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TWENTY YEARS OF ECOLOGICAL RESEARCH IN NOVA SCOTIA WILDERNESS AREAS AND NATURE RESERVES: A REVIEW OF STUDIES, 2002 TO 2022

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ABSTRACT

The following paper is a review of the research undertaken over the last twenty years in Wilderness Areas and Nature Reserves in Nova Scotia. A brief summary is presented of the main findings of each research project conducted by the author or contributed to by the author in a significant way. Inventories have included eleven bioblitzes and over four thousand plots from systematic transects. These have revealed significant new records for species including those of conservation concern. Results suggest there are many species than have not been identified in protected areas. Geographical Information System (GIS) Ecological Land Classification was completed for Nova Scotia and this led to ecosystem gap analysis to determine ecosystems that are not well represented in the current protected areas system. Long-term monitoring, using biodiversity transects and lichens, indicates that air quality is good throughout the protected areas system. Forests are returning to a more climax condition and with the exception of a few instances, non-native plants are generally not problematic. Carbon modeling of protected areas suggests that they will be a carbon sink for the next one hundred years and would be a carbon source if managed for forestry. Protected areas are well suited to provide ideal optimal settings in which climate change adaptation and mitigation can take place. Planning for climate change within protected areas can be facilitated by a Climate Change Adaptation Framework.

Research on species of special concern in protected areas has included turtles, Mainland Moose, Canada Lynx, America Marten, Lichens, Atlantic Coastal Plain Flora, forest plants and Piping Plover. Research on rare, sensitive, vulnerable ecosystems has involved predictive modeling and identification and characterization of heathlands, forest wetlands and Jack pine woodlands. Old Growth Forest research has included predictive modeling, biological inventories, dendrochronology studies and scoring using indicators. Human activities adjacent to protected areas can cause deleterious edge effects. An ongoing study in the Cloud Lake Wilderness Area is measuring the effect of adjacent forestry on birds and plants within

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the Wilderness Area. Several studies on connectivity have looked at the increase in connectivity caused by the establishment of protected areas in Nova Scotia. Other efforts on connectivity have identified key nodes of connectivity within the province which require protection. Human use of protected areas can lead to damage of ecosystems and so investigations on human use of protected areas has been focussed on motorized vehicles and to a lesser extent on human foot traffic. Although there have been many ecological studies in protected areas over the last twenty years, it is evident that there still is a great deal that is unknown about the biodiversity of protected areas.

INTRODUCTION

Understanding what needs protection and how it can be accomplished in order to conserve biodiversity is a key element in conservation planning. Research is vital in order to ensure that ecological integrity is maintained in the management of protected areas. Potential human-caused stresses to protected areas need to be identified and how these stresses may affect ecosystems needs to be determined. Protected areas are also ideal sites for research because they can provide benchmarks against which human altered landscapes can be compared. Protected areas represent more natural functioning systems and thus provide the best opportunity for studying changes occurring in natural areas.

In the early 2000s, Protected Areas and Ecosystems Branch (PAE) of Nova Scotia Environment, began a concerted effort to increase research in Wilderness Areas and Nature Reserves (Cameron 2010a). At the time, very little was known about the biodiversity within protected areas, how well protected areas were conserving species and ecosystems, or how they contributed to conservation in Nova Scotia and Canada. Increased research efforts were implemented by encouraging and developing partnerships with other research organizations and individuals. Partnerships included contributions from PAE in the form of ideas, staff time, finances and in-kind support. In addition to partnerships, PAE began its own in-house research. Systematic biodiversity surveys were conducted in protected areas, as well as projects examining specific questions such as how much edge effect occurs with adjacent human activity.

This paper does not describe all research that has taken place within Wilderness Areas or Nature Reserves by all researchers as much of this is already in published literature, and some is cited in this paper. Rather, the research reviewed here documents studies conducted in Nature Reserves and Wilderness Areas of Nova Scotia that comprise the largest total area of any type of protected area in the province. These are mostly terrestrial environments but do include some aquatic ecosystems, wetlands and marine tidal areas. Other designations of protection such as provincial and national parks are not reviewed.

Each study documented in this paper has its own specific aim or objective. Each helps to contribute to a greater understanding of the ecology, biodiversity and human use and impacts in protected areas. How each study contributes to this greater understanding and knowledge is outlined. This paper is divided into twelve general topic areas which include a number of sometimes unrelated studies. Some studies have overlap between general topic headings and thus some studies will be described more than once.

INVENTORY

Transects

In 2002, Protected Areas and Ecosystems (PAE) began a systematic survey of biodiversity in existing and proposed protected areas (NS Environment 2016). The survey consisted of transects that traversed the variety of ecosystems and included plant community quadrats in each new plant community encountered on the transects. Birds, observed or heard, were recorded as well as any species of other taxa that were of known conservation concern. The methodology enabled calculation of density and population estimates and this was done for species of conservation concern by Cameron (2019). In total, 437 plant abundance and community documentation plots were established, 413 km of transect were traversed, with 4130 presence plots established in 90 existing and proposed Wilderness Areas and Nature Reserves (Cameron 2021).

A number of indices of biodiversity can be calculated using transect data, and these have been summarized by Cameron (2020b). The data and indices have enabled a better assessment of biodiversity captured by protected areas in NS. Cameron (2019) assessed the fine filter – coarse filter approach used by PAE. The fine filter used by PAE consists of capturing habitat, occurrences or potential habitat for rare or at risk species and ecosystems. Coarse filter approach involves capturing the variety of ecosystems with the expectation that the majority of species will be captured (Cameron and Williams 2011). Cameron (2019) found that protected areas aimed at capturing the variety of ecosystems did not tend to capture rarer species that are often of conservation concern. Inclusion of a fine filter approach in conservation planning was needed to capture these rarer species. Cameron (2021) also found that for some species of conservation concern, declines in the broader landscape may not be occurring in protected areas in Nova Scotia. Similar trends are found elsewhere in the world (Geldman *et al.* 2013), suggesting that human impacts on species of conservation concern may be less in protected areas.

Transect data were also used to assess potential impacts of non-native species. Non-native species can become invasive, dominating or changing ecosystems and communities and thus eliminating or degrading habitat for native species (Jeschke *et al.* 2014). Cameron (2021) found nineteen species of non-native plants and no non-native species of birds in protected areas. Most frequently found non-native plants were red raspberry (*Rubus ideaeus* subsp. *strigosa*) and creeping buttercup (*Rannuculus repens*), although mean cover (percent coverage of plot) was low in all sites. Meadow fescue (*Fescue pratensis*) and Japanese knotweed (*Reynoutria japonica*) had the highest mean cover, but each occurred at only one site. Generally, Cameron (2021) found that non-native plants were confined to road sides, ditches and trails and very few species were found in interior habitats. The one exception was floodplains, which Cameron suggested needed a special effort to ensure that ecological integrity was maintained.

Ecosystem richness (number of different ecosystems) has been calculated for protected areas using transect data. In addition, identification of special, rare and unique habitats has been possible using the transect data. Some of these are described by Cameron and MacKinnon (2008), Cameron (2008) and Cameron and Bondrup-Nielsen (2013). These will be further explored later in this paper (see section on Rare, Sensitive, Vulnerable Ecosystems).

Plant and bird species richness has been calculated for protected areas (Cameron 2021), allowing for comparisons between protected areas, ecosystems and Natural Landscapes (ecological land classification system used by NS Environment and Climate Change). Plant and bird data have also been used to assess the effectiveness of protected areas in capturing biodiversity in Nova Scotia. Cameron (2021) used the Species Area Relationship (SAR), following methods of Desmet and Cowling (2004) to calculate the number of plant and bird species expected to occur in each Natural Landscape. Results indicate that there are considerable differences in the expected number of species between Landscapes (Fig 1). Some trends in species richness are apparent. For example, there is high species richness in Landscapes with high productivity or structural complexity, such as LaHave Drumlins, Shubenacadie Rolling Hills and the Cobequid Hills. Equally clear is the low species richness in Landscapes with low productivity, such as the Shelburne Barrens or Canso Coastal Barrens. Less clear are trends of low species richness in Landscapes with high productivity such as Chignecto Slopes or Landscapes with high structural complexity, such as in Cape Breton Highlands region. Some of these less obvious trends could be an artifact of low sample size. Other trends are likely related to the small area of the Landscape such as found in the numerous and small Cape Breton Highland Landscapes. It was also found that Landscapes with high plant species richness did not necessarily have high bird species richness. An assumption of this approach is a log-linear relationship between area and number of species (Fig 2). This assumption has been tested frequently

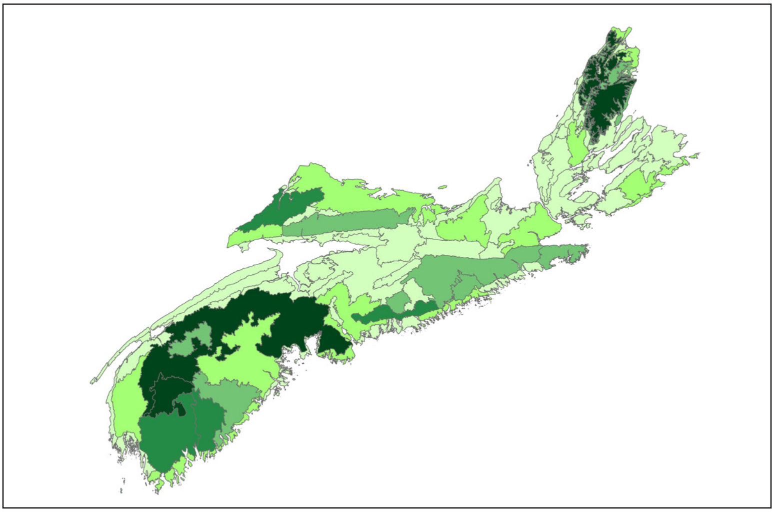

Fig 1 **Relative richness of plant species (z score) by Natural Landscape. Lighter green shade indicates greater plant species richness.**

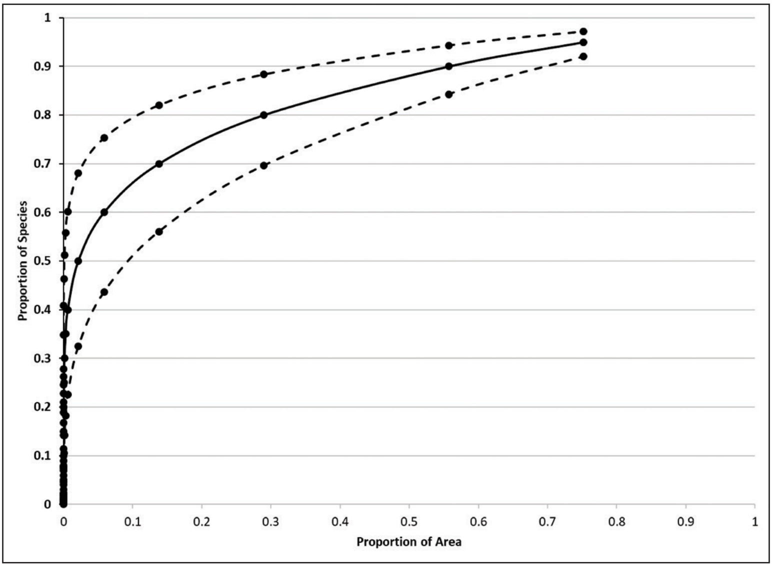

Fig 2 SAR curves using lowest, highest and mean z values for plant species in Natural Landscapes in Nova Scotia.

and has held true for multiple different taxa and multiple different scales (Lomolino 2001, Haila 2002). This assumption, when used in conservation science, has several important implications. The most significant implication is that as protected areas are established, initially the number of species captured increases very rapidly as a function of the size of the area and then levels off quickly. There is a point at which increases in the area under protection results in progressively smaller increases in the number of species captured. Finding this leveling–off point is valuable for determining the most efficient total amount of area of the overall system to protect to capture the most species (Desmet and Cowling 2004).

Herbarium Collections

In 2007, PAE entered an agreement with the E.C. Smith Herbarium, Acadia University, to house voucher samples of plants documented in the transect surveys. This arrangement provided a protected areas reference collection that can be examined by future researchers. Further contributions to this collection were made in partnership with the Harrison Lewis Centre and Acadia University, K.C. Irving Environmental Science Centre. Two students from the

Harrison Lewis Centre and a technician from Acadia University surveyed and collected plant specimens from the Port L'Hebert Nature Reserve in 2016. Collections were further augmented with the collection of marine algae in the adjoining shoreline with guidance from Dr. David Garbary of St. Francis Xavier University. About 250 specimens are now housed in the herbarium.

Bioblitz

Protected Areas has participated in eleven bioblitz events, five of which were led and organized by PAE and in four of which PAE was part of a larger organizing committee. The term "bioblitz" was first used during an event held at the Kenilworth Aquatic Gardens in Washington, DC, in 1996 (Shorthouse 2010). Over time, bioblitzes have become a useful tool for scientists to rapidly assess the biodiversity of protected areas, establish new species records for an area, and at times identify new species.

The first bioblitz involving PAE was in conjunction with the Biology Department of St. Francis Xavier University. This was the first multi-disciplinary bioblitz in Nova Scotia and was held at Canso Coastal Barrens Wilderness Area. Ten scientists and students conducted an inventory of a variety of species groups over a single day (Garbary *et al*. 2006). Since then, multi and single day events have occurred in six Wilderness Areas and one Nature Reserve.

Since bioblitzes have focussed on documenting the species present, the most significant results are in new records of species or new locations for species of conservation concern. In terms of new species records, the most noteworthy find was a previously undescribed species of fungus, *Trifoliellum bioblitzii*, discovered in 2009 during a bioblitz of the Blue Mountain-Birch Cove Lakes Wilderness Area by Strongman and White (2011).

One of the most extensive and comprehensive bioblitzes in Nova Scotia occurred on Scatarie Island Wilderness Area where PAE invited 15 scientists and students to conduct inventories on the island in August, 2005. Surveys took place over three days and included vascular plants, birds, beetles, fish and aquatic invertebrates. Organizations taking part included Cape Breton University, St Frances Xavier University, NS Environment and NS Department of Natural Resources (Williams and Cameron 2010). Many new records of species were found. For example, ninety-four species of Coleoptera were newly recorded for Scatarie Island. Seventeen of these species were recorded for the first time for Cape Breton Island and five were new records for Nova Scotia (Majka *et al*. 2010). The lichen list included five new records for Cape Breton and three new records for Nova Scotia (Cameron *et al*. 2010a). Vascular plant surveys included 15 species new for the Island (Ferrier *et al*. 2010) and 22 species of marine invertebrates not previously recorded for the island (White *et al*. 2010). Similar new records were found in other bioblitzes such as for Lake Rossignol Wilderness Area where 285 of the 294 species documented were new records for the protected area (Anderson *et al*. 2012). The discovery of 12 new species of conservation concern in the Lake Rossignol Wilderness Area was also of note. Findings from nine other bioblitzes in Ship Harbour Long Lake, Tangier Grand Lake, Blue Mountain Birch Cove Lakes, Pollet's Cove Aspy Fault Wilderness Areas and Abraham's Lake Nature Reserve were not published but lists of occurrences are deposited in the PAE database and voucher specimens in various museums. The large numbers of new species-occurrence records for protected areas reflect the limited state of knowledge of biodiversity in protected areas and within the province as a whole.

Transect surveys provide a systematic survey of elements of biodiversity which enable the calculation of densities and populations for temporal and spatial comparisons. This enables managers to assess whether the biodiversity was more or less than expected, determine trends, and have a general sense of which habitats, ecosystems and species are protected. However, it is clear from the results of the bioblitzes that many species are not captured in a general survey; further work is needed.

Seabird Nesting

David MacKinnon (mostly unpublished data but also in Cameron and Mackinnon (2008)) began collating and assembling existing data on seabird nesting in protected areas in the mid-2000s. MacKinnon also began his own systematic surveying of protected off-shore islands. Some of these surveys were done in partnership with various agencies including NS Natural Resources, Environment and Climate Change Canada and NS Nature Trust. Birds surveyed included cormorants, terns, eider ducks, storm petrels, gulls and puffins. Many species are of conservation concern and include Atlantic Puffin (*Fratercula arctica*), Great Cormorant (*Phalacrocorax carbo*), Arctic Tern (*Sterna paradisaea*) and Roseate Tern (*Sterna dougallii*).

These data provide a baseline against which to monitor changes over time, and aid in the planning of these protected islands.

ECOLOGICAL SYSTEM PLANNING

Ecological Land Classification

The primary purpose of Wilderness Areas and Nature Reserves in NS is to protect natural biodiversity including all the elements of genes, species and ecosystems. The scientific approach to capturing biodiversity within protected areas in NS has been largely with a coarse filter – fine filter method (Cameron 2017). The coarse filter approach has been to capture the variety of ecosystems present in each Natural Landscape. In order to provide a digital mapping tool to apply a coarse filter approach, Cameron and Williams (2011) completed a geographical information system (GIS) based ecosystem classification system (ECS) for NS Environment and Climate Change. The classification system integrated aspects of existing forest management classification system (Neily *et al.* 2017) (https://novascotia.ca/natr/forestry/ecological/ecolandclass.asp) and the national vegetation classification system (Langendeon *et al.* 2014) (http://cnvc-cnvc.ca/). Principles of landscape pattern that were incorporated into the system include: (1) hierarchy; (2) abiotic and biotic factors; (3) use of more abiotic factors at coarser spatial scales and more biotic factors at finer spatial scales; and (4) use of vegetation only at the finest scale. The ECS builds on previous work, allows for integration of existing landscape classification systems, and establishes methods that can be applied for a variety of landscape planning issues in other regions.

Cameron (2021) tested the assumptions of the ECS that abiotic and biotic factors are predictors of biodiversity distribution across the landscape. A preliminary exploratory analysis was done using a subsample of the biodiversity plot data (described above) (n=44) to test how well ECS attributes predict species richness. The biotic attribute (vegetation type) was the only significant predictor of species richness and the abiotic factors (soil drainage, soil texture, topographic pattern) were poor predictors of species richness (Cameron 2021). Abiotic factors are more enduring features compared to biotic factors and thus can form a framework to build an ECS. However, the analysis by Cameron (2020), although preliminary, does suggest the need for inclusion of biotic factors if an ECS is used to predict distribution of biodiversity on the landscape.

Gap Analysis

Using the ECS from Cameron and Williams (2011), a gap analysis was done to determine how well the variety of ecosystems were captured in existing or proposed protected areas (Cameron 2014). Representation was based on how well a particular protected ecosystem captures the expected number of species and ecosystem elements in the landscape. Representation was considered complete when 90% of the expected number of species were present in a protected ecosystem, and good when 75% to 89% of the expected number of species were present. Percentages for completeness of representation were based on a species-accumulation curve, following methods described by Desmet and Cowling (2004) and using data for Nova Scotia plant species (Cameron 2021). The result is a GIS based layer which identifies which ecosystems across the province are “complete” for protection (90%), which are “good” (75 to 90%), and which are less than complete (Fig 3). Results suggest

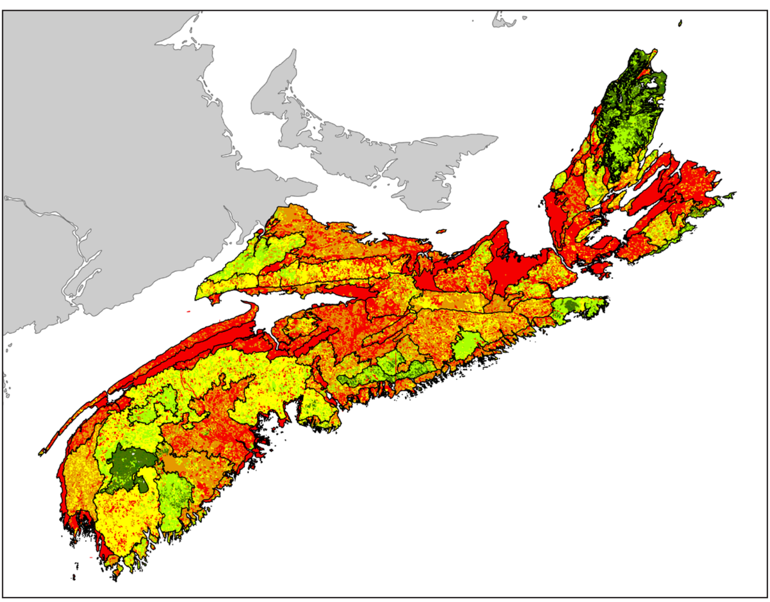

Fig 3 Gap analysis map of Nova Scotia. Redder colour indicates ecosystems with decreasing proportion within protected areas and darker green indicates increasing proportion within protected areas.

that there are large gaps in many landscapes and several landscapes have no representation in existing or pending protected areas.

Conservation Planning

The Colin Stewart Forest Forum (2009) was the most involved and extensive protected area planning process involving PAE. The Forum was established by multiple stakeholders, including forest industry, NGOs and the provincial government, in an effort to identify the most important areas for protection for the conservation of biodiversity. Cameron (2017) outlined the scientific criteria and systematic process for finding areas of highest conservation concern, which involved three main steps. Step one identified 3 types of potential areas, which involved use of remote data, including satellite imagery, aerial photographs, GIS remote data, expert input and existing field data from a variety of sources (Fig 4). Step 2 involved scoring each patch based on 5 systematic criteria. The final step involved selecting the most promising areas using decision trees (Fig 5).

National and International Standards

Increased global initiatives to help reduce biodiversity loss were sanctioned by Parties of the Convention on Biological Diversity by adoption of the Strategic Plan for Biodiversity 2011–2020 and the

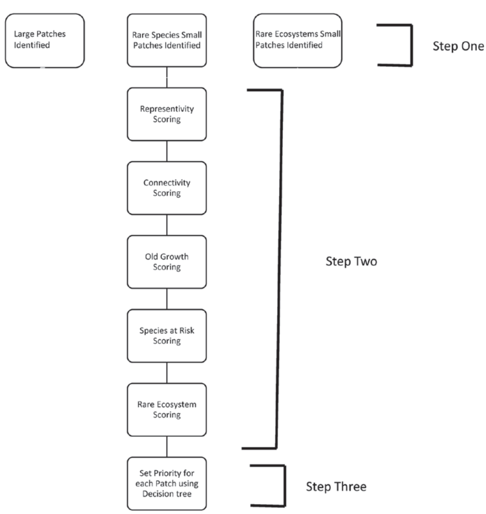

Fig 4 Process for using science to identify, score and set priorities for patches for potential protection in Nova Scotia.

A

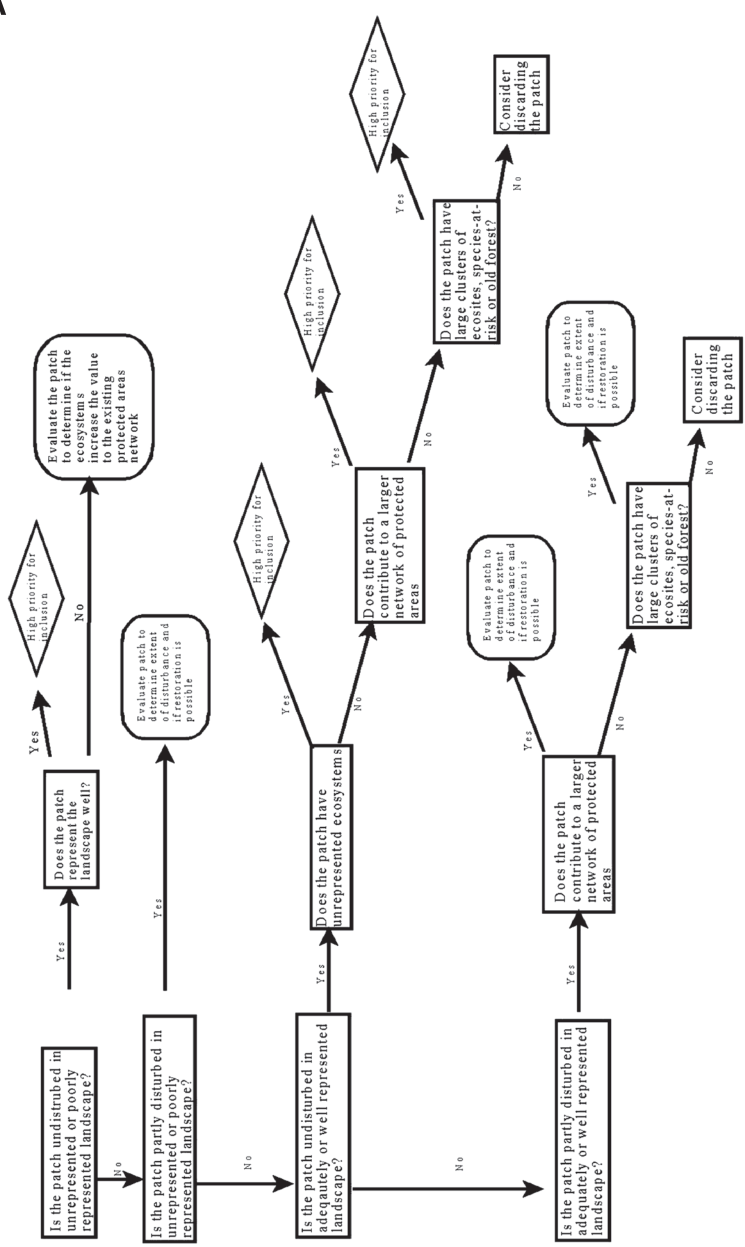

Fig 5A Decision trees used in setting priorities for protection for large patches (A – contiguous areas larger than 1000 ha) and small patches.

B

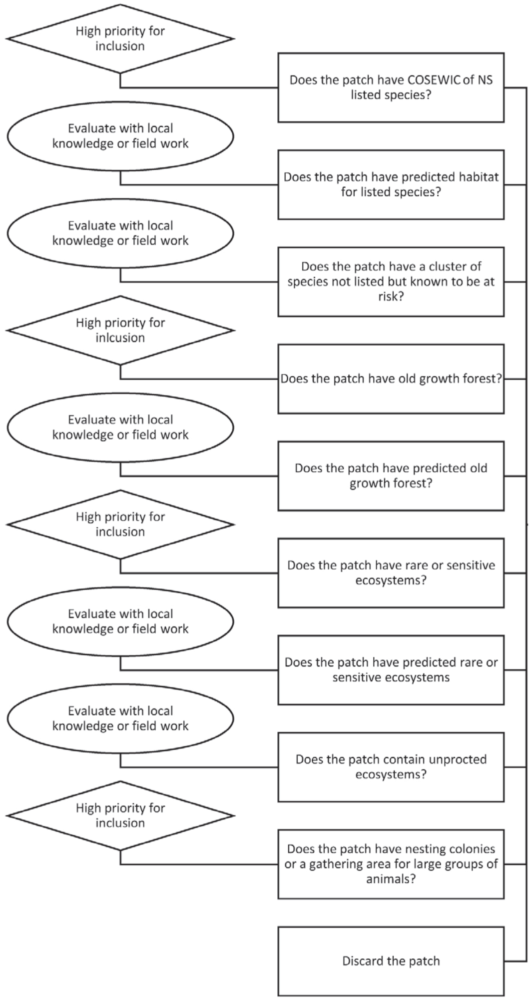

Fig 5B Decision trees used in setting priorities for protection for large patches (B – areas less than 1000 ha).

20 Aichi Biodiversity Targets in 2010. However, Aichi Biodiversity Target 11 stated that both protected areas and 'other effective area-based conservation measures' (OEABCMs) could be used to meet national protected areas targets. This presented a significant reporting and identification challenge in determining what counted as OEABCM (MacKinnon *et al.* 2015). In response, the Canadian Council on Ecological Areas (CCEA) developed a guidebook and

decision support tool for Canada (CCEA 2018) and for the Pathway to Canada Target 1 initiative (2021). Following this Canadian initiative and its' presentation as a case study (MacKinnon *et al*. 2015), the International Union for the Conservation of Nature (IUCN) established a task force to develop guidance internationally (Jonas *et al*. 2018). The result of the task force was the publication of an international guide for recognizing and reporting other effective, area-based, conservation measures (IUCN 2022). Significant contribution from PAE staff was made on the national and international projects (MacKinnon *et al*. 2015, Jonas *et al*. 2018).

LONG-TERM MONITORING

Transect

Cameron (2020b) examined the statistical power of using transect data for long-term monitoring. He found that for species that had high temporal variation or small spatial variation, a relatively small number of biodiversity plots (<20) were needed to have an 80% probability of detecting a change when it actually occurs. For species with high spatial variation or low temporal variation, more than 100 plots were needed to have an 80% probability of detecting a change. For detecting species richness changes and for diversity indices, only six plots are needed to have an 80% probability of detecting change. The conclusion was that transect and plot data are useful for monitoring general measures of richness or diversity or for species that show a large change over time.

Lichens

PAE developed a plan for long-term monitoring of air quality and climate change using lichens (Cameron 2004a). Lichens have long been used for environmental monitoring and a number of protocols have been developed (McCune 2000). PAE initially developed an indicator set of species for use in the monitoring program so that extensive training in lichens was not required to establish monitoring plots (Cameron *et al*. 2007). The program was later expanded to capture all species of lichens within a plot, using European protocols (Richardson 1992). Sixty-five plots were established in protected areas throughout the province (Cameron 2011). Todd (2008) examined the statistical power of the lichen monitoring data and found that to detect a trend of at least 10% (positive or negative) in lichen diversity in one plot, sampling every year for 13 years, or every third year for 22 years, is required. To detect a difference between two regions, the required sample size was calculated to be 38 plots. Both Todd (2008) and Cameron (2010b) found that the lichen data suggested that generally, NS had good air quality with the exception of the major urban and industrial centres, e.g., Halifax, Port Hawkesbury and Sydney.

In 2009, PAE partnered with Acadia University to study mercury (Hg) levels in the province using lichens in the genera *Usnea* and *Hypogymnia* (Saunders *et al*. 2016). Collections were made at all permanent lichen monitoring plots in protected areas. This was later expanded to 165 collections from around NS. Concentrations of Hg were highest around Kejimkujik National Park and Tobeatic Wilderness Area, which is consistent with high concentrations observed in biota in previous research (Evers *et al*. 2005, Little *et al*. 2015). Concentrations of Hg were not significantly different between protected areas and the surrounding landscape (Saunders *et al*. 2016).

An additional 12 metals were also sampled and collection sites increased to 190 (Klapstein *et al*. 2019). The data support the hypothesis that Hg in lichens is from historical gold mining and ongoing long-range transport and diffuse emission patterns, rather than localized pollution sources. Metal concentrations were shown to have median values that are similar to other remote regions such as the Antarctic; however, the maximum values for some metals (e.g. lead, cadmium) were substantially higher than other remote areas. This research demonstrates the usefulness of lichens as biomonitors and provides a baseline for future monitoring efforts.

CLIMATE CHANGE

Contributions to Adaptation and Mitigation

There is currently substantial research and modelling evidence that protected areas can significantly contribute to mitigation of, and adaptation to, climate change effects on natural systems and human infrastructure (Cameron 2012). In terms of adaptation, Cameron (2012) provides several examples from NS. An example of safe-guarding drinking water is the increasing area of municipal drinking water watersheds that are within, or partially within, protected areas in Nova Scotia including Antigonish, Amherst and Halifax. Additional ecosystem services that protected areas can help maintain during climate change are nursery grounds for marine and freshwater fisheries, pollinators and flood protection. The Gully, for example, is a marine protected area off the coast of Nova Scotia that provides a nursery ground for several fish and invertebrate species (Rutherford and Breeze 2002). Protected areas can continue to play a vital role in protecting biodiversity in the changing climate in Nova Scotia. The only krummholtz-boreal forest in the province is almost entirely within Cape Breton Highlands National Park, with disjunct portions in Margaree River and Pollets Cove Aspy Fault Wilderness Areas (Cameron 2004b). Species at the northern extent of their range in Nova Scotia include many species of coastal plain flora found in the south-western portions of the province. These coastal plain plants are distinct in Nova Scotia from the coastal plain of the eastern US. Many of these species are rare in Nova Scotia and susceptible to human impacts (Davis and Browne 1996). Northward migrations of coastal plain flora in a warming climate could be facilitated by protected areas which could act as travel corridors and stepping stones. Without protected areas, these rare plants could be in danger from human activities (Cameron 2012).

The Canadian Parks Council – Climate Change Working Group was tasked with identifying areas where protected areas could become "natural solutions" to climate change. PAE, as part of this group, provided specific examples from NS, along with other provincial and territorial jurisdictions across Canada (Canadian Parks Council Climate Change Working Group 2013). Mitigation examples from Nova Scotia included carbon sequestration and storage in protected areas, and corridor connectivity in the Chignecto Isthmus between Nova Scotia and New Brunswick.

Carbon Modelling

To get a better understanding of how protected areas in NS could contribute to mitigating the effects of climate change, carbon storage and sequestration modelling was done for a number of protected areas. Initially, four protected areas were modeled for carbon storage over a one-hundred-year period using the Canadian Forest Service – Carbon Budget Model (CFS-CBM) (Kull *et al.* 2006). Results were compared to forest product harvesting scenario carbon modelling as a base case. Continued protection over the next hundred-year scenario maintained higher carbon stocks than harvest scenarios in all modelled areas. Although the four modeled Nova Scotian protected areas represented a significant current stock of carbon (1.04 x 107 t C), there was only about a 15% increase in long-term carbon sequestration potential (Morton *et al.* 2010).

Cameron and Bush (2016) developed a Nova Scotia specific model for estimating carbon storage and sequestration over time). The model was run on existing protected areas comprising 514,000 ha and 245,000 ha of proposed protected areas under three scenarios: (1) protected status; (2) forestry management which maximized timber yield; and (3) forestry management with environmental considerations. The model suggested that 112 million tonnes of carbon are stored in existing and proposed protected areas and if protected, these forests would sequester carbon over the next 130 years. If the proposed and existing protected areas were managed for forestry, they would become a carbon source for the next 130 years for both maximum yield and forestry management with environmental considerations scenarios. There was a decrease of about 2 percent and 11 percent in total amount of carbon stored over 130 years for forestry management with environmental considerations and maximum yield scenarios, respectively. Frequent disturbance from clear-cut harvesting likely increases decomposition of organic matter in the forest, which exceeds carbon sequestration by regrowth (Cameron and Bush 2016). Both modelling studies indicated only a modest increase in sequestration of carbon over the study period, for protection designation, but the greatest advantage of protected areas is the greater certainty in land use and in maintaining the current and future carbon store. The carbon sequestration modelling in NS protected areas received an international award from Climate Change Impacts and Responses Organization in 2015, and results were presented at a conference in Iceland in 2014 (Cameron and Bush 2016).

Climate Adaptation Planning

While protected areas can provide optimal settings in which adaptation and mitigation can take place, managers and planners also have to ensure conservation of resources that they are managing. Hennigs (2014) reviewed relevant literature on protected areas management systems for integrating climate change into protected areas management planning. She presented the most promising frameworks which could be incorporated for a Nova Scotian situation and how they could be adopted or modified for the province. Conservation objectives might have to be re-formulated, stressing a holistic ecosystem approach with a long-term perspective. She identified the non-linear dynamics of ecosystems and also that humans should be considered as part of the ecosystem. Furthermore, the focus of conservation efforts should be to protect functions and services that ecosystems provide, instead of concentrating on individual species, because this will be more sustainable in the long run. The approach of conserving the "stage and not the actors", i.e., focusing on physiographic instead of bioclimatic representation, may be important for conservation, as well as giving connectivity a central role in all conservation efforts. By considering several climate scenarios and determining several adaptation options, the Adaptation for Conservation Targets (ACT) framework by Cross *et al*. (2012) will lead to the implementation of actions most defensible under most climate scenarios. This framework has already been applied across the United States, and it was also recommended by several experts contacted during the research for the Hennigs study. A workshop with natural resource professionals and scientists would be needed to begin implementing the ACT framework in Nova Scotia. The ACT has 4 steps: (1) Identify conservation features and management objectives (e.g. maintain viable population of a species at risk); (2) Assess effects of plausible future climate scenarios; (3) Identify management actions; and (4) Prioritize management actions.

With the ACT process in mind, PAE used localized climate change forecasts and ecological susceptibility to climate change for each protected area under management in order to identify and prioritize protected areas for possible management intervention or special attention in the light of a changing climate. Each individual protected area was first ranked on susceptibility to climate change based on 3 criteria: (1) Presence of species at risk (SAR) with susceptibility to climate change; (2) Percentage of protected area with boreal or arctic/alpine ecosystems; and (3) Presence of low elevation and erosional coastal ecosystems, e.g. salt marsh, beach, dune, lagoon, estuarine flat, erosional sea bluff (R.P. Cameron, unpublished data). Downscaled climate projections were produced from over 40 global climate models (IPCC 2013) for five geographical regions in NS. These climate forecasts were then overlaid on each protected area to produce a climate projection for each protected area (ClimAction Services 2017). The climate projections were then compared with climate susceptibility rankings to provide an overall ranking of climate change risk for each protected area (R.P. Cameron, unpublished data). These overall rankings will allow planners to target vulnerable areas for specific management interventions as needed.

In 2017, PAE as part of the Canadian Parks Council – Climate Change Working Group, developed a Climate Change Adaptation Framework for Parks and Protected Areas, which guides planners and managers through a five-step adaptation process. The framework was adopted by Parks Canada using two-day workshops. Eleven workshops were held between 2017 and 2019 at Parks Canada sites in the Yukon, Quebec, Manitoba, Alberta, Nova Scotia, British Columbia, Newfoundland, and Ontario. Input from the workshops was integrated into the approach which contributed to the development of tools and guidance for each phase of the process (Nelson *et al*. 2020). The process can be used by protected areas planners in any jurisdiction, level of government or other organization.

SPECIES OF CONSERVATION CONCERN

Protected areas in NS provide habitat and protection for populations of many species at risk (Cameron 2004b). In some cases, protected areas were established to protect known populations or habitat for SAR. In other cases, SARs are captured incidentally when representative ecosystems are protected.

Transects

Transect and plot sampling as described above is a systematic protocol used in Wilderness Areas and Nature Reserves that allows calculation of densities and population numbers of species of conservation concern (Cameron 2019). Two hundred and twenty-two occurrences of species of conservation concern were recorded between the period 2002 and 2017. Nine bird species and 19 plant and lichen species were recorded 2 or more times. Densities for bird species ranged from 0.023 individuals per km of transect (± 0.012) for Boreal Chickadee (*Poecile hudsonicus*) to 0.727

individuals per km (± 0.007) for Eastern Wood Pewee (*Contopus virens*). Plants densities ranged from 0.02 individuals per km (± 0.01) for Round-Leaved Orchid (*Platanthera orbiculata*) to 27.1 individuals per km (± 10.4) for Bulblet Bladder Fern (*Cystopteris bulbifera*). Most species of conservation concern were rare, with 66% being found only once (Cameron 2019). Analysis of transect data for species of conservation concern demonstrate the rarity of this group of species. It also demonstrates the important role of protected areas in providing habitat for such species.

Turtles

Researchers from Acadia University first identified the Tobeatic Wilderness Area as having potential endangered Blanding's Turtle (*Emydoidea blandingii*) habitat in 2005. Initial investigations included examining aerial photography for potential Blanding's Turtle habitat. A number of promising sites were identified with the most likely being along the Roseway River near Indian Fields and Third Bear Lake. Live trapping for turtles began in summer 2005 with 24 trap nights and 6 hours of visual searching for each of the Roseway River and Third Bear Lake sites within the Tobeatic Wilderness Area. No Blanding's Turtles were observed or trapped, however, 93 Painted Turtles (*Chrysemys picta*) were captured (Landry and Cameron 2005). In 2007, volunteers from Mersey Tobeatic Research Institute (MTRI) in cooperation with Acadia University, began searches and trapping in Mooseland Stream and Whitesand Stream in the Tobeatic Wilderness Area. Trapping continued through 2009 for a total of 728 trap nights on 3 waterbodies: Sporting Lake Stream, Whitesand Stream and Moosehide Lake Stream. Four Blanding's Turtles were found; two mature males, one mature female and a juvenile. In 2009, all turtles were radio tagged and movements monitored. It is likely that this is a very small, isolated group of Blanding's Turtles, with no close connection to any of the three main sub-populations, although no genetic work has been done to confirm this. The nearest sub- population, Kejimkujik, is over twenty kilometers to the east. There are many more areas in the Tobeatic Wilderness Area that appear to have favourable habitat and future visual surveys and trapping could lead to discoveries of other Blanding's turtles (Clapp *et al*. 2015).

Mammals

In 2008, six hair collection sites for Eastern Cougar (*Puma concolor couguar*) were established in Kejimkujik National Park. In 2009, two sites were established in the Tobeatic Wilderness Area. Sites consisted of an olfactory lure. Sample sites were checked several times a year and hair samples were collected. Between 2009 and 2014, samples were sent for DNA analysis according to standard protocols (Lang et al. 2013) to the Natural Resources DNA Profiling Forensic Center at Trent University, Peterborough, Ontario. All samples came back negative for eastern cougar (Clapp *et al.* 2017).

Wilderness Areas provide habitat for several provincially endangered mammals. The largest subpopulations of Endangered Mainland Moose (*Alces alces americana*) occur in the Tobeatic Wilderness Area and smaller populations occur in Tangier Grand and Eigg Mountain – James River Wilderness Areas (Parker 2003). PAE participated in the Mainland Moose Recovery Team between 2005 and 2014 and during this time, a Recovery Plan (McNeil 2013) and Special Management Practices for forestry and other development (NS DNR 2012) were created. Several studies on Mainland Moose were initiated, resulting in publications (e.g. Broders *et al.* 2012).

Protected Areas, including eight Wilderness Areas in the Cape Breton Highlands, provide important habitat for both Provincially Endangered Canada Lynx (*Lynx canadensis*) and American Marten (*Martes americana*). These protected areas provide functional connectivity and habitat protection (Nova Scotia Lynx Recovery Team 2006, Nova Scotia American Marten Recovery Team 2006).

Lichens

Lichen research in protected areas began with inventories for species at risk in the early 2000s, initially partnered with NS Department Natural Resources and then later with MTRI (Cameron 2004a). Survey sites were guided by habitat models which helped to narrow down large search areas (Cameron and Neily 2008, Cameron *et al.* 2011a, Pearson *et al.* 2018). With a large number of locations of lichen species of conservation concern in protected areas, PAE also contributed to authoring numerous species assessments for the Committee on Status of Endangered Wildlife in Canada (COSEWIC) which later led to their designations in Canada.

Most of these species also became listed provincially under the NS Endangered Species Act. As more data became available, population modeling was done (Cameron & Toms 2016) as well as a threat analysis for boreal felt lichen (Cameron *et al*. 2013a, Cameron *et al*. 2013b). These efforts along with those of other lichenologists (e.g., McMullin *et al*. 2008, Selva 2010, Richardson *et al*. 2011, Anderson and Neily 2012) led to the designation of a number of protected areas for, or partially for, conservation of lichens (Cameron 2020a). Eight areas representing 3405 ha were established in the last ten years entirely for the purpose of conserving lichens. In addition, over 5000 ha were established partly for conserving lichens and partly for other reasons. These eight protected areas help conserve some of Canada's most at risk and rare lichens and represent landmark conservation actions for Nova Scotia and Canada (Cameron 2020a).

Atlantic Coastal Plain Flora

Atlantic Coastal Plain Flora (ACPF) inventories were conducted on Crown land starting in the late 1990s into the early 2000s by PAE staff in cooperation with the ACPF recovery team (D. MacKinnon, unpublished data). Surveys focussed on lake, stream and river shores in southwestern NS and led to thousands of new locations for ACPF. These data contributed to an understanding of habitat and distribution of ACPF and recognition of the importance of protected areas in conservation of ACPF (Environment Canada and Parks Canada Agency 2010). These data, in conjunction with work from other researchers, led to establishment of 15 new protected areas and expansion of four existing protected areas in southwest NS, amounting to over 11,000 ha of land protected for ACPF (Nova Scotia Environment 2013).

Forest Plants

Forest dependent plants of conservation concern (FDPCC) have not been well studied in NS, with the exception of habitat specific species such as those associated with karst, floodplains or wetlands (Zinck 1998, Davis and Browne 1996). Upland forest plants of conservation concern have had little research. PAE, in a partnership with Dalhousie University and NS Lands and Forestry between 2018 and 2020, investigated locations, habitat and environmental variables associated with FDPCC (Cameron 2020b). The most significant trend for individual species was for Downey Rattlesnake

Plantain (*Goodyera pubescens*) and Hepatica (*Hepatica 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 Hepatica (Burns 2020). Habitat models were also created for these two species, indicating important habitat variables and locations for potential new sites and suggesting more protection may be needed for these species (Hodgson 2020). To help address issues of low sample size for individual species, FDPCC were divided into 3 plant functional groups (PFG) for further analysis: (1) Upland forest orchids; (2) Upland forest sedges; and (3) Upland forest geophytes (Verheye *et al*. 2003). All three PFGs were more likely to occur in protected areas than in forest managed for other purposes (PFG3 $p<0.0001$, $n=1150$; PFG2 $p<0.0001$, $n=1275$; PFG1 $p<0.001$, $n=1455$). All PFGs were also more likely to occur in landscapes with lower road density ($p<0.001$) and lower density of clearcutting ($p<0.001$), suggesting susceptibility of FDPCC to human impacts in the environment (PFG3 $p<0.0001$, PFG2 $p<0.0001$, PFG1 $p<0.001$) (Cameron 2020b).

Piping Plover

MacKinnon (2015) assessed trends in Piping Plover (*Charadrius melodus*) counts in 33 beaches in NS between 1961 and 2014. He found significant declines in the beaches with highest human use and infrastructure including Dominion, Clam Harbour, Rainbow Haven, Lawrencetown and Conrad beaches. Beaches that did not have declining counts of Piping Plover over the study period included more remote sites and those less used by humans, such as Crow Neck, South and North Beach and Red Head Beaches. Parking lot size was the single most important variable to explain declines in piping plover numbers (MacKinnon and Cameron 2016).

RARE, SENSITIVE, VULNERABLE ECOSYSTEMS

Some ecosystems are naturally rare within the landscape, such as talus slopes within NS (Davis and Browne 1996). Rare or uncommon ecosystems often provide habitat for rare species. Cliffs provide habitat for a variety of rare mosses (Ireland 1982) and vascular plants (Zinck 1998) in Nova Scotia. Talus slopes provide habitat for Gaspé shrew (*Sorex gaspensis*) (Davis and Browne 1996). Many of the ecosystems such as wetlands and riparian ecosystems are sensitive or vulnerable to human disturbance. PAE has embarked on research and partnerships to help identify, document and inventory many of these ecosystems.

Predictive Modelling

Cameron *et al*. (2011b) created predictive models for 17 types of rare ecosystems in NS using a variety of methods. Ability of the models to correctly predict where rare ecosystems occurred was high with an overall 4.3% error (false positive). The error varied widely between ecosystem type. The error of false negatives was not calculated. Results of these modeling studies were used to predict locations of rare or vulnerable ecosystems to aid in their conservation and protection (Colin Stewart Forest Forum 2009). Since then, the predictive models have been used for a variety of purposes including forestry management, conservation projects and woodlot management planning. The results also suggest that these 17 ecosystems are rare on the landscape.

Heathlands

The most extensive work on heathlands in NS has been conducted by Dr. Jeremy Lundholm and his students of Saint Mary's University (Porter *et al*. 2020). Oberndorfer and Lundholm (2009) studied heathlands in five protected areas on the Atlantic Coast. They made three conservation recommendations: (1) Rare species do not correlate with species richness, thus, protecting areas of high richness may not capture rare species and vice versa; (2) Heathland plant community composition differs widely among areas of the province, therefore, protecting any single "representative" coastal barren will not protect the range of vegetation communities; and (3) a coastal-inland gradient and a diversity of substrate types (including exposed rock and trees) should be included in protected areas planning. Cameron and Bondrup-Nielsen (2013) examined inland and Atlantic coastal barrens in eight different protected areas and reached conclusions similar to those of Oberndorfer and Lundholm (2009). They found differences between inland and coastal heathland as well as differences between regions. Thus, protected areas need to capture representative communities from the variety of landscapes. Heathland communities were found to have greater species richness and variation in community type than previously thought. Indeed, MacDonald *et al.* (2011) in a study of lichens of Atlantic Coastal barrens found six species of lichens new to the province, including one new to North America. Cameron and Bondrup-Nielsen (2013) also found that rare plants in heathlands were not restricted to any particular community type; rather, rare coastal plants in Nova Scotia occur in a wide variety of plant communities. Therefore, targeting rare species protection is needed rather than any specific type of plant community in order to help conserve rare heathland plants.

Other unique coastal communities are the nutrient enriched vegetation communities found on Hay Island in the Scatarie Island Wilderness Area (Cameron and MacKinnon 2008). Hay Island is a major haul-out for Grey seals (*Halichoerus grypus*) during the winter, and a nesting area for Great and Double-crested cormorants, Common Eider, Leach's Storm Petrels and several species of gulls. These animals contribute significant input of nutrients through defecation and decomposition of carcasses. Five terrestrial plant community types were found on Hay Island: (1) Cobble beach; (2) Rocky shore; (3) Grassy meadow; (4) Rich wetland; and (5) Herb meadow. Cobble beach and rocky shore had few plants, being dominated by the lichens. Northern Willow Herb (*Epilobium glandulosum*) and several species of grasses made up the wetland community while Reed Canary Grass (*Phalaris arundinacea*) dominated grassy meadows. Herb meadow had the greatest species richness on Hay Island. A comparison to the adjacent island, Scatarie, which has little seabird nesting and little or no seal haul outs, reveals entirely different communities. Similar communities found on Scatarie and Hay Island include cobble beach, rocky shore, and grassy meadow, although Scatarie Island had significantly fewer species in each community type compared to Hay Island. Even soil type on Hay Island indicated high soil fauna diversity compared to Scatarie (Cameron and MacKinnon 2008).

The richness of plant species and variety of community types documented by Oberndorfer and Lundholm (2009) and Cameron and Bondrup-Nielsen (2013) may not fully describe the complexity of these coastal ecosystems. Strang (1970) described inland barrens with undulating micro-topography reflected in the distribution of plant communities. He suggested that Broom-crowberry (*Corema* *conradii*) community occurred on hummock tops, Black Huckleberry (*Gaylussacia baccata*) community occurred on side slopes, and Rhodora (*Rhododenron canadense*) community in the hollows. Cameron and Bondrup-Nielsen (2013) describe changes in coastal barren communities with distance from the water. Lichen community was closest to the water, followed by Crowberry (*Empetrum* spp.) community, then low shrub and then high shrub communities. Finer scale data collection by PAE (unpublished data) from Duncan's Cove Nature Reserve found that the undulating community variation found by Strang (1970) in inland barrens was present at coastal barrens and is overlaid on the communities found by Cameron and Bondrup-Nielsen (2013). For example, it was found that the near shore lichen community actually was comprised of crustose lichens that dominated the hummock tops and fruticose and foliose lichens that were found in the hollows. Similar changes were found for the Crowberry and shrub barrens. Further investigation is needed to determine if these changes are variations in one community type or different communities altogether. Regardless, the work suggests highly complex communities and a greater variation than was previously thought for these "barren" communities.

Red Maple Wetlands

Another little studied ecosystem in Nova Scotia is Red Maple (*Acer rubrum*) wetland. Cameron (2009) studied 28 Red Maple wetlands in 15 NS protected areas. Cameron found a high plant species richness and diversity, and high structural complexity. Two species of rare vascular plants were found, and *Sphagnum* species richness was particularly high compared to upland forest and other peatlands, and included 4 species of conservation concern. Cameron (2009) found that Red Maple wetlands make a significant contribution to the biodiversity and heterogeneity of the landscape. Red Maple wetlands are also highly lichen diverse, particularly in epiphytic cyanolichens (Cameron 2011, Cameron and Neily 2008, Neily and Anderson 2010). These wetlands provide habitat for some of the rarest and most endangered lichens in NS.

Coastal Woodlands

Jack pine (*Pinus banksiana*) – Broom Crowberry woodland is a rare community type found only in NS and occurring in the Blandford Nature Reserve (MacKinnon and Cameron 2006) and the Canso Coastal Barrens Wilderness Area (Garbary *et al*. 2006). Basquill (2004) includes this community type as part of a Jack Pine-Huckleberry-Three Tooth Cinquefoil (*Sibbaldiopsis tridentate*) community. However, it may be a separate community because of the dominance of broom crowberry in the herb layer. Broom crowberry is found only in Northeastern North America and forms rare heathland communities in New England (Dunwiddie 1990, Dunwiddie *et al*. 1996). Jack pine found in this community is the form *procumbens*, so-named because it grows with a recumbent form (Zinck 1998). Several species of plants of conservation concern have been found in this community. Although it has been suggested that jack pine and the associated communities are of wildfire origin, field investigations suggest that this community type may be naturally regenerating without wildfire (MacKinnon and Cameron 2006).

OLD GROWTH FOREST

Prior to European settlement, old-growth forest likely covered large areas of Northeastern North America (Cogbill 2000, Mosseler *et al*. 2003). However, several centuries of logging, land clearing and human caused wildfires has reduced the area of old-growth significantly (Leverett 1996). Mosseler et al. (2003) estimates that as much as 50% of the Canadian Maritime Provinces forest area was occupied by late-successional tree species before European occupation. Currently, only 1 to 5% of the Canadian Maritimes forest area has old-growth forest (Lynds and LeDuc 1995, Mosseler *et al*. 2003). D'Amato *et al*. (2009) estimates that only about 0.1% of the forested land base of Massachusetts has old-growth forest and this is likely common for most Northeastern states.

Old Forest Predictive Modelling

MacKinnon (2005) created a predictive GIS model to determine where the most likely locations are for old forest. He used forest cover GIS data to identify forest stands using tree heights and species composition data. Although commission and omission errors were present, the data became a useful tool for identifying the most likely places where older forest could occur (Cameron 2017).

Dendrochronology

Hart and Laroque (2006) collected tree cores and measured ages of trees in potential old growth forest stands in protected areas and proposed protected areas across NS. Sampling was conducted by extracting 5.1 mm cores using a standard dendrochronology increment boring tool. Tree age was then determined by counting rings using image analyzing software and a microscope. Old-growth quality was analyzed based on species distribution, age structure, presence of stumps and presence of coarse woody debris. Several old growth forests were reported at Sixth Lake, Silver Lake, Lake Rossignol and French River Wilderness Area which included the oldest reported eastern hemlock in NS.

Old Forest Scoring

Identifying old forest in the field can be challenging and NS Natural Resources developed a system to score old forest (Stewart *et al*. 2003). Criticisms of this approach have been that it tends to rely heavily on tree ages and will miss old growth forests that have younger age trees but long continuity of forest cover.

Selva (1996, 2003) suggested one approach is to measure forest continuity rather than tree age. He proposed the use of lichens as a measure of forest continuity in Northeastern North America based on previous work by Rose (1976) in Britain. McMullin *et al*. (2008) proposed another suite of lichens for assessment of old growth forest in southwest Nova Scotia. The greatest challenge with using lichens as indicators is that it requires extensive expertise and often time-consuming identifications in the laboratory. Cameron and Bondrup-Nielsen (2012) suggested using abundance and frequency of a single species that is easy to identify in the field, coral lichen (*Sphaerophorus globosus*), as an indicator of old growth coniferous forest in NS.

Another approach to assessing old forest is being developed by PAE (Cameron 2020) using plant functional groups (PFG). Presence and abundances of certain PFGs (e.g. geophytes) have been used as indicators of human disturbance in forests in Quebec (Verheyen *et al*. 2003). Cameron (2020) measured abundances of 5 different PFGs in 48 old growth forest plots and compared them to previously harvested forest plots. A statistical model was developed which predicts the probability of old growth using PFGs from quadrat data. The proposed method can be used in any type of forest (coniferous, deciduous, mixed) regardless of soil moisture or tree age.

EDGE EFFECTS

Setting aside an area for protection does not mean the area will function naturally with no human impacts. There will be many human impacts such as from climate change and air pollution. One well-studied impact of adjacent human activity on protected areas is edge effect. Activities such as road construction, forestry and agriculture can cause impacts that extend into protected areas.

Literature Search

Cameron (2007) summarized the research on known edge impacts of forestry on protected areas. Edge effects can include changes to both ecological processes and organisms within the protected area. For example, tree harvesting can affect downstream conditions of sedimentation (MacDonald *et al*. 2003) and temperature (Story *et al*. 2003) which in turn can affect downstream fauna. In terrestrial environments, tree harvesting adjacent to protected forests can affect physical parameters such as light and wind within the protected area (Chen *et al*. 1995) which in turn can affect flora and fauna. Edge effects can also include changes in biota such as establishment of invasive exotic species (Parendes and Jones 2003, Greenberg *et al*. 1997) and increased nest predation of song birds (e.g. Poulin and Villard 2011). Road construction for forest access seems particularly problematic causing geomorphic hydrologic changes which can affect organisms (Hunter 2000, Gucinski *et al*. 2001). Habitat fragmentation, road avoidance behavior and facilitation of invasive species are a few of the issues related to species (Hunter 2000, Gucinski *et al*. 2001). Cameron (2010) concluded with four recommendations for forest managers working near protected areas: (1) Retain or restore natural climax forest species composition; (2) Reduce edge contrast between working forest and protected areas; (3) Maximize protection of watercourses draining into protected areas; and (4) Plan road networks to minimize undesirable effects on nearby protected areas.

Further investigation into the research literature on edge effects of forestry was done in 2017 in a joint project with Department of

Natural Resources, Wildlife Division and PAE. Efforts were made to find studies relating to distance of edge influence into a protected forest. There was wide variability in the scientific literature with effects distance as little as 10 m for some vascular plants (e.g., Matlack 1994) and as great as 500 m for frogs (Herrmann *et al*. 2005). Few data were available from local research on edge effects. However, Cameron *et al*. (2013a) in Nova Scotia found clearcutting was affecting mortality of endangered Boreal Felt Lichen (*Erioderma pedicellatum*) within 500 m, and MacQuarrie and Lacroix (2003) found invasive plants 300 m into the forest from an edge in Prince Edward Island.

Field Study

In order to get a better understanding of edge influence in a NS protected areas context, a joint study was undertaken between Department of Natural Resources, Wildlife Division and PAE in 2018 at Cloud Lake Wilderness Area. Six transects were established which transected the edge of a clearcut into the protected area for a distance of 150 m. Song meters were placed at regular intervals to record bird songs during nesting season over 2 years (2018, 2019). Vegetation quadrats were also established at each interval. Data are currently being analyzed but disturbance-associated plant species were found up to 150 m into the forest from the clearcut-forest edge (Cameron 2021).

CONNECTIVITY

Inglis (2007) studied connectivity in southwest NS using four indicator species. She found that connectivity was relatively good within protected areas and between Tobeatic Wilderness Area and Kejimkujik National Park but low between other protected areas in the region. Since that study, a number of protected areas have been established between existing protected areas in this region which help improve connectivity. These new areas include Dunraven Bog Nature Reserve, Sixth and Coades Lakes Nature Reserve, and Shelburne River Wilderness Area (Province of Nova Scotia 2013).

Cameron (2017) assessed the contribution of the Parks and Protected Areas Plan to connectivity in the province. Effective Mesh Size (EMS), as described by Jaeger (2000), was selected as the connectivity measure which is the sum of squared habitat areas divided by total area. It was found that an increase in protected areas across the province from about 8% of the land area to about 13% of the land area increased connectivity by 25% within the province.

MacKinnon and DeGooyer (unpublished data), in working with researchers from Dalhousie University and others, were able to identify key areas that are important for maintaining connectivity in the province. These are pinch-points or narrow corridors of natural habitat where there is natural movement of animals between regions. These included South Panuke Lake and the Chignecto Isthmus. The South Panuke Lake Wilderness Area was established, in part, to aid in this important connectivity node for the province (Province of Nova Scotia 2013).

Conservation efforts by the Nature Conservancy of Canada (NCC) and PAE enabled the establishment of key protected areas in the Chignecto Isthmus to aid in the movement of animals from NB, including endangered mainland moose. NCC entitled their efforts as the Moose Sex Project in a successful effort to gain public interest and support.

At the national level, PAE staff member, David MacKinnon, participated in the Canadian Council on Ecological Areas Committee examining connectivity in Canada (Lemieux *et al*. 2021). They presented the need for connectivity in Canada, governance, law and policy, as well as a needs assessment for implementing connectivity in Canada. Several successful case studies were presented including the Halifax Green Network Plan.

RAIN FOREST

Temperate rainforests are characterized by high rainfall and relatively cool summer temperatures. Most temperate rainforests occur in the oceanic mid-latitudes, with western North America being the largest area of temperate rainforest. Other rainforests occur in Chile, western Europe, southeastern Australia and western New Zealand. Coniferous or broadleaf evergreen trees dominate most temperate rainforests, although often deciduous trees can be found (Alaback 1991). Temperate rainforests are globally rare, comprising less than 0.02 percent of the earth’s land area (Della Sala *et al.* 2011). The long growing season of temperate rainforests means that they have some of the highest biomass of any terrestrial ecosystem. Temperate rainforests are biologically diverse, often with high levels of endemism (Cook and MacDonald 2001, Smith-Ramírez 2004).

Rain forests have been previously described for parts of NS (Holien and Tonsberg 1996, Thompson *et al.* 2003). PAE staff in working with Clayden *et al.* (2011) described these forests as per-humid hemi-boreal. Per-humid forests can be subject to short periods when water loss exceeds water gain but these are compensated for by longer periods of excess water in other seasons. Hemi-boreal describes the temperature-boreal transition zone found in NS. Using lichens as temperate forest indicators, Clayden *et al.* (2011) identified the Eastern Shore and parts of Eastern Cape Breton Island as rain forests of NS.

A narrow band of forest along the Atlantic coast of Nova Scotia has been continually recognized as unique. Dzikowski (1985) identified the Atlantic coast of Nova Scotia as a separate climatic region of the province. The Atlantic region was characterized as having relatively high annual precipitation, low summer and high winter temperatures. Loucks (1962) suggested the Atlantic coast of Nova Scotia as a distinct forest type within the Maritimes. Later ecological classification also identified this region as distinct (Davis and Browne 1998, Lynds and LeDuc 1995). The Atlantic coast of Nova Scotia has the coolest summer temperatures and warmest winter temperatures in the province (Davis and Browne 1996). Annual precipitation in this region is from 1400 to 1500 mm, with more than 80% falling as rain (Cameron *et al.* 2008).

More recent work by PAE helped define more clearly the zone of per-humid forests. We used five indicator lichens suggested by Clayden *et al.* (2011) and characterized the climate in the distribution area for these species using machine learning AI software BIOCLIM (Fick and Hijmans 2017). The zone of climate likelihood was plotted and indicates Eastern Shore and parts of eastern Cape Breton as the most likely areas of per-humid forests (Fig 6). The predictive value of the map needs to be verified by field surveys for indicator species in previously unsurveyed areas. This map can then be used to assess the level of protection within these unique forests and determine where gaps need to be filled for protection.

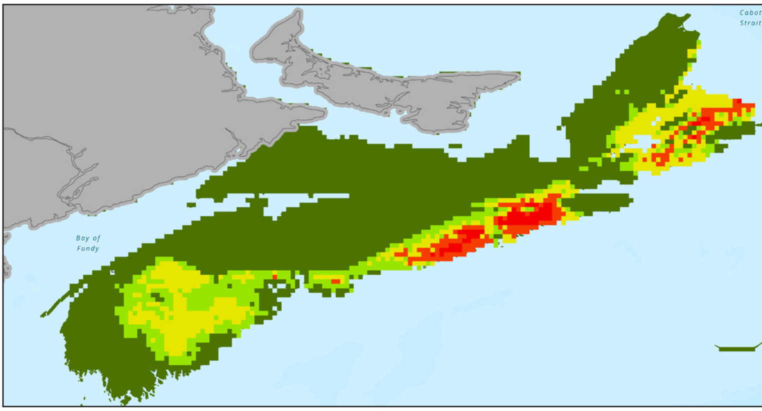

Fig 6 **Predicted area of per-humid, hemi-boreal forest using five indicator lichens in a machine learning environment.**

HUMAN USE OF PROTECTED AREAS

Motorized Vehicles

Human use of these protected areas is well known and some aspects have been documented. Negative human use has been well documented by Williams (e.g. Williams 2009, 2010, 2011, 2012). However, these are mostly inventories of human use rather than research investigations. Baker *et al*. (2004) studied the change in Off-highway Vehicles (OHV) use in Bowers Meadows and Tobeatic Wilderness Areas using aerial photography taken in 1988 and 2000. They found an overall 51% increase in OHV trails between these dates. Cameron (2016) reviewed over 200 published papers on environmental effects of OHV. He found extensive possible impacts from local soil erosion to landscape scale impacts such as animal avoidance behavior. Cameron notes the ecological need for large undisturbed Wilderness Areas and that National Parks and Wilderness Areas in NS represent the few remaining large natural areas.

Foot Traffic

Foot traffic by humans can also be cause for concern if excessive. Sora (2017) studied the human foot traffic at Duncan's Cove Nature Reserve and found damage to soil and vegetation from high use. Development of trails with resistant surfaces was suggested. Walking trails have been built in many protected areas, many of which are maintained by community groups. Some examples include

Gully Lake, Economy River, Waverley Salmon River Long Lake, Whites Lake, Tobeatic and North River Wilderness Areas. These trails have been well planned to minimize environmental impacts, avoiding rare or at risk species and habitats. Canoe routes are also established within many Wilderness Areas and include planned portage routes.

CONCLUSIONS AND FUTURE DIRECTIONS

Science in the support of managing protected areas is needed. There have been significant increases in the amount of area protected within the province over the last 20 years. For example, the Parks and Protected Areas Plan included adding four new provincial parks (960 ha), 44 new Wilderness Areas (128,760 ha), 118 new Nature Reserves (34,080 ha) and expanding 12 provincial parks (3,980 ha), 31 Wilderness Areas (77,460 hectares), and 11 Nature Reserves (4,620 ha) (Province of Nova Scotia 2013). Private land trusts have been expanding areas under their ownership and management as well. It will be important to understand where sensitive species and ecosystems occur, and how human activity within the protected areas might cause impacts. Managing human use of highly traveled areas will be needed and much of this information may come from the social sciences. Very little work to date has been done in NS with respect to social science studies in protected areas.

It is clear that changing climate is having a significant impact on natural areas. Efforts to understand these impacts and how to maintain biodiversity in a changing climate are needed. Many impacts of climate change are unforeseen, such as the establishment of invasive species. Thus, it is extremely challenging to monitor and react with timely management intervention. It is also clear that new arrangements of species in the landscape will occur resulting in novel ecosystems and communities (Root *et al*. 2003), therefore making it necessary to understand and manage for biodiversity in a dynamic way.

Protected areas can play a vital role as natural solutions to mitigating the effects of climate change. However, there is much effort needed to realize these benefits, particularly in the NS context. The limited research to date has shown great promise to help highlight protected areas as natural solutions.

A more holistic approach to species conservation is needed. Populations and habitats of species of conservation concern are often conserved in protected areas and these areas can be vital to these species' continued survival. However, an increasing number of species are being listed as being at risk as new investigations are made. For example, the number of Canadian species on the IUCN Red List of Threatened Species has more than doubled between 2010 and 2016 (Kraus 2016). Some effort has been made with a multi-species approach in the NS Lichen Recovery Team and the Atlantic Coastal Plain Flora Recovery Team (Elderkin pers. comm.) but this approach will have limitations. An ecosystem approach is another avenue that may be more holistic and achievable; more research is needed into how this might be possible. How ecosystems should be identified, what needs to be done to ensure the ecosystem conservation, and how and which species at risk will be impacted with ecosystem conservation efforts are all outstanding questions.

Large scale conservation planning within the province would benefit from further development. In particular, how protected areas can best be positioned to conserve biodiversity within multiple other approaches such as environmental assessments, SAR recovery teams, and Forestry Special Management practices, needs to be understood. Compounding the disjointed approach to biodiversity conservation are the multiple agencies involved, including NGOs, provincial and federal governments. There are a few recent examples of multi-agency, multi-method efforts, including the efforts around the Southwest and Bras D'Or Lakes Biosphere Reserves. These efforts include multi-agencies and more holistic approaches, but remain regional in scope.

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