				X	

Appendix IV.

Physical habitat measures taken at mussel survey sites, Summer 2018.

Site #	Waterbody	Boulder	Cobble	Pebble	Gravel	Sand	Silt	COM*	Aquatic Vegetation	Woody Debris
1	SW Br Fishdam River					100			N	Y
2	West Branch Lake							100	Y	Y
3	Sturgeon River	20	70	5	5				N	N
4	Van Winkle Lake					40	60		Y	N
5	Camp 7 Lake					60	40		N	N
6	Ramsey Lake							100	Y	N
7	Indian River					60	40		Y	Y
8	Crooked Lake					70	30		Y	N
9	Big Boot Lake					50	50		Y	Y
10	Mowe Lake					80	20		Y	N
11	Hugaboom Lake						##		Y	Y
12	McComb Lake					70	30		Y	N
13	Red Lake							100	Y	Y
14	Blue Joe Lake						##		Y	Y
15	Cookson Lake					40	40	20	Y	N
16	Indian River			10	30	40	20		Y	Y
17	Bar Lake					40	40	20	Y	Y
18	Indian River	2	10	30	20	20	18		Y	Y
19	Delias Run					100**			N	Y

* Coarse organic material

** Loose sand with ripple pattern

Appendix V.

Water chemistry measures taken at mussel survey sites, Summer 2018.

Site #	Waterbody	pH	Conductivity (µS)	Total Alkalinity (mg/l)	Hardness (Ca and Mg, mg/l)	Water Temp. (C)
1	SW Br Fishdam River	7.50	166.0	88	92	13.7
2	West Branch Lake	6.50	14.3	12	20	15.9
3	Sturgeon River	7.44	144.8	60	88	15.0
4	Van Winkle Lake	8.31	194.0	96	112	21.4
5	Camp 7 Lake	8.55	76.6	36	32	21.8
6	Ramsey Lake	6.50	10.5	4	8	20.4
7	Indian River	7.70	196.8	72	80	15.5
8	Crooked Lake	8.30	194.7	72	60	20.5
9	Big Boot Lake	8.26	165.8	44	52	20.6
10	Mowe Lake	8.06	19.8	12	12	23.1
11	Hugaboom Lake	8.10	263.0	124	128	22.3
12	McComb Lake	8.19	17.3	12	10	23.9
13	Red Lake	7.93	174.0	72	72	19.2
14	Blue Joe Lake	7.93	163.4	72	68	19.7
15	Cookson Lake	8.04	182.7	68	76	20.2
16	Indian River	7.81	151.7	64	68	19.1
17	Bar Lake	8.06	148.0	48	52	22.0
18	Indian River	8.12	191.0	80	72	18.2
19	Delias Run	8.34	230.0	112	108	13.8