Managing for Forest Dependent Plant Species of Conservation Concern

Report to Nova Scotia Habitat Conservation Fund

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Introduction

There are thousands of species that inhabit, and are dependent on, forests in Nova Scotia. Many of these species are of conservation concern. Species at risk, a subset of species of conservation concern, are those species that have been formally listed under provincial or federal legislation and half of these are forest dependent. However, there are a much greater number of species that are considered of conservation concern that have received little or no attention in terms of understanding the cause of their concern. Species of conservation concern for the purposes of this study are those ranked by the Atlantic Canada Conservation Data Centre (AC CDC) as S1 (critically imperiled), S2 (sensitive) or S3(vulnerable) (AC CDC 2017). Some work has been done on unlisted birds of conservation concern (e.g. Northern Goshawk; Beazley et al. 2005), mammals (e.g. Southern Flying Squirrel; Peterson and Stewart 2006), reptiles (e.g. Snapping Turtle; Power and Gilhen 2018) and even lichens (e.g. Vole Ears Lichen; Cameron et al. 2011). Surprisingly little effort has been focused on plant species in forests in NS. A few recent exceptions include Hill and Garbary (2011), Taylor and Tam (2012) and Cameron (2009).

The understory floral community is extremely important to functioning of and diversity of forests. Of all forest strata, species diversity is highest in the herb layer (Gilliam 2007). Threats to loss of biodiversity in forests are most often threats to species of the herbaceous layer (Jolls 2003). Understory plants also influence the establishment and development of tree seedlings thus affecting successional patterns of forests. Carbon cycling, energy flow and nutrient cycling are influenced by understory vegetation at levels that exceed their relative contribution of biomass to forests (Gilliam 2007).

Some information is known about forest dependent plant species of conservation concern (FDPSCC) which require specific habitats. For example, many of the plant species associated with forested floodplains may be of concern because of historical loss of this habitat in North America (Knutson and Klaas 1998) and in Nova Scotia (David and Browne 1996). Construction of dykes, dams, levees and agricultural development have eliminated many floodplains or significantly altered the physical and ecological structure of others (Freeman et al. 2003). Similarly, gypsum habitats have been mined and altered by human activity to the extent that they are rated as one of the most threatened ecosystems in the world (Gomez Campo 1987; Belnap et al. 2001; Mota et al. 2003) endangering many of the associated FDPSCC. Wetland obligates such as Southern Twayblade (*Neottia bifolia*), have been impacted by activities affecting wetlands such as infilling and adjacent development which alters hydrology (Hill et al. 2018).

There are still many plant species of conservation concern that are not obligates of the above-mentioned habitats and for which even less study has been done. During our initial study (2018), we found 36 species of forest plants were ranked S2 or S3 in NS (unpublished data). There may be some indication that some plant species are of concern because of the loss of older age classes in our forests due to logging (Moola and Vasseur 2004, D'Amato et al. 2016). Losses of FDPSCC have also been observed because of recreational development in parks and protected areas in NS (Cameron pers. comm.). During the first year of our study (2018) we found the mean density of FDPSCC in wilderness areas with high human impact was lower than for more pristine wilderness areas (t-test, p=0.057). These data suggest human activities likely affect FDPSCC.

There have recently been new initiatives in NS aimed at conserving forest biodiversity. These include ecosystem based management on crown land (Stewart and Neily 2006), Parks and Protected Areas Plan (Nova Scotia Government 2013), increased private land conservation with land trusts, and forest certification such as Forest Stewardship Council on private lands (e.g. Cape Breton Private Land Partnership). While these initiatives are laudable, there have been little work to determine how effective they are at conserving biodiversity.

Most studies of forest plants have focused on community or stand scale analysis and this is particularly the case for NS. However, studies from elsewhere, indicate landscape pattern of human activity can affect plants (Lavorel 1999). Human impact on landscapes has been shown for lichen in NS (Cameron et al. 2013). Other studies on plants from elsewhere, indicate fragmentation may affect plant survival (Malanson and Cairns 1997, Honnay et al. 2002, Freckleton and Watkinson 2002).

This study aimed to assess management effectiveness under differing management regimes at different spatial scales (landscape and stand scale) and determine environmental variables (e.g. soil, topography, hydrology) and management variables (e.g. management, distance to disturbance) that are important for a select number of FDPSCC to determine:

1. Are there specific areas of the province or certain landscapes that are of greater concern e.g. rich tolerant hardwood forest?
2. How well are these different management regimes doing in terms of conserving forest dependent species of concern?
3. What factors are important in explaining population density?
4. What management activities affect (positively or negatively) population density?

The following provides a summary of methods, some initial analyses and preliminary conclusions. Analyses of the data is ongoing and we expect to get several scientific publications from our results. A summary of expected publications is listed in the **Expected Publications** section and more detailed methods and conclusions can be found in these future publications.

Methods:

Assessing Existing Data for Human Impacts (Year: 2018)

Densities of plant species of conservation concern that occurred in forests were extracted from Cameron (2018). These data were collected systematically on 455 km of transect and 531 plots collected over 16 years. To determine if there were consistent environmental variables for FDPSCC, these density data were then compared across environmental data collected on site which included forest development stage (regenerating, stem exclusion, stand re-initiation, old growth), soil drainage, topographic position, aspect, elevation. To assess human impacts at the landscape scale FDPSCC densities were compared between landscapes with high scale human impact indices against landscapes with low human impact. Human impact was assessed using four criteria: 1. Fragmentation of the surrounding landscape; 2. edge effects of adjacent land; 3. human activity and accessibility to the protected area; and 4. Disturbance history – whether the area has been harvested for timber in the past, mined, settled or farmed (Cameron 2016).

Selecting Species for Field Study (2019)

To select the rare forest plant target species for field study, we choose all species with a S-rank between S2 and S3 from AC CDC NS vascular plant list. Those species ranked S1 were not included in this project because they are extremely rare and would require a much more intensive field study to meet the objectives of this project. Further, S1 species are also more likely to be listed as SAR and therefore have more associated research to produce status reports or management plans which are required under the Federal Species at Risk Act and Nova Scotia Endangered Species Act.

The S2-S3 species that were ranked as facultative upland or obligate upland under the Nova Scotia Wetland Indicator Plant List (Blaney 2011) were then selected. Next, these species were given habitat descriptions based on Nova Scotia Plants (Zinck 1998), Flora of North America (2019), and the New England Wildflower Society (2019). Finally, each species was examined and ranked according to how well their habitat matched an upland closed canopy forested environment.

Field Survey and Data Collection

Target species locations for field sampling were obtained from AC CDC. These sites were visited during the 2019 field season and surveyed to determine if any of the rare target plants still occurred. If the target species were present, 20x20 m quadrats were established. The 400 m^2 plot was large enough to capture the majority of plant species in the forest community as well as maximize rare species detections (Cameron 2019). The number of quadrats placed at each sampling site was based on having one quadrat for every vegetation type, as defined by Nova Scotia's Forest Ecosystem Classification (FEC) Guide (Neily et al. 2011), in which the studied species occurred at that site. The quadrat was placed randomly within each vegetation type using a random direction and distance table.

Site environmental measurements (site aspect, slope, elevation, topographic position, soil drainage, and relative soil moisture), percent cover of all plant species, by methods as described by Cameron (2009), target species counts, and a complete NS FEC, including vegetation, soil and ecosite classification as described by Neily et al. (2011) were done for each quadrat. The counts of the target species in the randomly placed quadrats was used to calculate the species density at each sampling site. The area in which each target species occurred was measured using a handheld GPS and total area (M^2) of occupancy was calculated. Distance to the nearest forest edge was measured using a GPS and type of edge recorded (e.g. road, clearcut, trail). Simple linear regression was used to assess any relationship between total area of cover of *Hepatica nobilis* and *Goodyera pubecsens* and distance to nearest edge.

Control sites (n = 15) were established by randomly selecting locations within upland forest within the same Natural Landscapes in which the target species occurred. The 400 m^2 quadrats were established at each control sites and environmental variables recorded as with target species quadrats.

To assess potential landscape scale impacts, a 500 m radius circle was placed around each study site in Geographical Information System (GIS). Human Foot Print (2Countries1Forest 2000) and Normalized Difference Vegetation Index (NDVI) (Copernicus Service Information 2020) were extracted and regression analyses done using total area of occurrence for *H. nobilis* and *G. pubecsens* as the dependent variable. *Goodyera pubescens* presence was also analyzed in a logistic regression to determine whether NS Road Network density and density of forest clearcut area as identified in satellite imagery by White et al. (2011) within the 500 m radius had an influence on presence. Other species were not tested due to lack of time, however this will be done by year end.

To assess human management, we compared the occurrences and density of *G. pubescens* and *H. nobilis* in protected areas versus the working forest. *Goodyera pubescens* presence was also analyzed in a logistic regression to determine whether management type (protected vs not protected) had an influence on presence. Other species were not tested this way due to lack of time but this will be done by year end.

Habitat Modeling

Habitat models were created for *G. pubescens* and *H. nobilis* to predict where these species are likely to occur and to help determine what habitat features are important in explaining their presence. Habitat models were created using maximum entropy analysis with MaxEnt software. Explanatory variables included forest cover data comprising stand tree height, crown cover, covertype (softwood, mixedwood, hardwood), and soil drainage and texture acquired from Ecological Land Classification (ELC) of the Department of Lands and Forestry. Models were created using all combinations of explanatory variables and final models based on which had the greatest Area Under the Curve (AUC) score. The MaxEnt output includes jackknife plots for the AUC, test gain, and training gain and response curve plots for each of the variables included in the model. The jackknife plots show the relative contribution to the performance of the model at each of the test and training sites, as well as to the overall model performance. The response curves show how the habitat suitability values change with the values of the variables, e.g. as tree height increases the habitat suitability. The MaxEnt output for each species and the parks and protected areas layer were examined in ArcGIS to determine the quantity of suitable habitat contained in the existing protected areas network.

Plant Functional Group Analyses

Issues of detectability and analyses of rare species are common and several ways to deal with these issues have been proposed. Nichols et al. (2000) suggested one approach for bird species is to group *a priori* different species with a similar predicted variation in detection probability (e.g. easy or difficult to detect). This approach can be tested *a posteriori*. In order for this approach to have some biological meaning, it may be necessary to additionally group species with similar population dynamics (Mackenzie et al. 2005) and habitat requirements (Cameron 2019).

One way to group plants is by plant functional group (PFG). Classifying plants based on function rather than phylogeny is particularly useful because they have strong predictive power of ecosystem responses to environmental change (Vergeyen et al. 2003). We classified 13 species of rare (S2 or S3 rank) plants by PFG based on international criteria (Cornelissen et al. 2003).

PFG 1 was the Upland Forest Orchids which form the functional group shade-tolerant early-life stage myco-heterotrophs (Table 1). These orchids have a complex life cycle with early-life stage dependent on specific fungal species (Nikishina et al. 2007).

Table 1 List of plant species in Plant Functional Group 1 (PFG1), which consists of the shade-tolerant early-life stage myco-heterotrophs.

Species
Goodyera oblongifolia
Goodyera pubescens
Goodyera repens
Platanthera hookeri
Platanthera huronensis
Platanthera macrophylla
Platanthera orbiculata

PFG 2 was the upland forest sedges which form the functional group shade tolerant rhizomatous monocots (Table 2). This PFG includes sedges which inhabit forests and tolerate shade or partial shade and form dense mats of rhizomes.

Table 2 Plant species in Plant Functional Group 2 (PFG2), which consists of the shade tolerant rhizomatous monocots.

Species
Carex adusta
Carex argyrantha
Carex hirtifolia
Carex rosea
Carex tenera

PFG 3 was the upland forest herbs which form the functional group shade tolerant geophytes and consist of only one species, *Pyrola minor*. Geophytes are species which store energy below ground usually in a large bulbous root.

Records for each species were extracted from the AC CDC database and grouped according to PFG. Presence of the 3 PFG were used as the part of the response variable in the statistical analyses. Three hundred and forty-four PFG 1, one hundred and sixty-four PFG 2 and thirty-nine occurrences were extracted from the database. In order to obtain absence data for logistic regression testing, we used permanent sample plots (PSP) from Department of Lands and Forestry. These plots are randomly placed within the forest landscape of NS and represent a random sample of the variety of environmental conditions. Although not a true absence data they serve as a proxy representing the variation found in the forest of Nova Scotia (Wisz & Guisan 2009).

Protected versus working forest was used as an independent variable in logistic regression analyses for the three PFG to determine if management regime affects probability of presence of a member of each PFG. Density of roads and trails from Nova Scotia Road Network (2016) and density of forest clearcut area as identified in satellite imagery by White et al. (2011) were used as explanatory variables in a second set of logistic regression analyses.

Results

Assessing Existing Data for Human Impacts (Year 2018)

Transect data detected 53 plant species of conservation concern, 37 of which were found in forests. Fourteen forest plant species had high enough densities to calculate confidence intervals. FDPSCC occurred more often on rich sites than poor sites (p=0.01) and while FDPSCC were found in second growth forest stands, they were found more often in mature or old growth forests although this difference was not statistically significant. Eleven species showed the most promise for potential study, occurring in well drained forests at high enough abundance levels for statistical analyses. The mean density of FDPSCC in wilderness areas with high human impact was significantly lower (0.106 individuals/km) than for more pristine wilderness areas (1.820 individuals/km) (t-test p=0.057), suggesting human impact on density at the landscape scale.

Selecting Species for Field Study (Year 2019)

The highest ranked species for this project were *H. nobilis* (Round-lobed Hepatica), *Carex rosea* (Rosy Sedge), *Conopholis americana* (American Cancer-root), *Goodyera oblongifolia* (Menzies' Rattlesnake-plantain), and *Goodyera pubescens* (Downy Rattlesnake-Plantain), *Platanthera hookeri* (Hooker's Orchid), and *Platanthera macrophylla* (Large Round-leaved Orchid). Due to the time constraints of only having a single sampling season, the following species were the focus of field sampling *H. nobilis, Conopholis americana, and Goodyera pubescens*.

Field Data

Fifteen sites with *H. nobilis* were located and studied. *Hepatica nobilis* occurred more often on southeast and southwest facing slopes. All of the sites with this species have a moderate slope (15 – 30 degrees), with the largest occurrence of sites having a slope of 20 and 25 degrees. There was a large distribution of site elevation although most sites were below 200 m asl. *Hepatica nobilis* occurred more often on well to rapidly drained soils with fresh soil moisture and most often on crests and mid-slope positions. Development stages of sites ranged from early to late and stem exclusion to re-initiation.

Fourteen sites with *Conopholis americana* were located and studied. *Conopholis americana* occurred most often on northeast and south facing slopes with moderate degree of slope. This species did not occur on steep slopes or flats. There is a large distribution of site elevations although most sites were below an elevation of 200 m. The greatest majority of sites were on middle slopes and were well drained. Soils at *Conopholis americana* sites were fresh but a few were dry. Seventy-nine percent of sites were in early to mid-successional in stem exclusion stage.

Fifteen sites with *Goodyera pubescens* were located and studied. *Goodyera pubescens* occurred most often on north and northeast facing slopes with varying degree of steepness. There was a large distribution of site elevations although most sites were below an elevation of 200 m. *Goodyera pubescens* occurred on a range of slope positions with well to rapid soil drainage. Soils were mostly fresh but ranged from moist to very dry. Sixty-seven percent of sites were in late successional forest in re-initiation or old stages and this distribution was found to be significantly different than found in provincial forests as a whole ($p=0.01$).

Regression analyses showed no significant relationship between field studied species and distance to nearest edge, Human Foot Print or NDVI. *Goodyera pubescens* occurred more frequently in protected areas than working forest and *H. nobilis* occurred more frequently in working forest than protected area although the differences were not significant. There was no significant difference in density for either species between management type.

Goodyera pubescens presence was not significantly correlated with management type but was significantly negatively correlated with road density ($p<0.001$) and clearcut density ($p<0.001$).

Habitat Models

The *G. pubescens* final habitat model had an AUC of 0.8 (Figure 1). Tree canopy height was the most important variable but tree cover type and crown closure also contributed to identifying suitable habitat. The *H. nobilis* final habitat model had an AUC of 0.7 (Figure 2). Slope was the most important variable, but tree cover type and tree height also contributed to the final model.

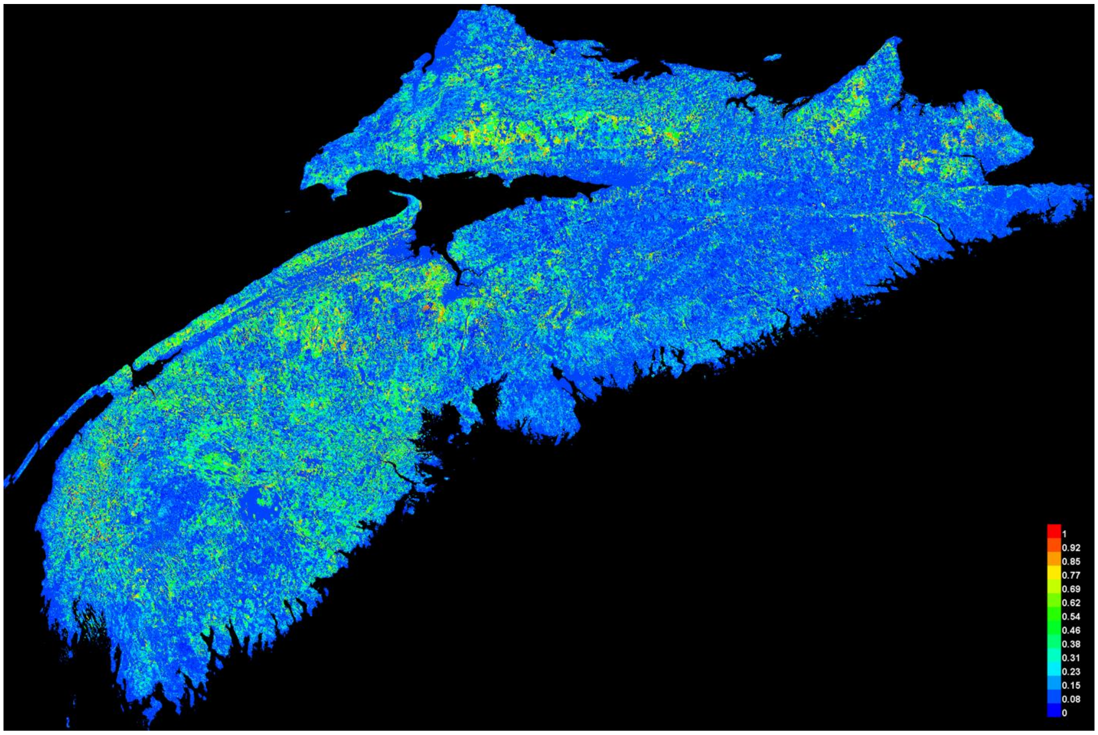

Figure 1 Average MaxEnt habitat model for Goodyera pubescens. Areas in warmer colours indicate higher probability of habitat suitability, areas in blue indicate lower probability

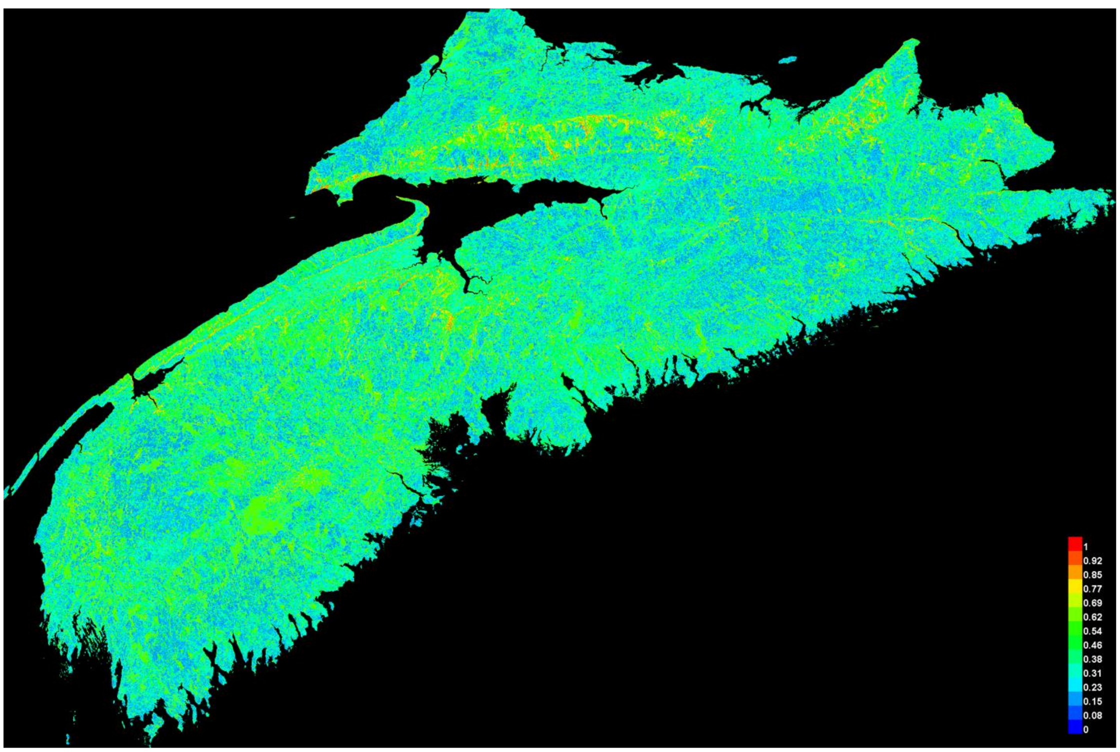

Figure 2 Average MaxEnt habitat model for H. nobilis. Areas in warmer colours indicate higher probability of habitat suitability, areas in blue indicate lower probability

There was a total of 3639 km2 of greater than average quality *G. pubescens* habitat in mainland Nova Scotia and 15% of that was already contained in protected areas. Area of greater than average quality *H. nobilis* habitat covered 8648 km2 and 13% of this habitat was already contained in protected areas.

Plant Functional Groups

All three PFG had significantly higher probability of occurring in protected areas than working forest (PFG3 $p<0.0001$, n=1150; PFG2 $p<0.0001$, n=1275; PFG1 $p<0.001$, n=1455). All three PFG had significantly lower probability of occurring with higher road density and for clearcut harvest area density within 500 m (Table 3).

Table 3. Results of logistic regression analyses with three Plant Functional Groups (PFG) presence as dependent variable and road density and clearcut density as explanatory variables.

	PsuedoR^2	P	AUC	Predicted %Correct
PFG1	0.453	<0.001	0.789	76.43
PFG2	0.273	<0.001	0.782	83.85
PFG3	0.238	<0.001	0.834	96.70

Discussion

The low sample size from the field studies makes it difficult to draw conclusions for individual species. These results are typical of work with rare species (Mackenzie et al. 2005), but underscores the need for further research. Little research has been done on the target species specifically. Some community research has been done which has included some of these species (e.g. Reddoch and Reddoch 2007, Falk et al. 2008). The present study will lay the ground work for further research providing a framework upon which to build. As new locations for these species are found, further in depth work can be done.

Several conditions limited the extent of field work. Hurricane damage to forests closed Kejimkujik National Park back country and prevented field sampling in some remote locations for the target species. A second field season in Kejimkujik Park and other locations could significantly increase sample size.

The most significant trend for individual species is for *G. pubescens* and *H. nobilis,* both of which were found more often in later successional stages (stand re-initiation, old growth) and older maturity classes of forest (mature to old) although this trend was not statistically significant for *H. nobilis*. Other researchers have suggested *Goodyera* species as occurring in older mature forests (Olivero and Hix 1998, Harper et al. 2003). From a conservation perspective, this underscores the need to maintain older forests in the landscape which have significantly declined in the Maritimes (Mossler et al. 2003).

Habitat modeling also indicates habitat variables that are important to these species and can give insights to environmental factors that need management attention. *Goodyera pubescens* modeling indicates softwood forest with high crown cover with tall trees is important. For *Hepatica nobilis*, well drained flat ground with tall deciduous trees is important. The height of the trees for both species may be a reflection of the affinity for older forest. The need for high crown cover for *Goodyera pubecsens* habitat could reflect a sensitivity to micro-climate or light changes and thus adjacent clearcut harvests or selective harvests could impact this species.

Habitat modeling may help further research and provide areas for targeting conservation. The models for both *Goodyera pubescens* and *H. nobilis* indicate there may be more unsurveyed habitat in the landscape. These modeled habitats are ideal places to search for new locations of these species, potentially providing more areas to target for conservation and greater sample sites for further research.

Habitat models for both species indicate habitat protection is close to the amount of protected area in the province, 12.4%. For *G. pubescens*, 15% of the greater than average habitat suitability values and for *H. nobilis*, 13% of that was located in existing protected areas. It is unknown how much habitat is needed to ensure conservation of these rare species. However, for a species of conservation concern it is ideal to protect more habitat than the amount for species not of conservation concern (Deguise and Kerr 2006). No special practices for forestry, road construction or other human developments are in place for these rare species.

PFG analyses may reveal trends in groups of species that were not evident in the low sample sized individual species analyses. Generally, trends suggest that rare FDPCC may be impacted by human disturbance on the landscape. All three PFG were more likely to occur in protected areas than forest managed for other purposes. All PFG were also more likely to occur in landscapes with lower road density and lower density of clearcutting. There are groups of plants and lichens that are associated with older forests (e.g. bryophytes, lichens McMullin et al 2008, Selva 2002) and landscapes with more clearcuts are less likely to have older forests. These PFG trends could also be related to level of human disturbance. For example, roads can channelize water and change local hydrology and soil conditions, potentially affecting plants sensitive to soil hydrologic changes (e.g. Hill et al.2018). Clearcutting creates more openings increasing solar radiation and drying winds, thus increasing temperature in adjacent forests (Spies and Turner 2000). Plants sensitive to micro-climate could be affected by adjacent clearcutting.

PFG analyses is preliminary and some caution is needed in interpreting these results. Few studies have been done using PFG particularly in Eastern North America. However, this type of analysis shows some promise for studying groups of rare species. Examining function that groups of plants play in ecosystems may indicate how human disturbance may be impacting ecosystems (Cornelissen et al. 2003). For example, shade-tolerant early-life stage myco-heterotrophs (PFG1) have a complex reproductive ecology that require the convergence of particular species of fungi and insects at the right life stage for the plant (Nikishina et al. 2007). It is possible that human disturbance may affect this important confluence of species rather than habitat changes per se. Thus it is possible that human disturbance is affecting ecosystem function. Shade tolerant geophytes require long periods of little disturbance to establish a well-developed energy rich root systems which allows them to be tolerant to disturbance later in their life stage (Sobey and Barkhouse 1977, Bierzychudek 1982). Disturbance of forests at early life stages could affect their ability to survive.

Although further research is needed, ongoing analyses will continue to help address the questions around conservation of FDPSCC. For example, we are going to prepare a habitat model for *Conopholis americana*, which will help identify key habitat features for this species. Principle component analysis of the environmental features will also help identify key habitat features of all target species. Non-metric multidimensional scaling will help identify if the target species are faithful to particular plant communities. We expect to finish these analyses by July 2020 with final reports and papers by fall 2020.

Further research should focus on finding new locations for these target species. This will help increase sample size and better strengthen analyses. Our habitat models will be helpful in identifying potential new locations for these species. Research on PFG shows promise for increasing sample size of study groups but also has the potential to increase understanding in how human impacts may affect ecosystem processes and function. Stand scale research on PFG is one avenue worth further pursuit.

Initial Recommendations for Land Managers

1. Maintain older age forest in the landscape. Ideally, identifying a proportion or amount of old forest that is needed in the landscape to maintain these plant species would be useful. However, we are unable at this point in the research to suggest an amount of old growth. As we undertake further analyses, we may be able to provide an indication of an ideal area of old growth needed to ensure presence of FDPSCC. Our data does support the Lands and Forestry Old Forest Policy of providing at least 8% old forest in the landscape;
2. For sites with FDPSCC or with suitable habitat, reduce human impact by having less clearcutting and less road construction or other human disturbance within the landscape (within a 500 m radius). Our preliminary analysis suggests that any more than 30% of the landscape in clearcut or more than 100 m of road construction in every 80 ha of landscape significantly reduces the probability of presence of FDPSCC;
3. Increase the area of habitat for FDPSCC within protected areas, we suggest at least to 30% of predicted habitat.

We recognize that these recommendations are preliminary and need further investigation. However, given the unprecedented decline in species of conservation concern, we suggest a precautionary approach is needed for FDPSCC.

Publications Expected from this Project

Publication Title	Lead Author	Date Expected
• MSc Thesis Rare Forest Dependent Plant Species of Conservation Concern	Chad Simmons	July, 2020
• Honours Thesis The role of protected areas in the conservation of two rare Acadian Forest plants	Lucy Burns	May, 2020

• Honours Thesis Investigating population size of two rare Nova Scotia forest plants, *Goodyera pubescens* and *Hepatica nobilis*, in relation to human disturbance	Jean Hodgson	May, 2020
• Habitat Ecology of *Goodyera Pubescens*	Chad Simmons	Fall 2020
• Habitat Ecology of *Hepatica nobilis*	Chad Simmons	Fall 2020
• Habitat Ecology of *Conopholis americana*	Chad Simmons	Fall 2020
• Rare Forest Plant Functional Groups Sensitivity to Human Disturbance	Robert Cameron	Fall 2020

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