A Strategic Research Plan for Forest Biodiversity Conservation in Nova Scotia

by

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TABLE OF CONTENTS

1.0 Introduction ... 3
1.1 Forest Biodiversity Science Advisory Committee ... 3
1.2 Need for a Research Plan ... 3
1.3 Assessment of Department of Lands and Forestry Knowledge and Staff Priorities ... 3
1.4 Structure of the Strategic Research Plan ... 3

2.0 Forest Biodiversity Themes Requiring Improved Knowledge
2.1 Forest Characterization ... 4
2.2 Forecasting Forest Dynamics ... 5
2.3 Inventory Enhancement ... 6
2.4 Biodiversity Targets and Thresholds ... 7
2.5 Forest Landscape Planning ... 9
2.6 Role of Private Forest Land in Biodiversity Conservation ... 10
2.7 Natural Disturbance Regime ... 12
2.8 Forest-Dependent Species at Risk ... 13
2.9 Invasive Alien Species and Irruptive Native Species ... 15
2.10 Land Use ... 17
2.11 Climate Change ... 18

3.0 Implementation ... 19
3.1 Overview ... 19
3.2 Research Funding ... 20
3.3 Human Resources ... 20
3.4 Organizational Structure ... 20
3.5 Collaborations and Partnerships ... 21

4.0 Conclusion ... 21

5.0 References ... 22

6.0 List of Actions ... 26

1.0 Introduction

1.1 Forest Biodiversity Science Advisory Committee

In August 2015, the Forest Biodiversity Science Advisory Committee (FBSAC) was appointed by the Minister of Natural Resources (now Minister of Lands and Forestry). The mandate of the FBSAC was to provide independent advice on science and research. It was also to provide high-level advice on Departmental initiatives including the Forest Management Policy, Ecological Landscape Analysis, and Landscape-Level Management Planning. This mandate also included specific objectives to:

- "Undertake a current state assessment of Department knowledge as it pertains to the goals;
- Identify priorities for the development of existing knowledge, research, data gathering and the development of tools;
- Propose a strategic research plan that outlines the Department's research priorities and requirements over the next 10 years.
- Assist in the design of research projects under the strategic research plan." (excerpted from the FBSAC Terms of Reference)

1.2. Need for a Research Plan

FBSAC acknowledges that Department staff currently undertake research projects in several priority areas of forest biodiversity science. The Department also supports, through research grants and contracts, academics and other parties to undertake additional forest biodiversity science projects. However, FBSAC identified several gaps and an overall lack of coordinated effort across the research projects. This research plan is offered as a means by which to improve research co-ordination, reduce research gaps, and thereby improve forest biodiversity management in the province.

1.3 Assessment of Department of Lands and Forestry Knowledge and Staff Priorities

The FBSAC conducted a workshop on September 28, 2017 with over 20 Department staff and managers who are involved with forest biodiversity science and/or management. The workshop was held for staff to help inform the FBSAC of what programs and research related to forest biodiversity were currently being undertaken in the Department. There was also an opportunity for staff to provide the FBSAC what they considered to be the needs and gaps for research on forest biodiversity. The FBSAC used the information gathered from staff about current work and priorities, along with an informal scan of other jurisdictions and committee members' knowledge and experience, to develop the list of research priorities presented below.

1.4. Structure of the Strategic Research Plan

The research plan is organized into 11 key research themes. Section 2 presents each theme, beginning with a brief overview of the issue, followed by a description of the research needs and recommended actions. Section 3 presents implementation recommendations relating to funding, human resources, organizational structure, collaborations, and partnerships.

2.0 Forest Biodiversity Themes Requiring Improved Knowledge

2.1 Forest Characterization

Overview

Assessing the status of biodiversity, evaluating impacts of natural and anthropogenic change on biodiversity, and establishing forest condition goals to meet biodiversity objectives all require the forest to be characterized in terms relevant to biodiversity. Such characterization provides a means to quantitatively assess forest condition from a biodiversity perspective. The absence of an appropriate characterization scheme precludes that assessment, and as such, the scheme's importance cannot be overstated.

Biodiversity is viewed through multiple lenses (*e.g.* habitat for vertebrate species, old-growth forest, vegetative communities, species at risk) each of which could influence the basis for characterization. Regardness of the specific lens, a biodiversity-relevant forest characterization should meet several key criteria. The characterization scheme should:

- be derivable from forest inventory information available comprehensively across the forest;
- incorporate compositional, structural, developmental, and spatial stand and forest characteristics relevant to the biodiversity perspectives in question;
- be derivable from strategic forecasts of forest dynamics through time;
- be responsive to anthropogenic and natural disturbances; and
- strike an appropriate balance between detail and simplicity.

Research Needs and Actions

As stated by Basquill *et al.* (2016), there exists “no common ecological standard for producing and summarizing current land cover conditions. This inconsistency makes it difficult to ensure landscape and natural resource assessments are comparable across management units, regions, or between government and non-governmental partners”. This statement is equally applicable to the summarization of forest conditions from a biodiversity perspective and it highlights the importance of addressing forest characterization in a biodiversity research strategy for the province.

The forest classification currently employed in strategic planning only partly reflects elements of biodiversity, but with recognized inadequacies, *e.g.* defining mature forest as that being over 40 years of age. Further, it is not obvious that it incorporates any consideration of habitat suitability and thus offers no useful link enabling inferences about wildlife populations.

The scheme should at minimum meet the criteria stated above. The independent variables employed in the characterization scheme – *i.e.*, those used to calculate biodiversity indicators - could be drawn from the photo-interpreted stand attributes, ecological land classification, and permanent-sample-plot data.

The latter can provide details of stand structure, such as canopy structure, snag abundance, tree diameters, and other variables that may have biodiversity relevance. These variables are not presently available for every stand, which thus precludes spatial representations of biodiversity as defined by these variables. However, by linking the ground plots to photo-types, frequency distributions of biodiversity conditions can be derived which, while imperfect, are useful and an important advance.

Because the interpretation of forest condition in terms of biodiversity value could vary depending upon the perspective (*e.g.* habitat for different taxa), a set of schemes could be developed (each with a unique classification algorithm using forest inventory variables as input). Biodiversity assessment could then be made from whatever perspectives are deemed of interest (and for which unique classification schemes have been developed).

Action 2.1.1: Using the work of Basquill *et al*. (2016) as a starting point, and with engagement of individuals from all forestry and wildlife units, outside researchers, and other knowledgeable parties, devise a forest characterization scheme adequate for coarse-filter assessment of biodiversity from whatever perspectives are deemed important by the Department.

Applying the forest characterization scheme by combining photo-interpreted and permanent-sample-plot data would allow a quantitative assessment of biodiversity (in coarse-filter terms) across all ownerships. This would help identify areas of particular concern and thus provide a basis for strategic management of biodiversity.

Action 2.1.2: Apply the forest characterization scheme to the existing forest inventory to create a summary of biodiversity status of the current forest.

2.2 Forecasting Forest Dynamics

Overview

Applying the forest characterization scheme discussed in Section 2.1 to current inventory data enables quantitative assessment of biodiversity conditions today. Evaluating future biodiversity conditions under alternative management scenarios and designing strategies that meet biodiversity objectives requires the independent variables used in the scheme to be included in the forecasts of stand development. The growth and yield models used for those forecasts must therefore include any stand attributes (*e.g.* snag abundance, canopy layers) employed in the forest classification scheme.

Research Needs and Actions

The adequacy of existing growth and yield models to provide these variables cannot be assessed until the forest characterization scheme discussed in Section 2.1 is developed and the nature of the necessary variables is known. According to Departmental staff, merchantable volume per ha is the only dependent variable provided by the current stand growth forecasting models. It is likely that other stand structure characteristics, such as snag content, coarse woody debris, and diameter distribution, will be needed to adequately support forest characterization relevant to biodiversity status assessment.

Action 2.2.1: Once the forest characterization scheme is developed, modify existing growth and yield models to ensure that all stand variables employed in that scheme are provided as model outputs.

The nature and magnitude of this effort will hinge upon the number and type of stand variables absent from existing models.

2.3 Inventory Enhancement

Overview

In the likely event that the forest characterization scheme employs detailed stand variables (*e.g.* snag abundance, tree diameters), frequency distributions (*i.e.* area) of biodiversity conditions can be derived by linking photo-types with permanent sample plots (where the former provide area and the latter the proportion of that area possessing certain characteristics). While valuable, this has the shortcoming of offering limited or no spatial resolution as to the location of those conditions.

A spatial distribution of biodiversity conditions requires that all independent variables employed in the forest characterization be available for all stands in the forest. Photo-interpretation is simply incapable of providing detailed stand variables (*e.g.* snag abundance). However, Light Detection and Ranging (LIDAR) data have the potential to provide such variables on a stand-specific basis and thus offer the opportunity to create spatially explicit assessments of biodiversity conditions.

The approach employed requires LIDAR data to be accurately geo-registered to specific ground locations for which detailed stand measurements have been made. The former provides the independent variables used in construction of regression equations to predict the independent variables provided by the latter. Since LIDAR is capable of providing the independent variables for all stands, stand-specific point cloud data can be input to the regression models to provide detailed stand variables comprehensively across the forest. This would enable application of the forest characterization scheme to each and every stand which, in turn, would enable spatially explicit assessment of forest biodiversity.

Research Needs and Actions

Significant advances have been made in building quantitative relationships between LIDAR point cloud data and detailed stand characteristics and such work is being conducted in many jurisdictions and by many agencies (Treitz *et al.* 2012, and Valbuena *et al.* 2017).

The Department's permanent sample plot network provides ideal ground locations and inventory data to which LIDAR data can be registered, thus enabling construction of relationships between LIDAR data and stand variables of interest. LIDAR has been collected on approximately 16% of the province and full provincial coverage is expected to be complete within five years. The Department has collaborated with a vendor in the development of enhanced forest inventory (EFI) metrics for 13% of the province while internal capacity and processes are built to develop the EFI metrics in-house. In addition to the EFI metrics, it is expected that statistics generated directly from LIDAR point clouds can be of use in modeling. Several agencies, including the Canadian Forest Service and New Brunswick Department of Energy and Resource Development, have considerable experience analyzing LIDAR data which should prove valuable in fostering the Department's efforts in this regard.

Action 2.3.1: For areas in which LIDAR is available, initiate research to construct relationships between LIDAR point cloud data and stand variables employed in the forest characterization scheme.

2.4 Biodiversity Targets and Thresholds

Overview

The maintenance of biodiversity is predicated on establishing that enough habitat exists to maintain viable populations of desired species. There are hundreds of species of vertebrates and thousands of species of invertebrates, plants, and fungi in the forests of Nova Scotia. With this high number of species, managing the forests of Nova Scotia on a species-by-species approach is not feasible. Hunter (1990) introduced the coarse-filter and fine-filter approaches for managing forest wildlife habitat. Coarse-filter targets and thresholds can provide habitat requirements for the majority of species, while a fine-filter approach facilitates the maintenance of habitat required by a small number of selected species that are valued by society (*e.g.* species at risk (SAR), and keystone, surrogate, hunted species).

The Department of Lands and Forestry currently uses some coarse-filter and fine-filter approaches in its forest management planning system. Coarse-filter targets and thresholds are set up in strategic forest planning modelling and are proposed to be used in landscape (tactical) forest planning. Coarse-filter targets and thresholds are based on forest communities (forest elements) and maturity classes. The present targets for the amount and age class of forest are based on broad-scale existing forest cover (*i.e*., based on enduring features, and age class associated with natural disturbance regimes). FBSAC is recommending that these targets be additionally supported by setting targets based on the minimum habitat required for viable populations of surrogate species. Surrogate species typically are strongly dependent on a certain forest type and/or age class and have large space requirements; enough habitat for these species potentially encapsulates viable populations of many species needing smaller amounts of the same habitat.

The fine-filter approach is primarily used at the operational forest planning level through Special Management Practices (SMPs). Fine-filter modelling is being done in the strategic and landscape level planning pilot project for a few selected species (*i.e.,* 'Strategic species': Moose, Deer, and Marten; 'landscape pilot species': Goshawk, Pileated Woodpecker, Eastern Wood Pewee, Olive-sided Flycatcher). No formal process has been established for the selection of species to be used in the forest management planning. The current species used seem to have been selected on an ad-hoc basis. There is uncertainty on whether these are the best species to feature in the fine-filter approach, and which species may be useful in a coarse-filter approach. Species need to be linked to the forest inventory. A key criterion for species selection is their sensitivity to forest/land management or land-use changes - the more sensitive, the higher their utility. Some of these species are at risk of extirpation and are listed under federal or provincial legislation (Section 2.8). Current targets for fine-filter species are not related to minimum viable populations (MVPs).

There is a need for a more comprehensive and structured approach to the coarse- and fine-filter approaches. This issue is apparent in the management of old-growth forests. Old-growth forests in Nova Scotia are hot spots for biodiversity. Within the Acadian Forest Region, old-growth has declined significantly through several centuries of land use. The Department established an 8% target under its Old Forest Policy (NSDNR 2012) for each ecodistrict to conserve old forest and the associated biota. The 8% value is based on a coarse-filter approach that incorporates the amount of old-growth derived from natural disturbance regimes, land ownership, and society's diverse, and sometimes conflicting, demand on the forest resource. The Old Forest Policy specifically defines the tree species and forest ages that determine what is considered old-growth forest but there is uncertainty whether these old-forest definitions and targets appropriately conserve these unique ecosystems. One means of setting targets for old-growth is to combine coarse- filter approaches (*e.g.* natural disturbance, and minimum habitat thresholds of surrogate species), with fine-filter approaches (*e.g.* habitat requirements of listed species dependent on old-growth condition).

Research Needs and Actions:
Habitat targets for coarse- and fine-filter species at the strategic level need to be aligned with a more appropriate classification of forest habitat, as outlined in section 2.1. The Department needs to understand the types of species that are mostly likely associated with this new ecosystem (habitat) classification.

The vertebrate species known to be associated with specific forest types are already established (*e.g.* Maine Biodiversity [DeGraaf *et al.* 1992]; Ontario [D'Eon and Watt 1994]; New Brunswick [NBDERD habitat programme], but it is recommended that a collaborative effort of the Department, environmental organizations, industry, and academics be used to select species most relevant to ecological units in Nova Scotia.

Action 2.4.1: Identify the forest-dependent species associated with the new habitat classification (section 2.1 of this report).

Current targets for fine-filter species are not established in relation to MVPs. Is there enough habitat to maintain populations of those selected species? This knowledge is in hand for some species (*e.g.* forest passerine birds; *e.g.* Betts *et al.* 2007), which may dictate which species are selected. Otherwise, further research is needed.

Action 2.4.2: Conduct research on minimum habitat thresholds for selected species.

Most species in Nova Scotia forests are not vertebrates and it is possible that targets based on vertebrates do not adequately protect these species. There is limited understanding of how well these species respond to forest practices or relate to forest inventory datasets (and thus our ability to forecast viability). The coarse-filter approach is promoted as the most practical means to deal with this uncertainty. Notwithstanding, it would be prudent to review this approach. The review could lead to an increased, and more taxonomically diverse, set of species used in the fine-filter approach.

Action 2.4.3: Conduct an assessment of the efficacy of focusing on vertebrates for biodiversity conservation planning.

Once surrogate and fine-filter species have been selected, the Department needs to establish targets that can be tracked in future forest modelling of wood supply and habitat abundance. Given the societal pressures on a finite forest area, there is a tendency for minimum habitat targets to become the maximum that will persist into the future. Therefore, the setting of minimum targets needs to be somewhat precautionary to accommodate uncertainty with climate change.

Action 2.4.4: Establish new targets and thresholds, unique to appropriate ecological zones, for new habitat classifications (section 2.1) and NDRs (section 2.7).

The Department has created targets by ecodistricts for the amounts of old forest under its Old Forest Policy. These old-forest targets provide a coarse-filter approach to forest species conservation. Is conservation of some forest types inadequate (thus imperiling dependent flora and fauna) under the Old Forest Policy because the targets are set at an inappropriate spatial level?

According to Stewart and Neily (2008), the 8% targets set out in the Old Forest Policy have not been reached in a number of ecodistricts. The Department needs to rectify this management deficiency. In addition, it needs to evaluate the old-growth definitions contained in the policy (*e.g.* types of species considered), examine whether the policy targets are being used appropriately, and develop an approach for better representation of other old-forest types.

Action 2.4.5: Integrate coarse- and fine-filter approaches with enduring features and natural disturbance in setting old-growth targets.

2.5 Forest Landscape Planning

Overview

Traditional biodiversity conservation measures have focussed on the site level, that is, at a fine spatial unit. Because forests cover over three-quarters of the province, forest biodiversity can appropriately be understood and managed at all spatial levels, from the site through the landscape up to the full province. Some native species with small home ranges can have viable populations at the site level, but many require appropriate habitat area at the landscape level to ensure persistence. Understanding how forest management activities and patterns across the landscape influence biodiversity is essential.

In recent decades, landscape ecology has advanced considerably as a discipline (Turner *et al*. 2001). This emerging science has been applied in other Canadian provinces in forest analysis and planning (*e.g*., in Alberta - Boutin and Hebert 2002; Doyon and Duinker 2003), but applications are lacking in Nova Scotia and therefore the potential insights from landscape ecology are unavailable here. The province needs the planning insights and uncertainty reduction anticipated from the Department's landscape planning pilot project. The coarse-filter approach to conservation of forest biodiversity (Hunter and Schmiegelow 2011), as used in the pilot project, is as yet untested in Nova Scotia. A first-approximation assessment of landscape-level biodiversity responses to alternative forest-management strategies is within reach with available data and reasonable assumptions. First results should indicate timings and locations where choices about forest practices are least and most important from a biodiversity perspective.

Research Needs and Actions

Over periods of several decades to a century into the future, and across landscapes at the ecodistrict and ecoregional levels, there is limited understanding of how alternative arrays of forest practices (*i.e*., types, timings, extents) might affect the full array of characterizations of biodiversity in terms of ecosystems and species. Spatial simulation is the appropriate approach to reduce these uncertainties.

Action 2.5.1: Accelerate the completion of the landscape planning pilot project and bring its results out for peer review by a broad range of NS forest experts and stakeholders.

Action 2.5.2: Undertake research to reduce the specific uncertainties revealed by the pilot project and aim to replicate improved versions of the approach across all Crown forests in the province.

2.6 Role of Private Forest Land in Biodiversity Conservation

Overview

Only about one-third of NS's forest land is in public ownership; the rest is private. The pattern of ownership in the province varies widely across regions and forest types. Thus, it is highly challenging, if not impossible, to conserve the province's forest biodiversity on public lands alone. Land use can isolate and fragment forest and thereby alter the amount, configuration, and function of habitat.

Ownership patterns have tremendous potential to influence metapopulation dynamics and gene flow of forest species. The ecological scales at which species operate often diverge significantly from the scales of ownership and forest management. As a result, mechanisms are needed to encourage, or even oblige, biodiversity conservation measures on private forest land, and to integrate forest practices across land ownerships on larger areas. Private land can be crucial to biodiversity conservation, both in maintaining landscape connectivity and protecting 'biodiversity and species-at-risk hotspots', but its potential role is constrained by tenure and its security (Kamal *et al.* 2014).

Such landscape-level management issues might even necessitate changes in ownership patterns through mechanisms such as land exchange. However, the process of conservation on private forest land begins by engaging landowners, informing them of the biodiversity value of their lands, and informing them of appropriate management alternatives that conserve biodiversity values. While the approach may be landowner-specific, it is essential to communicate to the landowner the biodiversity value at both local (woodlot) and regional levels and practical ways by which to conserve it.

Research Needs and Actions

Biodiversity- and species-at-risk hotspots are well documented for some taxa. However, the spatial resolution of knowledge varies both taxonomically and geographically.

Action 2.6.1: Resolve further the distribution of known hotspots relative to land tenure, and identify additional hotspots.

The relationship between land tenure patterns and landscape connectivity in NS has been explored for some areas and taxa (*e.g.*, Beazley *et al.* 2005), but a systematic and broadly taxonomic approach is lacking to date. This is challenging, since connectivity is largely taxon-dependent. To ensure existing and future integrity of a broad array of SAR, such an approach is essential, particularly in light of projected climate change.

Action 2.6.2: Map connectivity (present) and projected climate-change impacts on connectivity patterns (future) for an array of species at risk province-wide.

The ecological, spatial, and temporal scales at which biota, particularly fauna, operate (*e.g.*, food acquisition, reproduction, predator avoidance, seasonal movements, dispersal) vary across taxa. Spatial activity may or may not be affected by land ownership, depending on the taxon involved and existing land use/management practices.

Action 2.6.3: Examine the degree of congruence between spatial dimensions of land ownership and the ecological levels at which SAR operate, across a diverse array of taxa.

Private landowners are frequently unaware of the multi-faceted value of biodiversity on their properties, both at the local (woodlot) level and beyond. A variety of approaches is available to communicate those values, but research on their relative effectiveness is limited.

Action 2.6.4: Evaluate a range of messaging scenarios to communicate biodiversity values to private landowners. Assess the level of understanding of values both pre- and post-communication, as well as attitudinal and behavioural shifts.

Since the spatial dimensions of biodiversity often diverge significantly from those of ownership and forest management, it is essential to encourage landowners to consider participation in novel and integrated forest management across multiple ownership and private/public domains.

Action 2.6.5: Explore and test models for collaborative/integrated forest management across multiple ownerships and private/public domains. Adoption of existing models from other jurisdictions, suitably adapted to Nova Scotia, may be both cost-effective and efficacious.

2.7 Natural Disturbance Regime

Overview

The natural disturbance regime (NDR) is the combination of disturbance types, intensities, and frequencies to which a forest area is naturally prone. The premise in biodiversity planning is that biota are adapted, at least in part, to both the enduring features of the landscape (*e.g.* geology, slope, soil, *etc*..) and a disturbance regime that alters the forest age, composition, and structural elements. An understanding of the NDR of an area and its impact on forest composition, configuration, and structure can thus be used to establish objectives for the amount of old growth, the sizes of forest patch or clearcuts, the presence of tree islands and corridors, and the amount of snags and debris (Seymour *et al*. 2002; Stewart *et al.* 2003; Perrera *et al*. 2004) deemed necessary to maintain extant species. In Nova Scotia, NDR is used in setting targets for the amount of mature forest; for example, areas exposed to frequent disturbance (from fire, wind, or insects) would have a lower target for mature forest than forests where disturbance is infrequent, such as tolerant hardwood stands. The province's NDR programme is detailed in Neily *et al*. (2008).

There is uncertainty regarding how well a forest that is managed based on NDR principles actually maintains biodiversity. Fundamental differences in residual structures, nutrient levels, and return intervals in post-fire and clearcut stands are a concern.

Research Needs and Actions

Presently, NDR is used at a strategic level in setting targets for the amount of mature forest. However, there also are operational practices, such as pre-treatment assessments (PTAs), that could affect the meeting of those targets. The PTAs result in harvest prescriptions, such as whether a clearcut or selection harvest is recommended, based on stocking, wind-throw risk, *etc*., in each stand. There is a risk that the accumulation of many separate operational actions, such as clearcut harvest, may impede targets for maintaining mature forest in a landscape characterized as low-frequency disturbance.

Action 2.7.1: Establish explicit coordination between site-level prescriptions and strategic-level targets.

NDR is based on data about the past and present. As such, our understanding is limited to the quality and resolution of written accounts, witness tree data, and various bio-physical assessments (*e.g*., charcoal in soil; Ponomorenko and Ponomorenko 2000). The amount of human-origin fires has increased over the last 300 years during European colonization; therefore, stand-replacing disturbance may be overestimated because it is difficult to separate natural and human-origin fires (Fernow *et al*. 1912; Mosseler *et al*. 2003).

Action 2.7.2: Research the extent of high frequency, stand-replacing disturbance events in the last 300 years, by ecoregion.

Some forest originated from disturbance events occurring hundreds of years ago and it is difficult to assess how existing or future disturbance events will compare to past conditions. There is evidence that wind storms, for example, are changing in frequency (Walmsley 2009). It is likely that future climate-related disturbances will vary in intensity and impact compared to historical regimes but the way in which biodiversity will respond is unknown. Therefore, it is important to critically assess the role and value of historical natural disturbance regimes in guiding management decisions. At some point, the use of historical data for setting targets will need to be abandoned, and new targets will be derived from a new NDR.

Action 2.7.3: Develop more sophisticated methods for forecasting potential types, intensities, and frequencies of future NDR, with predictions on how biodiversity may be able to respond and adapt.

2.8 Forest-Dependent Species at Risk

Overview

Nova Scotia supports a diverse array of species at risk (SAR); history and geography have shaped the present patterns of distribution and abundance of those taxa. It is worthwhile to examine and understand that past, since for many of these species it holds the key to predicting their future and facilitating their adaptation to changing environments.

Many of our SAR have disjunct distributions with either southern or northern affinities – relicts from warmer or cooler post-glacial climates, respectively. Although the two groups share common features (*e.g.* low effective population size (N_e), evolutionary distinctiveness from main range populations, local adaptation), the probable population and evolutionary trajectories for the two groups under a warming climatic regime differ dramatically.

Degrees of public and scientific awareness, understanding, and interest vary tremendously among taxa. The focus in Nova Scotia to date has been primarily on relatively large charismatic and wide-ranging mammals (*e.g.,* American Moose, Canada Lynx, American Marten), birds (*e.g.,* Bicknell's Thrush, Canada Warbler, Eastern Wood Peewee, Olive-sided Flycatcher), turtles (Blanding's Turtle, Wood Turtle), herbaceous plants (particularly Atlantic Coastal Plain flora), and more recently lichens (*e.g.,* Boreal Felt), bats (Northern Myotis, Little Brown, Tri-coloured), and trees (*e.g.,* Black Ash). However, significant knowledge gaps remain, even for large, listed species (*e.g.*, Eastern White Cedar).

These species face an array of threats – some unique, some shared; habitat loss, degradation, and fragmentation (inside and outside Nova Scotia for migratory species.); human-subsidized predators; invasive pathogens; climate change; traffic-related disturbance and mortality; genetic bottlenecks). Many of these threats result directly or indirectly from past and present forest management practices, often with time lags. However, the connections to those practices are not always well understood.

Our knowledge of the ecological roles and resilience of Nova Scotia SAR is far from complete. Additionally, the vast majority of forest SAR is yet to be documented; entire taxonomic groups remain unexplored, including some that play critical functional roles in forests (*e.g.* fungi).

Research Needs and Actions

The degree to which forest practices contribute to stress on SAR is poorly understood for most species. Any assessment of impacts begins with an understanding of species distributions. Present distributions are well documented for only a handful of primarily large and charismatic species; most forest SAR are still undocumented and for many taxa status remains unassessed. For instance, there is virtually no knowledge of fungi or most invertebrate groups (including forest arthropods).

Action 2.8.1: Carry out inventories to detect presence and distribution of SAR taxa (presently known or suspected to occur in NS).

For most SAR, population history and genetic structure, including N_e, as well as the ecological scale(s) at which the taxa operate, are poorly known. Understanding these elements is critical to incorporate SAR management in the design of forest management protocols. In particular, the understanding of spatial scale is essential to assess the nature of landscape connectivity required for the existing and future integrity of individual SAR taxa (D'Eon *et al.* 2002).

Action 2.8.2: Promote and support population assessments for SAR.

Once presence, distribution, and population structure of SAR are documented, monitoring regimes are required to measure impacts of ongoing forest management practices and other activities. Monitoring protocols and secure databases already exist for some forest SAR in Nova Scotia, and a web platform is already in place [**www.speciesatrisk.ca**].

Action 2.8.3: Develop and/or tap into existing standardized and integrated (where appropriate) monitoring protocols and secure databases for SAR.

After status of SAR is determined, timely comprehensive recovery planning should follow. Delays in creation of recovery teams and/or in the creation of recovery plans are not uncommon. Recovery plans are living documents, and as such evolve as understanding of individual taxa and environmental influences on them grows.

Action 2.8.4: Complete or update conservation/recovery plans as soon as possible.

Traditionally, SAR assessment and conservation have focussed on individual species. This species-specific approach is costly, and often assumes that 'all species are created equal' and that species operate independently. Neither is true. While we still do not understand all the critical ecosystem roles that individual SAR may play, we do know that some taxa influence ecosystem structure and function more than others. We also know that management actions to support one species can be incompatible with those for supporting another.

Action 2.8.5: Encourage collaboration among recovery teams, when possible and appropriate, to realize synergies, reduce duplication of effort, and minimize contradictory management actions.

In Nova Scotia, management for harvested wildlife has historically been well coordinated with forest management, but has operated largely independently of management for other biota, including SAR. Any long-term sustainable ecosystem management requires a more coordinated and integrated approach, including consideration of cumulative effects of forest management on all biodiversity. Cumulative effects assessment is challenging to implement but definitely worthwhile as insights from robust applications are powerful guides in resource and environmental decision-making (Sinclair *et al.* 2017).

Action 2.8.6: Broaden expertise on species-specific recovery teams to include experts in forest management and forest wildlife-habitat relationships, as well as traditional ecological knowledge.

Action 2.8.7: Coordinate among managers to minimize potential conflict among forest habitat objectives for species-at-risk and other priority species, such as harvested wildlife.

Action 2.8.8: Implement cumulative effects assessment to ascertain impacts of forest practices.

The unifying feature and single greatest forest management challenge for both forest-dependent SAR and harvestable taxa is climate change. The potential direct and indirect impacts are far-reaching, influencing physiology and growth, competitive dynamics, and exposure and resistance to pathogens. Effective management requires understanding the degree of resilience to climate change, as well as the likely landscape-level influences on populations and ecosystems. Extensive modelling on species-specific and ecosystem-level impacts of climate change exists, including some specific to Nova Scotia (*e.g.,* Herman and Scott 1992; Steenberg *et al.* 2012).

Action 2.8.9: see 2.11.

2.9 Invasive Alien Species and Irruptive Native Species

Overview

"An invasive alien species [IAS] is one introduced outside its normal distribution, whose establishment and spread can affect ecosystems, habitats, or other species" (NSDNR 2017). An avian example is the European Starling. An irruptive native species (INS) is one native to a habitat but for which conditions that control its abundance (*e.g.,* food, weather) change to a sufficient degree that its population increases dramatically and overshoots the habitat's carrying capacity. These are also known as outbreak species (Wallner 1987). An insect example is the Eastern Spruce Budworm.

Two major forces are driving potentially massive changes in the biodiversity complexion of the world's ecosystems: climate change and globalization. Climate change can potentially alter local habitats so that they become newly hospitable to species not previously found there (*i.e*., alien species), and increasingly inhospitable to some native species. Globalization, be it economic, cultural, or ecological, has meant dramatically increased movements of people and goods around the world, with the inevitable deliberate and accidental introductions of new species to Nova Scotia. Clearly, both these drivers facilitate movement of species around the world to ecosystems in which they are novel, and sometimes, if invasive, to the serious detriment of native species (NSDNR 2017).

Numerous examples of IAS are relevant to Nova Scotia's forests: Brown Spruce Longhorn Beetle (Natural Resources Canada 2018a), Emerald Ash Borer (Natural Resources Canada 2018b), Hemlock Woolly Adelgid (Canadian Food Inspection Agency 2017), Norway Maple (Belliveau 2012), Scots Pine (Belliveau 2012), European White Poplar (Swearingen and Bargeron 2016). Climate change is expected to alter species relationships sufficiently among some native species themselves to modify "normal" forest dynamics. The Mountain Pine Beetle serves as a noteworthy Canadian example; this insect is indigenous to the Lodgepole Pine forests of western Canada but became seriously irruptive with the loss of long and deep winter cold periods in central British Columbia. In Nova Scotia, the Eastern Spruce Budworm is a native species that exhibits significant outbreaks with concomitant high mortality rates among the spruces and Balsam Fir (Natural Resources Canada 2018c). Both IAS and INS are potentially highly disruptive to the conservation of native biodiversity in Nova Scotia's forests. Their negative or positive effects on native biodiversity should be considered during the design of forest practises.

Research Needs and Actions

Considerable uncertainty exists in regard to the spread, infection, and damage rates of IAS and INS in Nova Scotia. Appropriate methods for keeping IAS out of the province are unclear. For example, what are the prospects for controlling the importation of firewood into Nova Scotia from Quebec or New Brunswick where the nearest infestations of Emerald Ash Borer currently exist? What IAS are being imported into Nova Scotia by landscaping firms, plant nurseries, and garden centres? Additionally, the prospects for future populations of existing IAS and INS, and how those future populations might jeopardize the conservation of native biodiversity in Nova Scotia, are unknown. Furthermore, confidence is currently low in predicting responses of all species in Nova Scotia to a changing climate, including IAS and INS.

Action 2.9.1: Develop a broad program of research to support creation of an IAS and INS management program, ensuring that it addresses the population dynamics of IAS currently in Nova Scotia as well as the influence of climate change on those population dynamics.

The forest ecosystems of Nova Scotia will face a panoply of stresses during the 21st century, including IAS and INS. Forest ecosystem persistence in the face of such stresses will depend on their resilience.

Action 2.9.2: Research how to characterize forest resilience and discover what factors enhance resilience of forest ecosystems, especially in the face of IAS and INS, including alternative approaches to adjustment of forest structure and tree-species composition.

Presumably, forest owners and managers in Nova Scotia will want to do something if they find that IAS and INS are negatively affecting their woodlands. The tools for dealing with IAS and INS are relatively well known compared to the understanding of the social acceptability of the various methods for controlling the full range of IAS and INS including tree species, other plant species, vertebrate species, invertebrate species, and others.

Action 2.9.3: Determine what the people of Nova Scotia are willing to accept with respect to control measures, and under what conditions that acceptance might exist or be developed.

2.10 Land Use

Overview

Forest practices for timber production are doubtless a major influence on forest biodiversity. However, other human activities on the land cannot be discounted as additional potential threats to biodiversity - minerals extraction, oil-and-gas development, wind farms, urban expansion, new and expanded highway corridors, agriculture (including blueberry production), aggregate extraction, and others. It is important for the Government of Nova Scotia to know how the full range of human activities in and on the forest landscape may cumulatively affect key elements of forest biodiversity. The critical starting point in cumulative effects assessments is to define the full range of human activities that are key drivers of biodiversity conditions, including analysis of the potential spatial distribution of such activities for several decades into the future. This analysis is best accomplished by first using participatory scenario construction, then determining how the individual effects of each driver interact with those of other drivers, in potentially complex ways. The outcome will better identification of appropriate management and policy directions to conserve native forest biodiversity because separate land-use practices are integrated into a more holistic analysis.

Research Needs and Actions

What is the current state of intensive land uses (*e.g.* farms, oil and gas, urban) in Nova Scotia, and what type of impacts do they have on biodiversity?

Action 2.10.1: Determine the current state of developed lands and develop comprehensive, current land-use mapping and characterization of land-use intensity (related to biodiversity, *e.g.* ecological emphasis index).

How does the location of intensive land-use influence remaining patches of forest habitats? What is the current degree of forest fragmentation in ecodistricts with intensive land-use (*e.g.*, Annapolis Valley, Truro area)?

Action 2.10.2: Determine the current degree of forest fragmentation in each ecodistrict.

Transportation corridors have significant undesirable impacts on forest-dependent species, including impacts on species movements (this relates to connectivity). To better conduct land-use planning, it is essential to understand the key areas for wildlife movement across the major highways in Nova Scotia. The overall intensity of roads within an area can have many impacts on biodiversity (Bennett 2017; Basille *et al.* 2013). Understanding current road intensities can help integrate land-use and road network planning with forest management planning.

Action 2.10.3: Develop and apply tools to determine the areas that are important for wildlife movement associated with road corridors.

Action 2.10.4: Evaluate and possibly update Nova Scotia's road index (road density) tool (Stewart and Neily 2008) .

2.11 Climate Change

Overview

Climate models suggest that Nova Scotia will have warmer and drier summers and milder and rainier winters, which likely will influence growing conditions for most plant species, alter forest-fire frequency and intensity, and facilitate epizootic events of existing and invasive insect species. These changes will ultimately result in altered tree-species assemblages, vegetative communities, forest spatial patterns, and age-class distribution, which in turn will affect habitat for most forest-associated wildlife. Landscape connectivity will be increasingly relevant because some species will need to alter their range in order to persist. Increased intensity of rain events likely will exceed capacity of existing infrastructure (roads, culverts) and cause increased sedimentation events in forested waterways and wetlands. Changes in natural disturbance dynamics will render restoration and NDR-based management less relevant and useful as approaches for managing forests and the biodiversity therein. It will be beneficial to extend existing tree species as long as possible as a means of retaining existing biodiversity, and facilitating changeover to new species-habitat relationships in the future.

The Government of Nova Scotia has presented modeled baseline information on temperature (maximum and minimum), precipitation (including extreme precipitation events), and growing season length for each region of Nova Scotia. Data are available for a historical baseline period (1961-1990) with projections in 30-year increments to 2100, based on the Canadian Global Climate Model (Nova Scotia Environment 2014). Several projects have modeled growing conditions for commercial tree species, identifying those species likely to thrive or decline in the next 100 years (*e.g.* Bourque *et al.* 2007; Steenberg *et al.* 2011, 2012; Ashraf *et al.* 2015). Understanding of the impact of climate change on other wild species is weak, with studies limited to a small number of species, and even then only at a general, unquantified level (*e.g.*, Herman and Scott 1992; Snaith and Beazley 2004).

Research Needs and Actions

The impact of future natural disturbance events on biodiversity is unknown. An understanding of predicted impacts will inform old-forest objectives, habitat objectives, and SAR recovery plans.

Action 2.11.1: Determine the impact of increased frequency and intensity of natural disturbance events (fire, wind, insect defoliation) on habitat types characterized in biodiversity planning. Establish amount of habitat loss (and, if possible, population change) associated with natural disturbance regimes.

The response of species to predicted future conditions is unknown for most species. The Department is mandated to maintain viable populations of native wildlife, in particular SARs, but lacks enough understanding of how species are expected to respond to the changing type, amount, and configuration of vegetative communities. This knowledge will inform a variety of management practices, such as endangered species recovery plans, use of indicator species to set minimum habitat objectives, and appropriate species and provenance for planting/reforestation.

Action 2.11.2: Determine the viability of SARs considering a changing climate. Assess the ongoing utility of existing indicator species used to gauge ecological effects of forest management practices. Identify tree species that are resilient to change. **Determine the role of soil biota in influencing which new tree species (and communities) will colonize a changing landscape.**

The adequacy of existing and projected landscape connectivity for facilitating the movement of wildlife in a changing landscape is unknown. This knowledge will inform protected-area planning as well as adjacency/connectivity objectives in forest operations.

Action 2.11.3: Identify and forecast the location and structure (*e.g.*, gap size, canopy height, width) of forested corridors and protected areas as vehicles to facilitate migration of species during climate change.

3.0 Implementation

3.1 Overview

Given the imperative to conserve forest biodiversity in Nova Scotia, and the substantial uncertainty about how to do so, it would be prudent and timely to proceed with the research directions outlined above. Implementation priorities should respect and reflect the Natural Resources Strategy (NRS) of 2011, the Forest Practices Review recently undertaken by

William Lahey, and the emerging Biodiversity Act.

The NRS commits the Government to "strengthen research capacity". We see three ways to accomplish this: (a) increase research funding; (b) prioritize research in workloads of research-qualified staff; and (c) increase contributions of other research agencies through partnerships. Each is addressed in turn.

3.2 Research Funding

Although any increase in research funding for forest biodiversity conservation must be rigorously justified in a time of public-sector fiscal constraint, improved knowledge is critical to advance conservation. Therefore, the FBSAC strongly urges the Government of Nova Scotia to increase its funding allocations to high-priority research on forest biodiversity. The Government should consider establishing a forest biodiversity research fund, through which provincial research staff and university researchers can collaborate to supervise students working on priority forest-biodiversity knowledge needs.

3.3 Human Resources

In recent years, the Department of Lands and Forestry has increased its complement of PhD-qualified staff (there are currently four PhD holders in the Forestry Division and two in the Wildlife Division). Many additional staff hold bachelor's and master's degrees and have valuable research experience and expertise.Those motivated and skilled to engage in forest-biodiversity research should be assigned to such research to the greatest extent possible. This requires that they be mandated to do so and not overwhelmed with engagement in non-research activities. Their participation in adjunct professorships with Nova Scotia universities is strongly encouraged.

Accomplishing appropriate research and reducing key uncertainties for conservation of forest biodiversity requires scientific leadership. At present, the Department has neither a person nor a small group of qualified individuals to adequately and appropriately direct the overall program of forest-biodiversity research. The Department might consider the appointment of a chief biodiversity scientist. It might also make room in the civil service job classification for a class of scientist, with all the normal elements of research productivity for job and rank advancement.

3.4 Organizational Structure

FBSAC acknowledges the Department's achievements in implementing high-quality forest biodiversity science in recent years, but also observes what appear to be too many uncoordinated scientific efforts spread across multiple small groups. We recommend that the Department consider consolidating small research-oriented units with an eye to coordinating and integrating research in support of biodiversity conservation.

3.5 Collaborations and Partnerships

Additional expertise in forest biodiversity exists in the province's Department of Environment, and ways need to be found to enhance research cooperation between the two departments. Moreover, the Department needs to increase its research collaborations and partnerships with external organizations, including the Government of Canada (*e.g.*, Canadian Forest Service, Canadian Wildlife Service), universities (with their substantial capacity to attract diverse research funds and exceptional research students), and non-government organizations (*e.g.,* Mersey Tobeatic Research Institute). The Department needs to use its limited research funds more effectively to leverage external research funds for forest biodiversity conservation.

The recent demise of the Nova Forest Alliance and lack of ongoing organizational structure for convening Nova Scotia's forest stakeholders to address forest sustainability has reduced awareness among stakeholders of the state of forest biodiversity and the initiatives being taken to address its conservation. The FBSAC urges the Department to work with key stakeholders to organize an annual forest biodiversity science forum for various parties to share research findings and perspectives.

4. Conclusion

We urge the Department of Lands and Forestry to take our recommendations and turn them into a detailed research plan to address key uncertainties related to the conservation of forest biodiversity. The elements are outlined above. With the knowledge of Departmental resources, opportunities, and constraints, the Department can readily develop such a plan. In accordance with the 4th objective in the Committee's Terms of Reference (*i.e*., "Assist in the design of research projects under the strategic research plan"), we stand ready to assist in crafting and implementing the detailed plan.

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6.0 List of Actions

Action 2.1.1: Using the work of Basquill *et al*. (2016) as a starting point, and with engagement of individuals from all forestry and wildlife units, outside researchers, and other knowledgeable parties, devise a forest characterization scheme adequate for coarse-filter assessment of biodiversity from whatever perspectives are deemed important by the Department.

Action 2.1.2: Apply the forest characterization scheme to the existing forest inventory to create a summary of biodiversity status of the current forest.

Action 2.2.1: Once the forest characterization scheme is developed, modify existing growth and yield models to ensure that all stand variables employed in that scheme are provided as model outputs.

Action 2.3.1: For areas in which LIDAR is available, initiate research to construct relationships between LIDAR point cloud data and stand variables employed in the forest characterization scheme.

Action 2.4.1: Identify the forest-dependent species associated with the new habitat classification (section 2.1 of this report).

Action 2.4.2: Conduct research on minimum habitat thresholds for selected species.

Action 2.4.3: Conduct an assessment of the efficacy of focusing on vertebrates for biodiversity conservation planning.

Action 2.4.4: Establish new targets and thresholds, unique to appropriate ecological zones, for new habitat classifications (section 2.1) and NDRs (section 2.7).

Action 2.4.5: Integrate coarse- and fine-filter approaches with enduring features and natural disturbance in setting old-growth targets.

Action 2.5.1: Accelerate the completion of the landscape planning pilot project and bring its results out for peer review by a broad range of NS forest experts and stakeholders.

Action 2.5.2: Undertake research to reduce the specific uncertainties revealed by the pilot project and aim to replicate improved versions of the approach across all Crown forests in the province.

Action 2.6.1: Resolve further the distribution of known hotspots relative to land tenure, and identify additional hotspots.

Action 2.6.2: Map connectivity (present) and projected climate-change impacts on connectivity patterns (future) for an array of species at risk province-wide.

Action 2.6.3: Examine the degree of congruence between spatial dimensions of land ownership and the ecological levels at which SAR operate, across a diverse array of taxa.

Action 2.6.4: Evaluate a range of messaging scenarios to communicate biodiversity values to private landowners. Assess the level of understanding of values both pre- and post-communication, as well as attitudinal and behavioural shifts.

Action 2.6.5: Explore and test models for collaborative/integrated forest management across multiple ownerships and private/public domains. Adoption of existing models from other jurisdictions, suitably adapted to Nova Scotia, may be both cost-effective and efficacious.

Action 2.7.1: Establish explicit coordination between site-level prescriptions and strategic-level targets.

Action 2.7.2: Research the extent of high frequency, stand-replacing disturbance events in the last 300 years, by ecoregion.

Action 2.7.3: Develop more sophisticated methods for forecasting potential types, intensities, and frequencies of future NDR, with predictions on how biodiversity may be able to respond and adapt.

Action 2.8.1: Carry out inventories to detect presence and distribution of SAR taxa (presently known or suspected to occur in NS).

Action 2.8.2: Promote and support population assessments for SAR.

Action 2.8.3: Develop and/or tap into existing standardized and integrated (where appropriate) monitoring protocols and secure databases for SAR.

Action 2.8.4: Complete or update conservation/recovery plans as soon as possible.

Action 2.8.5: Encourage collaboration among recovery teams, when possible and appropriate, to realize synergies, reduce duplication of effort, and minimize contradictory management actions.

Action 2.8.6: Broaden expertise on species-specific recovery teams to include experts in forest management and forest wildlife-habitat relationships, as well as traditional ecological knowledge.

Action 2.8.7: Coordinate among managers to minimize potential conflict among forest habitat objectives for species-at-risk and other priority species, such as harvested wildlife.

Action 2.8.8: Implement cumulative effects assessment to ascertain impacts of forest practices.

Action 2.8.9: see 2.11.

Action 2.9.1: Develop a broad program of research to support creation of an IAS and INS management program, ensuring that it addresses the population dynamics of IAS currently in Nova Scotia as well as the influence of climate change on those population dynamics.

Action 2.9.2: Research how to characterize forest resilience and discover what factors enhance resilience of forest ecosystems, especially in the face of IAS and INS, including alternative approaches to adjustment of forest structure and tree-species composition.

Action 2.9.3: Determine what the people of Nova Scotia are willing to accept with respect to control measures, and under what conditions that acceptance might exist or be developed.

Action 2.10.1: Determine the current state of developed lands and develop comprehensive, current land-use mapping and characterization of land-use intensity (related to biodiversity, *e.g.* ecological emphasis index).

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Action 2.11.3: Identify and forecast the location and structure (*e.g.*, gap size, canopy height, width) of forested corridors and protected areas as vehicles to facilitate migration of species during climate change.