Focal Species and the Design and Selection of Ecological Benchmarks to Support the Implementation of Landscape Conservation Design in the Northwest Boreal LCC Planning Region

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INTRODUCTION

As priority conservation areas, ecological benchmarks support the implementation of monitoring and adaptive management, fundamental components of Landscape Conservation Design (LCD; U.S. Fish & Wildlife Service 2013). Ecological benchmarks are reference sites or controls for understanding the response of biodiversity to human activity, and are designed using coarse-filter features that represent large-scale ecological and evolutionary processes that shape landscape-level patterns. These coarse-filter features include intactness, natural disturbance (*e.g.*, fire), terrestrial and hydrologic connectivity, climate, primary productivity, and land cover (BEACONs 2017a). It is assumed that benchmark networks designed using these coarse-filter features will represent finer-scale elements of biodiversity and sufficient amounts of habitat to support monitoring programs. However, benchmark networks may fail to represent some elements of biodiversity such as rare or endangered species or habitats (Groves *et al.* 2002). The effectiveness of the coarse-filter features can be addressed by incorporating fine-filter conservation features, such as focal species (Lambeck 1997), into the design and selection of benchmark networks. For example, species data can inform the size and location of benchmarks (*e.g.*, Wiersma and Nudds 2009, Weeks *et al.* 2017), and species habitat models can be combined with simulation modelling to assess the long-term ability of benchmarks to support monitoring programs and other conservation objectives for species (*e.g.*, Carroll *et al.* 2003, Leroux *et al.* 2007a). When options exist, the selection process can be enhanced by ranking benchmark networks based on their contribution to conservation goals for focal species.

To support the use of focal species in the design and selection of ecological benchmarks, the Northwest Boreal Landscape Conservation Cooperative (NWBLCC) identified five objectives:

1. Identify priority focal species for the NWBLCC;
2. Synthesize existing conservation goals and measurable objectives for priority focal species within the NWBLCC;
3. Locate and integrate existing datasets and models for priority focal species from multiple sources (*e.g.*, federal and state/provincial agencies, non-governmental organizations). Data types for focal species include: distribution, abundance, predicted abundance and probability of occurrence models (*e.g.*, resource selection functions), minimum viable population estimates, home range size, relationships to human disturbances, and critical habitats (*e.g.*, Caribou calving grounds);
4. Identify gaps and opportunities for developing species-based products; and
5. Use priority focal species data to rank ecological benchmark network options.

In this report, we address objectives 1-5, with the fifth objective shared between this report and the main report describing the identification of benchmark networks (BEACONs 2017a). While the information gathered from this work is discussed and applied directly to the identification of benchmark networks (Objective 5), it can also be used to inform other elements of the broader LCD process such as the management of human activities and the maintenance of connectivity and migration corridors.

FOCAL SPECIES AND THE IDENTIFICATION OF BENCHMARK NETWORKS

The design and selection of candidate benchmark networks is a four-step process. The process is summarized here with a comprehensive description provided in BEACONs (2017a).

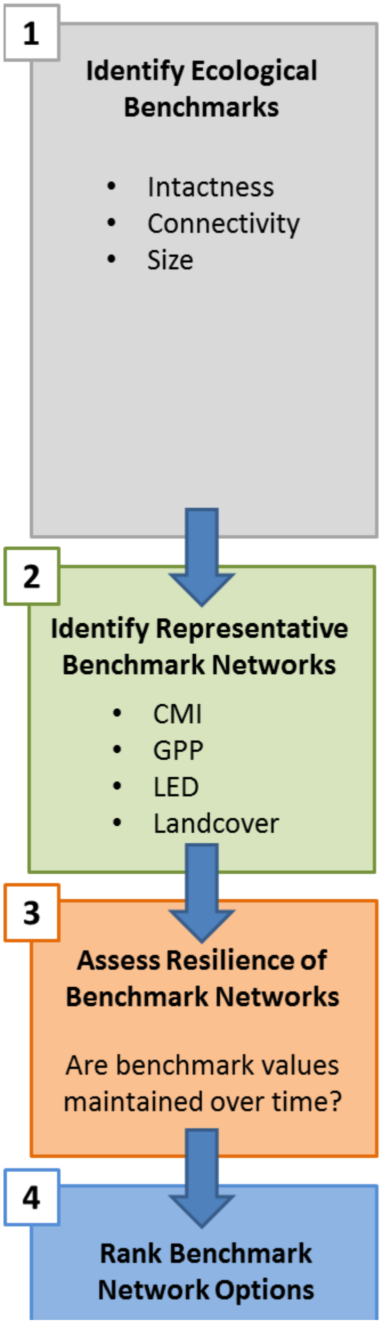

Figure 1: Stages of benchmark design and selection. Stages 1-3 are design, while Stage 4 is the use of additional information to guide the selection of networks from a suite of options.

The process starts with the identification of potential ecological benchmarks.

Benchmarks are designed to:

- Be **intact**, with little to no human disturbance, so that ecological and evolutionary processes are operating without influence by human activity.
- Support **terrestrial and hydrologic connectivity** to facilitate the flow of nutrients and organisms that in turn support ecological and evolutionary processes. To integrate terrestrial and hydrologic connectivity, benchmarks are assembled from catchments along stream networks, using hydrology-based assembly rules. And,
- Be of sufficient **size** to capture large-scale ecological processes and maintain habitat types vulnerable to natural disturbance. To achieve these objectives, benchmark size is the Minimum Dynamic Reserve (MDR) size estimated for the planning region (Leroux *et al.* 2007b).

Second, potential benchmarks are assembled into benchmark networks representative of the planning region.

Benchmarks are assembled into benchmark networks representative of the planning region using four biophysical indicators that serve as surrogates for biodiversity: climate moisture index (CMI, Wang *et al.* 2016), gross primary productivity (GPP; Zhao and Running 2010), lake-edge density (LED; BEACONs 2015), and land cover (CEC 2013).

Third, benchmark networks are evaluated with regards to resilience to natural disturbance.

Resilience to natural disturbance is addressed within the benchmark design process by using Minimum Dynamic Reserves to inform benchmark size. However, an MDR is a minimum estimate that may not be of sufficient size for all areas within the planning region. As such, a secondary testing of resilience through dynamic simulation modelling is recommended for all benchmarks in the network.

Finally, benchmark networks are ranked based on fundamental benchmark properties and the ability to support other conservation objectives.

Benchmark networks can be ranked based on other values including fundamental benchmark properties of the network (*e.g.*, vulnerability to upstream/downstream anthropogenic disturbance), resilience to climate change, contribution towards other conservation goals and targets (*e.g.*, representation of habitat for focal species), and avoidance of conflict with human activities.

While the design elements described above are based on coarse-filter features, there are multiple entry points for considering fine-filter focal species information. The identification of goals and associated targets for focal species is important for determining the appropriate point(s) of entry. Focal species information can be used as follows:

1

BENCHMARK SIZE - The habitat needs of focal species can be used to estimate the size of Minimum Dynamic Reserves (MDR; Leroux *et al.* 2007b). MDRs are designed to be resilient to natural disturbance (*e.g.*, fire) such that **internal recolonization** sources for vegetation types vulnerable to natural disturbance are maintained within the reserve at all times. Internal recolonization sources are **life-boats** for species that rely on habitats vulnerable to natural disturbance such as flammable vegetation types in the case of fire. The MDRs are estimated using dynamic simulation modeling that includes fire and vegetation succession models. MDRs must be of sufficient size to maintain specified minimum amounts of flammable vegetation types at all times during a 250-year simulation, repeated 100 times to capture the stochastic characteristics of wildfire. The minimum amount of flammable vegetation types required can be based on species needs and/or needs of a monitoring program. For example, if the target was *to maintain sufficient habitat to support 10 individuals of Species A for monitoring at all times given an active fire regime (e.g., 100 ha of old coniferous forest)*, the MDR size would be derived based on the condition that there would always be a minimum of 100 ha of old coniferous forest within the reserve. For more information on the identification of MDR estimates for the NWBLCC, see the MDR Report for the NWBLCC (BEACONs 2017b).

2

REPRESENTATIVE BENCHMARK NETWORKS – There are two options for incorporating focal species in the design and selection of representative benchmark networks. The first option is to add species habitat to the four biophysical indicators, where it is given equal weighting in the representation analysis. The second and more advisable approach is to identify benchmark networks based on the four biophysical indicators, and then follow up with a secondary ranking of the benchmark networks based on how well focal species habitat is represented, as described in 4 below.

3

RESILIENCE OF BENCHMARKS – Dynamic simulation modeling is used to assess the resilience of benchmark networks to natural disturbance to confirm that Minimum Dynamic Reserve requirements have been satisfied. This assessment can include species' models that track the amount of habitat available in the benchmark network over time, and rank candidate benchmarks networks on this basis.

4

RANK BENCHMARK NETWORK OPTIONS – Benchmark networks can be ranked based on how well they achieve the conservation goals and targets identified for focal species. For example, if the target was to protect 40% of early open water sites in the planning region, networks can be ranked based on their contribution to the target.

Objective 1 – Selection of Priority Focal Species

The NWBLCC selected a suite of priority focal species based on vulnerability to future landscape change as well as social/cultural importance. After consulting with partner organizations and external experts, the NWBLCC identified a set of 10 focal species that includes two species groups (Table 1). All species reside within both Canada and Alaska. The waterfowl species were merged into a Waterfowl Guild because data are scarce. The five species of Old-Forest Birds were selected based on their association with old forest and predicted decline under climate change (Stralberg *et al.* 2014). Other species considered, but not included, were brown bear, golden eagle, snowshoe hare, and two old-forest birds: Blackpoll Warbler and Common Redpoll.

***Table 1*.** List of priority focal species selected by the NWBLCC.

Species or Species Guild
Caribou (*Rangifer tarandus*)
Moose (*Alces americanus*)
Dall/Thinhorn Sheep (*Ovis dalli*)
Beaver (*Castor canadensis*)
Chinook Salmon (*Oncorhynchus tshawytscha*)
Chum Salmon (*Oncorhynchus keta*)
Broad Whitefish (*Coregonus nasus*)
Rusty Blackbird (*Euphagus carolinus*)
Old- Forest Birds - Boreal Chickadee (*Poecile hudsonicus*), Brown Creeper (*Certhia americana*), Pine Grosbeak (*Pinicola enucleator*), White-Winged Crossbill (*Loxia leucoptera*), Swainson's Thrush (*Catharus ustulatus*)
Waterfowl Guild - Trumpeter Swan (*Cygnus buccinator*), Lesser Scaup (*Aythya affinis*), White-Winged Scoter (*Melanitta deglandi*)

Objective 2 - Synthesis of Existing Conservation Goals and Targets

Conservation goals and targets guide planning efforts and provide measures that signal the success of the planning exercise. Conservation goals are the desired outcomes from a conservation planning process. A conservation target is a quantitative statement of what is required to achieve the goal (Margules and Pressey 2000, Groves and Game 2016). A target answers the questions protect what, how much, and where (*e.g*., protect 25% of wetlands in an ecoregion), and may include a time frame. Once goals and targets have been established, the various elements of the LCD process can be assessed with regards to how they can contribute to goals for coordinated and efficient conservation action. For example, while the primary function of benchmarks is controls for adaptive management, benchmarks can also contribute to a range of focal species goals through the protection of current and/or future habitat. If the goal is to maintain viable populations of caribou, a conservation target may be to protect all calving areas, and the selection of benchmark networks could be prioritized based on the representation of calving areas.

Under Objective 5, priority focal species are used to rank benchmark networks. To establish ranking criteria, conservation goals and targets for focal species and the protection of habitat are needed. Rather than independently derive goals and targets for the priority focal species, we chose to align the ranking of benchmark networks with conservation efforts underway within the NWBLCC planning region. To this end, U.S. Fish & Wildlife Service (Megan Boldenow and Charleen Veach) and BEACONs reviewed the management plans of federal, state, and provincial/territorial agencies, and non-governmental organizations (N=109; **Appendix A**), and compiled conservation goals and targets for priority focal species (**Appendix B**). The review is biased towards Alaska with 78% of conservation plans from Alaskan agencies and organizations, despite a thorough literature search for all jurisdictions. While there are regional nuances, the overarching goal for all species is *to conserve or maintain sustainable populations*. The goals for harvestable species (moose, caribou, sheep, beaver, fish, and waterfowl) are often framed in the context of maintaining sustainable populations while allowing for harvest, with some regions also wanting to increase (or restore) populations to either historic levels or to allow for greater harvest opportunity. Some management plans for caribou, moose, and sheep include explicit goals for population size (*e.g*., 1800 individuals) and composition (*e.g.*, bull:cow ratio). For fish species, a common sub-goal is to maintain the quantity and quality of water resources. Goals for old-forest birds are sometimes framed within the context of managing forest resources. Across species, the need for baseline information and monitoring of populations is often listed as an objective, and in the case of fish and waterfowl, this includes monitoring water resources and quality. Features for protection are listed in some plans (*e.g*., mineral licks, movement corridors, nesting habitat; Table 2); however, no quantitative targets (or measurable objectives) are provided (*e.g.*, protect 100 km^2 or 10%).

***Table 2*.** Features listed for protection within management plans reviewed for the NWBLCC.

Species	Features Listed for Protection
Caribou	lichen used as caribou winter forage; calving, post-calving (including mineral licks), summer (including insect-relief), pre-calving and winter habitats, as well as migration corridors
Moose	habitat; winter range, calving and rutting areas; critical habitat; (maintain) movement corridors; calving, late winter, rutting, and riparian and willow shrub habitats; mineral licks
Dall/Thinhorn Sheep	habitat; mineral licks; summer, lambing, and winter habitat; movement routes
Beaver	habitat
Chinook & Chum Salmon and Broad Whitefish	habitat; upstream areas and lakes containing anadromous fish; spawning, rearing, and overwintering areas; critical habitat
Rusty Blackbird	none listed
Old-Forest Birds	habitat
Waterfowl Guild	habitat; nesting, rearing, and staging habitat

OBJECTIVE 3 - INVENTORY AND ACQUISITION OF EXISTING DATASETS AND MODELS

The use of focal species depends upon the availability of data and/or models supporting conservation goals and targets. An inventory of existing datasets and models for priority focal species was compiled by U.S. Fish & Wildlife Service (Megan Boldenow and Charleen Veach) and BEACONs. Prior to gathering data, focal species experts were interviewed for their knowledge of existing datasets and models. The following information was requested:

- Known Threats (*e.g.*, harvesting)
- Map of Threats - current and planned (*e.g.*, traplines, dams, culverts, access)
- Distribution Map
- Range Boundaries (*e.g.*, caribou herds)
- Home Range Sizes (*e.g.*, 1 ha, 25 km2; note sex and seasonal variation if applicable)
- Location Data (*e.g.*, point counts, VHF/GPS collar locations)
- Habitat Requirements Known (e.g., old-growth coniferous forest)
- Habitat Models (*e.g.*, HSI, RSF)
- Probability of Occurrence, Habitat, or Density Maps
- Critical Habitat Requirements for specific life-history traits (*e.g.*, migration routes, early open water, spawning sites)
- Maps of critical use areas (*e.g.*, migration routes, early open water sites, spawning grounds)
- Climate Change Projections for any of the previously listed datasets
- Other Spatial Datasets

The list of experts consulted and their responses can be can be found in **Appendices C and D**, respectively. Available datasets vary geographically and across species, and include species range, herd ranges, seasonal habitat, core habitat, habitat quality, future habitat, climate refugia, habitat models (*e.g.*, RSF), and location data (*e.g.*, GPS) (**Appendix D**). The spatial data and models acquired to support Objective 5 are listed in Table 3.

Table 3. Spatial data and models for priority species acquired to support Objective 5.

Focal species	Data	Jurisdiction	Provider and References
Caribou	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Naturserve; Patterson *et al.* (2003)
	Herd ranges / Seasonal distribution	☑ Alaska	AK Center for Conservation Science; Gotthardt *et al.* (2014)
		☑ BC	BC Ministry of the Environments – Ecosystems (2015), Heinemeyer *et al.* (2004), McKay *et al.* (2009). Polfus *et al.* (2010)
		☐ NWT	
		☑ Yukon	Environment Yukon (2012)
	Habitat quality	☐ Alaska ☑ BC ☐ NWT	BC Government; Heinemeyer *et al.* (2004), McKay *et al.* (2009)

		☐ Yukon	
	Habitat distribution	☑ Alaska ☐ BC ☐ NWT ☐ Yukon	AK Center for Conservation Science; Gotthardt *et al.* (2014)
	Suitable Bioclimate 2020-29 & 2050-59 (calving and winter)	☑ Alaska ☐ BC ☐ NWT ☐ Yukon	SNK BLM REA; Harkness *et al.* (2012)
	Seasonal forage quality	☑ Alaska ☐ BC ☐ NWT ☐ Yukon	BEACONs (2016a); modified from Boucher *et al.* (2015).
	Resource Selection Functions	☐ Alaska ☑ BC ☐ NWT ☑ Yukon	BC Government; Polfus *et al.* (2010), Polfus *et al.* (2014) Environment Yukon; Florkiewicz *et al.* (2007)
Moose	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Naturserve; Patterson *et al*. (2003)
	Habitat quality	☐ Alaska ☑ BC ☐ NWT ☐ Yukon	BC Government; Heinemeyer *et al.* (2004), McKay *et al.* (2009)
	Habitat distribution	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	AK Center for Conservation Science; Gotthardt *et al.* (2014) BC Government; Heinemeyer *et al.* (2004), McKay *et al.* (2009) BEACONs (2016b)
Dall / Thinhorn Sheep	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Naturserve; Patterson *et al*. (2003)
	Habitat quality	☐ Alaska ☑ BC ☐ NWT ☐ Yukon	BC Government; Heinemeyer *et al.* (2004), McKay *et al.* (2009)
	Habitat distribution	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	AK Center for Conservation Science; Gotthardt *et al.* (2014) BEACONs (2016c) – Alpine Grassland
	Resource Selection Functions	☐ Alaska ☐ BC ☐ NWT ☑ Yukon	Environment Yukon; Barker (2012)
Beaver	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Naturserve; Patterson *et al.* (2003)
	Habitat distribution	☑ Alaska	AK Center for Conservation Science; Gotthardt *et al.* (2014)

		☐ BC ☐ NWT ☐ Yukon	
Chinook Salmon	Occurrences	☑ Alaska ☑ BC ☐ NWT ☑ Yukon	Anadromous Water Atlas and Catalog; AKDFG (2015) BC Ministry of the Environment (2009) (points only) de Graff (2015) (point locations only)
	Habitat distribution, rearing, spawning, summer, fall, & historic presence	☑ Alaska ☑ BC ☐ NWT ☑ Yukon	Anadromous water catalog; AKDFG (2015) Heinemeyer *et al.* (2004), McKay *et al.* (2009) von Finster (2015) (point locations only)
Chum Salmon	Occurrences	☑ Alaska ☑ BC ☐ NWT ☑ Yukon	Anadromous water catalog; AKDFG (2015) BC Ministry of the Environment (2009) (points only) de Graff (2015) (point locations only)
	Habitat distribution, rearing, spawning, summer, fall, & historic presence	☑ Alaska ☑ BC ☐ NWT ☑ Yukon	Anadromous Water and Atlas Catalog, USFWS; AKDFG (2015), Harris *et al.* (2015) BC Government; Heinemeyer *et al.* (2004), McKay *et al.* (2009) de Graff (2015) (point locations only)
Broad Whitefish	Occurrences	☐ Alaska ☑ BC ☐ NWT ☐ Yukon	BC Ministry of the Environment (2009) (points only)
Rusty Blackbird	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	BirdLife International and NatureServe (2015)
	Current & future density	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Stralberg *et al.* (2014), Stralberg *et al.* (2015)
	Current & future core habitat	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Stralberg *et al.* (2014), Stralberg *et al.* (2015)
	Climate refugia	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Stralberg *et al.* (2014); Stralberg *et al.* (2015)
Old-forest birds	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	BirdLife International & NatureServe (2015)
	Current & future density	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Stralberg *et al.* (2014), Stralberg *et al.* (2015)
	Current & future core habitat	☑ Alaska ☑ BC ☑ NWT	Stralberg *et al.* (2014), Stralberg *et al.* (2015)

		☑ Yukon		
	Climate refugia	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Stralberg *et al.* (2014), Stralberg *et al.* (2015)	
Lesser Scaup	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	BirdLife International and NatureServe (2015)	
	Occurrences and local abundance (Breeding & Migration surveys)	☐ Alaska ☐ BC ☐ NWT ☑ Yukon	Environment Canada; CWS (2015)	
	Probability of observation models	☐ Alaska ☑ BC ☐ NWT ☐ Yukon	Bird Studies Canada; Burger (2015)	
	Habitat distribution	☑ Alaska ☐ BC ☐ NWT ☐ Yukon	AK Center for Conservation Science; Gotthardt *et al.* (2014)	
	Density and abundance	☐ Alaska ☑ BC ☑ NWT ☑ Yukon	Ducks Unlimited Canada; Barker *et al.* (2014)	
White-Winged Scoter	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	BirdLife International and NatureServe (2015)	
	Occurrences and local abundance (Breeding & Migration surveys)	☐ Alaska ☐ BC ☐ NWT ☑ Yukon	Environment Canada; CWS (2015)	
	Habitat distribution	☑ Alaska ☐ BC ☐ NWT ☐ Yukon	AK Center for Conservation Science; Gotthardt *et al.* (2014)	
	Density and abundance	☐ Alaska ☑ BC ☑ NWT ☑ Yukon	Ducks Unlimited Canada; Barker *et al.* (2014)	
Trumpeter Swan	Species range	☑ Alaska ☑ BC ☑ NWT ☑ Yukon	Birdlife International	BirdLife International and NatureServe (2015)
	Occurrences and local abundance (Breeding & Migration surveys)	☑ Alaska ☐ BC ☐ NWT ☑ Yukon	US FWS; Groves & Hodges (2013) Environment Canada; CWS (2015)	
	Habitat distribution	☑ Alaska ☑ BC	AK Center for Conservation Science; Gotthardt *et al.* (2014) BEACONs (2016d)	

	☑ NWT ☑ Yukon	
Probability of observation models	☐ Alaska ☑ BC ☐ NWT ☐ Yukon	Bird Studies Canada; Martell (2015)

Objective 4 - Gaps, Opportunities and Next Steps for Developing Species-based Products

Effective conservation planning for focal species requires explicit goals and quantitative targets supported by high-quality spatial data (Margules and Pressey 2000, Lindenmayer *et al.* 2002). Based on the overarching goal for species identified under Objective 2, *to conserve or maintain sustainable populations*, and habitat features identified for protection (Table 2), the following information is required:

- habitat use, distribution, and quality,
- predicted future habitat given climate change, including climate refugia,
- critical habitat and/or rare habitat features (*e.g.*, early open water for waterfowl, mineral licks),
- habitat models (*e.g.*, RSF) for dynamic landscape simulation modelling of habitat, and
- samples sizes (*e.g.*, number of individuals) and amount of habitat required to support robust monitoring.

Here, we identify gaps in the NWBLCC-wide coverage of focal species habitat based on the best available data and models. We did not thoroughly assess the strengths and limitations of data and models, so while they may be the best available, this does not guarantee high quality, and users are advised to review the data and models in the context of their work to ensure the information is used appropriately. For example, models that estimate breeding pair density for Lesser Scaup and White-Winged Scoter developed by Barker *et al.* (2014) represent the only spatial data describing the distribution of these species in the Yukon. These models are national in scope with the greatest uncertainty occurring in the Yukon. This uncertainty is likely driven by a combination of lack of waterfowl data and novel environments (Barker *et al.* 2014). To address this uncertainty, it is advised that these data layers be used in consultation with regional experts, such as Jamie Kenyon (Ducks Unlimited Canada).

Information on habitat use, location of habitat (*e.g.*, habitat distribution), and relative quality of habitat assists planners with identifying areas for protection that are best able to support populations and achieve conservation goals. Except for Rusty Blackbird and Old-Forest Birds, gaps exist in NWBLCC-wide coverage of habitat distribution and habitat-quality for all remaining species (Table 4). Alaska has the most comprehensive inventory of spatial habitat data. Habitat-quality data for moose, caribou, and sheep are limited to portions of BC and the Yukon. Habitat data for beaver do not exist beyond Alaska. Habitat distribution and quality does not exist for White Broadfish. Habitat-quality data do not exist for salmon species. Within the Waterfowl Guild, there are gaps in habitat distribution and quality for all species. For Scaup and Scoter, predicted density maps serve as a relative measure of habitat quality in Canada.

Focal species distributions and habitats will shift geographically with a rapidly changing climate. As a result, protected areas may fail to achieve long-term conservation goals and targets when designed based on current climatic conditions (Hannah *et al.* 2007; Tingley *et al.* 2014). Spatial datasets of habitat distribution based on predicted future climatic conditions can be used to evaluate the likelihood that quantitative targets will be maintained within proposed protected areas (*e.g.*, benchmarks). These climate-projected habitat layers can also be used to identify climate refugia (Keppel & Wardell-Johnson 2012) and stepping stones (Hannah *et al.* 2014) that can assist species with range shifts and adaptation to climate change, and ultimately the goal to maintain populations. Except for Rusty Blackbird and Old-Forest Birds, gaps exist in NWBLCC-wide coverage of climate-projected habitat datasets (Table 4). Future habitat based on predicted climatic conditions does not exist for Moose, Sheep, Beaver, Salmon, White Broadfish, and the Waterfowl Guild. In Alaska, climate-projected habitat spatial layers are available for the Western Arctic Caribou herd only. Rusty Blackbird and Old-Forest Birds are the only species with climate refugia datasets.

The spatial layers described above are static. For conservation planning to be most effective, it should account for system dynamics, such as natural disturbance (*e.g.*, fire) and vegetation succession (Pressey *et al.* 2007). Habitat models (*e.g.*, resource selection functions or RSF and Habitat Suitability Index or HSI) can be used with dynamic landscape simulation modelling software (*e.g.*, CONSERV) to test the likelihood that benchmarks and other protected areas will maintain habitat targets through time given landscape dynamics (Leroux *et al.* 2007b). For the NWBLCC priority species, there are RSFs for caribou and sheep only, though limited in geographic scope (Table 4).

The review of management plans for priority focal species (Objective 2) identified the need for baseline information and monitoring of populations. Ecological benchmarks are control areas for adaptive management to study the response of biodiversity to human activities (*e.g.*, resource extraction, subsistence and recreational hunting), as well as reference areas for collecting baseline information on ecological processes including population dynamics. When monitoring species populations, a minimum sample size (*e.g.*, number of individuals or sampling sites) is required to detect changes in the population. Sample size is determined via power and precision statistical analyses (Gerrodette 1987; Seavy & Reynolds 2007). Once the sample size is known, the habitat requirements needed to support the sample can be calculated and used as a habitat target in the design of benchmarks and protected areas networks. At the time of this work, we were not able to find such analyses for any of the focal species.

Opportunities and Next Steps for Developing Species-based Products

1. Identify goals and targets for species. This will guide next steps to identify and prioritize datasets.
2. Potential opportunities to readily improve the availability of habitat distribution and habitat-quality datasets include:
   a. Explore feasibility and appropriateness of extending existing habitat models into neighbouring regions, such as waterfowl models for Lesser Scaup and White-Winged Scoter into Alaska using the methods of Baker *et al.* (2014) and beaver distribution models for Alaska into Canada.

b. Where location data exists (**Appendix D**), explore the ability to develop habitat models (*e.g.*, resource selection functions) for use in dynamic landscape simulation modelling.
c. Location data for BC and Yukon Salmon species and Broad Whitefish are points. Consultation with local experts could identify stream networks used by these species.

3. Some datasets are available only as partial coverages so were not included in the analysis. These datasets are labelled as “limited” under Data Availability in Table 4. Planners may wish to include these layers when undertaking regional planning where the data exists.

Table 4. Availability and gaps in spatial data and models for priority focal species. The references for datasets can be found in Table 3. The grey shading identifies jurisdictions with available data. Gaps in Data Availability identifies gaps in the NWBLCC-wide coverage of spatial habitat data and models. Here, "habitat models" refers to habitat models that could be used with the dynamic landscape simulation software tool CONSERV (Leroux *et al.* 2007b).

Focal species	**Spatial Data and Models**	**Data Available**				**☒ Gaps in Data Availability**
		☑ Alaska	**☑ BC**	**☑ NWT**	**☑ Yukon**	
Caribou	Species range					☒ Habitat distribution ☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Herd ranges					
	Habitat distribution					
	Habitat quality		limited			
	Seasonal forage quality					
	Habitat projections based on bioclimatic variables for 2020-29 & 2050-59 for Western Arctic Herd					
	Habitat model (RSF)		limited		limited	
Moose	Species range					☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Habitat distribution					
	Habitat quality		limited			
Dall / Thinhorn Sheep	Species range					☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Habitat distribution					
	Habitat quality		limited			
	Habitat model (RSF)				limited	
Beaver	Species range					☒ Habitat distribution ☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Habitat distribution					
Chinook Salmon	Occurrences			n.a.		☒ Habitat distribution ☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Distribution, rearing and spawning areas		limited	n.a.		
	Summer and fall habitat, and streams with historic presence		limited	n.a.		
Chum Salmon	Occurrences			n.a.		☒ Habitat distribution ☒ Habitat quality ☒ Future habitat
	Distribution, rearing and spawning areas		limited	n.a.		
	Summer and fall habitat, and streams with		limited	n.a.		

	historic presence					☒ Habitat models
Broad Whitefish	Occurrences			n.a.		☒ Habitat distribution ☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Streams with historic presence		limited	n.a.		
Rusty Blackbird	Species range					☒ Habitat models
	Current & future core habitat					
	Current & future density					
	Climate refugia					
Old-Forest Birds	Species range					☒ Habitat models
	Current & future core habitat					
	Current & future density					
	Climate refugia					
Lesser Scaup	Species range					☒ Habitat distribution ☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Occurrences and local abundance (Breeding & Migration surveys)					
	Probability of observation					
	Habitat distribution					
	Density and abundance models					
White-Winged Scoter	Species range					☒ Habitat distribution ☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Occurrences and local abundance (Breeding & Migration surveys)					
	Habitat distribution					
	Density and abundance					
Trumpeter Swan	Species range					☒ Habitat distribution ☒ Habitat quality ☒ Future habitat ☒ Habitat models
	Occurrences and local abundance (Breeding & Migration surveys)					
	Probability of observation					
	Habitat distribution					

OBJECTIVE 5 – RANK BENCHMARK NETWORK OPTIONS USING PRIORITY FOCAL SPECIES

The purpose of this work was to incorporate focal species information into the design and selection of candidate benchmark networks. When to best incorporate focal species data into this process depends on two main factors: (1) conservation goals and targets, and (2) available information. We identified focal species goals, and associated protected area objectives and targets, based on the goals and features highlighted for protection (Table 2) identified under Objective 2 (Table 5). The **protected area objective** describes the role of protected areas (*e.g.*, benchmarks) towards achieving the focal species goal. The **protected area target** is the quantitative target for protection. Based on the review of management plans, no explicit numerical targets were identified. To avoid setting arbitrary targets, we chose to rank benchmark network options based on *maximizing representation* of habitat, which would also give users the flexibility to apply a quantitative target to the results should new information emerge. There are four stages to the design and selection of benchmark networks (Figure 2). Without explicit numerical targets and/or information on sample sizes for monitoring (*e.g.*, precision analysis, gap under Objective 4), focal species cannot inform benchmark size in Stage 1. Given poor availability and limited geographic extent of habitat models (*e.g.*, RSF, Table 4), benchmark networks cannot be ranked based on *maximizing representation* over time via dynamic landscape simulation modelling in Stage 3. While Stage 2 is an option, given the number of species and the imbalance in dataset availability, introducing focal species data here is not advised. As such, focal species information was used to rank benchmark networks in Stage 4 only.

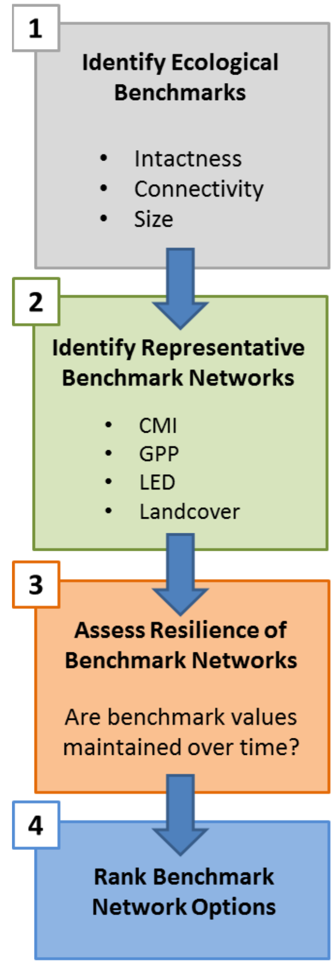

Figure 2: Stages of benchmark design and selection. Stages 1-3 are design, while Stage 4 is the use of additional information (*e.g.*, focal species, socio-economics) to inform the selection of benchmark networks from a suite of options.

The representation of focal species habitat by benchmark networks was measured using spatial overlays in GIS. Data layers were available as rasters of variable resolution (60–4000 m) and polyline and polygon features (*e.g.*, polyline stream networks for fish species; Table 6). Prior to analysis, polyline and polygon features were converted to rasters using the cell sizes listed in Table 6. Networks were given a rank for each species. When multiple datasets were available for a species, the networks were given a mean species rank. The ranks from all species were then combined to create an overall mean focal species rank for the network. Most rankings were based on maximizing the area of habitat within the network (*e.g.*, km^2), except for Rusty Blackbird and Old-Growth Forest Birds, where refugia potential was measured as a mean, and Waterfowl, where representation included mean density of breeding pairs per km^2. We report on the ranking of benchmark network options in BEACONs (2017a). All datasets are available for download at www.beaconsproject.ca/nwb.

Table 5. Conservation goals and targets, and spatial data, used to rank benchmark network options. Protected Area Objectives describe the role of protected areas (*e.g.*, benchmarks) towards achieving the focal species goal. Protected Area Target is the quantitative target for protection. Data Availability lists the datasets used to measure representation of the target. The acronyms AK, BC, NWT and YT indicate the jurisdictions for which the dataset or model was available. Modified Target indicate protected area targets modified given data availability. Stage indicates the stage at which focal species information was incorporated in the design and/or selection of benchmark networks (Figure 1).

Species	Conservation Goal	Protected Area Objective	Protected Area Target	Data Availability	Modified Target	Benchmark Design Stage
Caribou	Maintain (and restore) self-sustaining (and/or increasing) Caribou populations	Protect caribou herd ranges	Maximize protection of caribou herd ranges	☑ Caribou herd ranges (AK, BC, NWT, YT)	No	☑ 4 – Rank benchmark networks
		Protect habitat	Maximize protection of habitat	☑ Habitat distribution (AK)	No	
			Maximize protection of high-quality habitat	☑ Habitat quality (YT – RSF Carcross Herd)	No; limited extent, not used to rank	
		Protect seasonal habitat	Maximize protection of high-quality forage habitat within herd ranges: calving, summer, and winter	☑ Caribou herd ranges (AK) ☑ Forage quality (AK)	No	
			Maximize protection of high-quality summer, fall, and winter habitat	☑ Habitat quality (BC – RSF Atlin herd) ☑ Habitat quality (BC – RSF northwest BC)	No; limited extent, not used to rank	
		Protect secondary seasonal habitat to allow for range expansion and/or shift	Maximize protection of high-quality forage habitat outside herd ranges: summer, winter, calving	☑ Caribou herd ranges (AK) ☑ Forage quality (AK)	No	
		Protect lichen used as Caribou winter forage	Maximize protection of lichen winter forage	Data not available at time of analysis	n.a.	
		Protect migration corridors	Maximize protection of migration corridors	Data not available at time of analysis	n.a.	
		Protect mineral licks and summer insect-relief areas	Maximize protection of mineral licks and insect-relief areas	Data not available at time of analysis	n.a.	
		Protect future habitat under climate change and climate refugia	Maximize protection of future habitat for calving and winter seasons	☑ Bioclimate habitat projections 2050-59 (AK; Western Arctic Herd)	No	

		Serve as control to monitor populations numbers and composition and to assess cumulative impacts of land-use activities, effectiveness of management actions, and impacts of environmental change	Protect sufficient habitat to detect population changes and serve as control *as per* protected area objective	☐ Precision analysis required ☑ Habitat distribution (AK) ☑ Caribou herd ranges (AK, BC, NWT, YT)	Yes: maximize protection of Caribou range and habitat in the absence of precision analysis	☑ 4 – Rank benchmark networks
	Maintain sustainable Caribou populations that support harvest	Serve as controls to monitor populations and the effects of subsistence and recreational harvest	Protect sufficient habitat to evaluate the effects and sustainability of Caribou harvest			
Moose	Maintain sustainable Moose populations that support subsistence and recreational harvest	Protect moose habitat	Maximize protection of high-quality habitat	☑ Habitat distribution (AK, BC, NWT, YT) ☑ High-quality seasonal forage habitat (BC; limited extent and not used to rank) ☑ High-quality seasonal safe habitat (BC; limited extent and not used to rank)	No	☑ 4 – Rank benchmark networks
		Protect future habitat under climate change and climate refugia	Maximize protection of future habitat and climate refugia	Data not available at time of analysis	n.a.	
		Serve as control to monitor populations and the effects of subsistence and recreational harvest, as well as cumulative impacts of land-use activities, effectiveness of management actions (*e.g.*, prescribed fires), and impacts of environmental change	Protect sufficient habitat to detect population changes and serve as control *as per* protected area objective	☐ Precision analysis required ☑ Habitat distribution (AK, BC, NWT, YT) ☑ High-quality seasonal forage and safe habitat (BC; limited extent and not used to rank)	Yes: maximize protection of high-quality habitat in the absence of precision analysis	
Dall/ Thinhorn Sheep	Maintain Sheep populations that support subsistence and recreational harvest	Protect habitat	Maximize protection of habitat	☑ Habitat distribution (AK, BC, NWT, YT)	No	☑ 4 – Rank benchmark networks
			Maximize protection of alpine grasslands within species range	☑ Species range ☑ Distribution of alpine grasslands	No	

			Maximize protection of seasonal habitat: calving, summer, winter	☑ Seasonal habitat (BC)	No; limited extent, not used to rank	
		Protect habitat to support range shift under climate change	Maximize protection of alpine grasslands outside of species range	☑ Species range ☑ Distribution of alpine grasslands	No	
		Protect future habitat under climate change and climate refugia	Maximize protection of future habitat and climate refugia	Data not available at time of analysis	n.a.	
		Serve as control to monitor populations and the effects of harvest as well as environmental changes (*e.g.*, snow condition)	Protect sufficient habitat to detect population changes and serve as control *as per* protected area objective	☐ Precision analysis required ☑ Habitat distribution (AK) ☑ Distribution of alpine grasslands (AK, BC, NWT, YT) ☑ Habitat quality models/RSF (BC, YT; limited extent and not used to rank)	Yes: maximize protection of habitat in the absence of precision analysis	
Beaver	Maintain sustainable and harvestable Beaver populations	Protect habitat	Maximize protection of habitat	☑ Habitat distribution (AK)	No	☑ 4 – Rank benchmark networks
			Maximize protection of high-quality habitat	Data not available at time of analysis	n.a.	
		Protect future habitat under climate change and climate refugia	Maximize protection of future high-quality habitat	Data not available at time of analysis	n.a.	
		Serve as control for monitoring Beaver populations	Protect sufficient habitat to monitor populations and the sustainability of Beaver harvest	☐ Precision analysis required ☑ Habitat distribution (AK)	Yes: maximize protection of habitat in the absence of precision analysis	
Chinook Salmon	Restore & maintain sustainable Chinook Salmon populations and their habitats Restore & maintain sustainable Chinook	Protect spawning, rearing, and overwintering areas and migration routes	Maximize the protection of stream networks used by Chinook Salmon for spawning, overwintering and/or migrating	☑ Rearing and spawning streams (AK) ☑ Summer and fall streams (BC; limited extent and not used to rank)	No	☑ 4 – Rank benchmark networks

	Salmon populations that support subsistence harvest	Protect upstream areas & lakes with anadromous fish	Maximize protection of upstream areas & lakes with anadromous fish	Data not available at time of analysis	n.a.	
		Protect migration routes	Maximize protection of migration routes	Data not available at time of analysis	n.a.	
		Protect future habitat under climate change and climate refugia	Maximize protection of future habitat and climate refugia	Data not available at time of analysis	n.a.	
		Serve as control to monitor populations, quantity and quality of water, and the effects of harvesting	Protect the amount of habitat needed to detect population changes and serve as control *as per* protected area objective	☐ Precision analysis required ☑ Rearing and spawning streams (AK) ☑ Summer and fall streams (BC; limited extent and not used to rank)	Yes; maximize protection of streams used by Chinook Salmon in the absence of precision analysis	
Chum Salmon	Restore and maintain sustainable Chum Salmon populations and their habitats	Protect Chum Salmon spawning and overwintering habitat, and migration routes	Maximize the protection of stream networks used by Chum Salmon for spawning, overwintering and/or migrating	☑ Rearing and spawning streams (AK) ☑ Summer and fall habitat (BC; limited extent and not used to rank)	No	☑ 4 – Rank benchmark networks
	Restore & maintain sustainable Chum Salmon populations that support subsistence harvest	Protect upstream areas & lakes with anadromous fish	Maximize protection of upstream areas & lakes with anadromous fish	Data not available at time of analysis	n.a.	
		Protect future habitat under climate change and climate refugia	Maximize protection of future habitat and climate refugia	Data not available at time of analysis	n.a.	
		Serve as control to monitor populations, quantity and quality of water, and the effects of harvesting	Protect the amount of habitat needed to detect population changes and serve as control *as per* protected area objective	☐ Precision analysis required ☑ Rearing and spawning streams (AK) ☑ Summer and fall habitat (BC; limited extent and not used to rank)	Yes; maximize protection of streams used by Chum Salmon in the absence of precision analysis	

Broad Whitefish	Maintain sustainable populations of Broad Whitefish populations that support subsistence harvest	Protect spawning and overwintering habitat, and migration routes	Maximize the protection of stream networks for spawning, overwintering and/or migrating	Data not available at time of analysis	n.a.	☑ 4 – Rank benchmark networks
		Protect future habitat under climate change and climate refugia	Maximize protection of future habitat and climate refugia	Data not available at time of analysis	n.a.	
		Serve as control for monitoring Whitefish and water resources Serve as controls to evaluate the effects and sustainability of subsistence harvest	Protect the amount of habitat needed to detect population changes and serve as control *as per* protected area objective	☐ Precision analyses required Data not available at time of analysis	n.a.	
Rusty Blackbird	Maintain sustainable Rusty Blackbird populations	Protect core habitat	Maximize protection of high-quality core habitat	☑ Current core habitat (AK, BC, NWT, YT	No	☑ 4 – Rank benchmark networks
		Protect climate refugia	Maximize protection of *ex situ* and *in situ* climate refugia potential	☑ *Ex situ* and *in situ* climate refugia RCP 8.5 2041-70 (AK, BC, NWT, YT)	No	
		Protect future core habitat **(did not include in analysis)**	Maximize protection of future core habitat	☑ Projected future core habitat (AK, BC, NWT, YT)	n.a.	
		Serve as control for monitoring	Protect the amount of habitat needed to detect population changes	☐ Precision analyses required ☑ Current core habitat (AK, BC, NWT, YT)	Yes: maximize protection of core habitat in the absence of precision analysis	
Old-Forest Birds	Maintain sustainable populations of old-growth forest birds	Protect core habitat	Maximize protection of high-quality core habitat	☑ Current core habitat (AK, BC, NWT, YT)	No	☑ 4 – Rank benchmark networks
		Protect intact old-growth forest	Maximize protection of intact old-growth forests	Data not available at time of analysis	n.a.	
		Protect climate refugia	Maximize protection of *ex situ* and *in situ* climate refugia potential	☑ *Ex situ* and *in situ* climate refugia RCP 8.5 (AK, BC, NWT, YT)	No	
		Protect future core habitat **(did not include in analysis)**	Maximize protection of future core habitat	☑ Future core habitat (AK, BC, NWT, YT)	n.a.	

		Serve as control for monitoring and detecting changes in populations	Protect the amount of habitat needed to detect population changes	☐ Precision analysis required ☑ Current core habitat (AK, BC, NWT, YT)	Yes: maximize protection of core habitat in the absence of precision analysis	
Waterfowl Guild	Maintain sustainable waterfowl populations of Trumpeter Swan (TRUS), Lesser Scaup (LESC), & White-Winged Scoter (WWSC) that support subsistence harvest	Protect habitat	Maximize protection of habitat	☑ TRUS, LESC & WWSC Habitat distribution (AK) ☑ TRUS Habitat distribution (YT)	No	☑ 4 – Rank benchmark networks
			Maximize protection of high-quality habitat	Data not available at time of analysis	n.a.	
			Maximize protection of breeding pair density	☑ LESC & WWSC density breeding pairs (Canada)	No	
		Protect nesting, rearing, and staging habitat	Maximize protection of nesting, rearing, and staging habitat	Data not available at time of analysis	n.a.	
		Protect future habitat under climate change and climate refugia	Maximize protection of future high-quality habitat	Data not available at time of analysis	n.a.	
		Serve as control to monitor populations and the effects of subsistence harvest, as well as environmental change (*e.g.*, water quantity and quality)	Protect the amount of habitat needed to detect population changes and serve as control *as per* protected area objective	☐ Precision analysis required ☑ TRUS, LESC & WWSC Habitat distribution (AK) ☑ TRUS Habitat distribution (YT) ☑ LESC & WWSC density breeding pairs (Canada)	Yes: maximize protection of habitat in the absence of precision analysis	

Table 6. Datasets and dataset classes used for ranking, pixel size of the original datasets (Table 2), pixel size used for analysis, and the habitat units (*e.g.*, km^2) used to rank benchmark networks based on the spatial overlay with the dataset. The geographic extent of the dataset is shown with AK = Alaska, BC = British Columbia, YT= Yukon Territory, and NWB = full extent of the NWBLCC planning region.

Species	Datasets and classes/values used to rank	Original pixel size (m)	Analysis pixel size (m)	Habitat units
Caribou	Caribou herd ranges (NWB)	n/a	250	km^2
	Habitat distribution (AK)	60	60	km^2
	SNK-REA bioclimate winter long term (2050-2059) projection (AK) – classes of greatest climate model agreement (4 & 5)	2000	250	km^2
	Calving forage habitat quality within herd ranges (AK) – highest quality only	60	60	km^2
	Calving forage habitat quality outside herd ranges (AK) – highest quality only	60	60	km^2
	Summer forage habitat quality within herd ranges (AK) – highest quality only	60	60	km^2
	Summer forage habitat quality outside herd ranges (AK) – highest quality only	60	60	km^2
	Winter forage habitat quality within herd ranges (AK) – highest quality only	60	60	km^2
	Winter forage habitat quality outside herd ranges (AK) – highest quality only	60	60	km^2
	Habitat quality Carcross herd (RSF) (YT) – high quality only = classes 6-10	30	30	km^2
Moose	Habitat distribution (AK)	60	60	km^2
	Moose habitat (NWB)	250	250	km^2
Dall / Thinhorn Sheep	Habitat distribution (AK)	60	250	km^2
	Distribution of alpine grasslands within sheep range (NWB)	250	250	km^2
Beaver	Habitat distribution (AK)	60	60	km^2
Chinook	Streams with Chinook presence (AK)	n/a	60	km^2
	Rearing streams (AK)	n/a	60	km^2
	Spawning streams (AK)	n/a	60	km^2
Chum	Streams with Chum presence (AK)	n/a	60	km^2
	Rearing streams (AK)	n/a	60	km^2
	Spawning streams (AWC) (AK)	n/a	60	km^2
	Spawning streams Koyukuk river (AK)	n/a	60	km^2
Broad Whitefish	Stream with broad whitefish presence (AK)	n/a	60	km^2
Rusty Blackbird	Current core habitat (values = 0 to 1) (NWB) – high quality only = 0.6-1	4000	250	km^2
	Ex situ climate refugia potential RCP 8.5 2041-70 (NWB)	4000	4000	mean
	In situ climate refugia potential RCP 8.5 2041-70 (NWB)	4000	4000	mean
Old-forest birds	Current core habitat (values = 0 to 1) (NWB) – high quality only = 0.6-1	4000	250	km^2
	Ex situ climate refugia potential RCP 8.5 2041-70 (NWB)[2]	4000	4000	mean

	In situ climate refugia potential RCP 8.5 2041-70 (NWB)	4000	4000	mean
Lesser Scaup	Habitat distribution (AK)	60	60	km^2
	Density (breeding pairs per km^2) (Canada)	4000	1000	mean #pairs/km^2
White-Winged Scoter	Habitat distribution (AK	60	60	km^2
	Density (breeding pairs per km^2) (Canada)	4000	1000	mean #pairs/km^2
Trumpeter Swan	Habitat distribution (AK)	60	60	km^2
	Habitat distribution (Canada)	60	60	km^2

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