Ecoregion 23b – North Ogilvie Mountains

Area of ecoregion km² (mi²)	Area of planning region km² (mi²)	Minimum Dynamic Reserve km² (mi²)	Number of protected area benchmarks	Number of new system-level benchmarks	Number of candidate benchmark networks (spatial groups)
11,243 (4,341)	37,752 (14,576)	361 (139)	0	421	24 (6)

The identification of candidate benchmark networks is a three-step process. First, potential benchmarks are identified based on size, intactness, and hydrologic connectivity. Next, benchmarks are assembled into candidate networks that are representative of the planning region, where the number of benchmarks required to achieve representation may vary amongst planning regions (*e.g.*, ecoregions). Finally, if multiple benchmark network options exist, to assist with the selection process, the networks are ranked using additional criteria such as fundamental benchmark properties, climate change, and focal species, as done below.

Benchmark potential of existing protected areas and regions that support the construction of benchmarks

The planning region for ecoregion 23b is defined by the ecoregion and intersecting hydrologic units (FDAs). Prior to identifying new benchmarks, existing protected areas (PAs) were clipped to the planning region and evaluated for their potential to serve as system- and subsystem-level benchmarks for the ecoregion (Figure 1). System-level benchmarks are assemblages of intact catchments that are of sufficient size to capture large-scale processes and maintain habitats vulnerable to natural disturbance (*i.e.*, Minimum Dynamic Reserve or MDR). There are two levels of benchmark intactness, I and II, which denote a minimum catchment intactness of 100% and 80%, respectively. Subsystem-level benchmarks do not meet the size and/or intactness criteria for system-level benchmarks. For this study, subsystem benchmarks are no less than 80% MDR in size. One potential PA system-level II benchmarks was identified in ecoregion 23b (Figure 1; Table 1). However, it did not have sufficient overlap with the ecoregion (≥ 80% MDR) to be included as explicit benchmarks in the design of benchmark networks. As such, new system-level benchmarks were identified. Ecoregion 23b has high benchmark potential with benchmarks identified over 96% of the ecoregion (Figure 1).

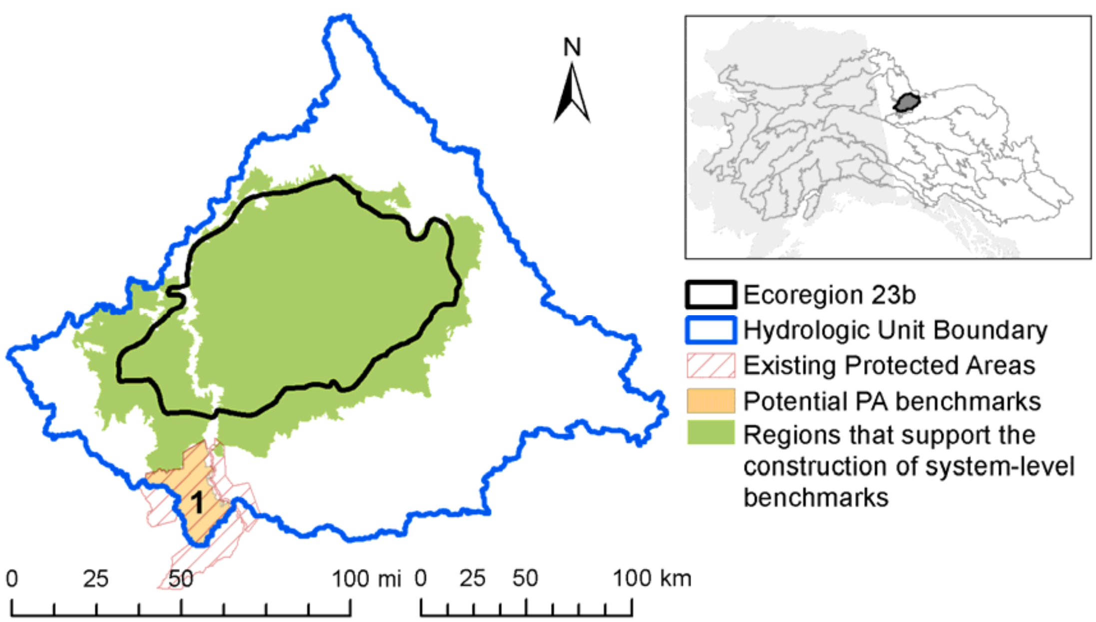

Figure 1: The planning region for ecoregion 23b is defined by the ecoregion (black outline) buffered by FDAs (blue outline). Potential protected area (PA) system-level II benchmarks are shown in orange; labels correspond to the PA ID in Table 1. Regions that support the identification of new system-level benchmarks (≥80% catchment-intactness) are shown in green.

Table 1: Characteristics of the system-level II protected area (PA) benchmark identified in ecoregion 23b (Figure 1). To be included in the design of benchmark networks, the ecoregion portion of PA benchmarks must be ≥ 80% MDR in size.

PA ID	Area km² (mi²)	Benchmark Type	% MDR area intersecting ecoregion
PA_1	848 (327)	System-level II	0

Identification of candidate benchmark networks

Candidate benchmark networks for the planning region were identified based on the representation of four indicators of environmental variation: Climate Moisture Index (CMI), Gross Primary Productivity (GPP), Lake-Edge Density (LED), and Land Cover (Figures 2 & 3). Representation was assessed using MDR-based representation targets for indicator classes. Representation targets were derived for each class by multiplying the MDR for the ecoregion by the proportion of the class in the ecoregion. For example, if the class makes up 10% of the ecoregion, the target would be 0.1 x MDR. For a representation target to be achieved, it must be fully met within a single benchmark, except when benchmarks overlap. For ecoregion 23b, two system-level benchmarks are needed to achieve all MDR-based representation targets. In total, 24 benchmark networks were identified, and assigned to 6 spatial groups. For reporting, the set of candidate benchmark networks was reduced to the top network from each spatial group (Figure 2, Table 2). The top networks were selected using the same criteria and methods as described below for ranking candidate benchmark networks. For a full description of the methods, see the main report.

Table 2: Area and representation characteristics of the top networks selected from the 6 spatial groups in Figure 2. The networks differ in area due to variable overlap of benchmarks within networks. All networks achieved MDR-based representation targets for CMI, LED, GPP, and land cover, but representation varied amongst networks when evaluated using Kolmogorov-Smirnov (KS; continuous indicators CMI, LED, and GPP) and Bray-Curtis (BC; categorical indicator land cover) dissimilarity metrics (DMs). DMs range from 0 to 1, with values closer to 0 indicating better representation.

Network ID	Area km² (mi²)	Upstream area km² (mi²)	KS & BC Dissimilarity Metrics				
			CMI	GPP	LED	Land Cover	Mean Dissimilarity
N1	722 (279)	11,379 (4,393)	0.161	0.082	0.064	0.089	0.099
N2	721 (278)	5,675 (2,191)	0.244	0.155	0.292	0.213	0.226
N3	713 (275)	9,151 (3,533)	0.048	0.133	0.102	0.158	0.110
N4	724 (280)	11,074 (4,276)	0.256	0.115	0.044	0.150	0.141
N5	724 (279)	11,034 (4,260)	0.130	0.085	0.084	0.138	0.109
N6	723 (279)	3,047 (1,176)	0.133	0.039	0.118	0.093	0.096

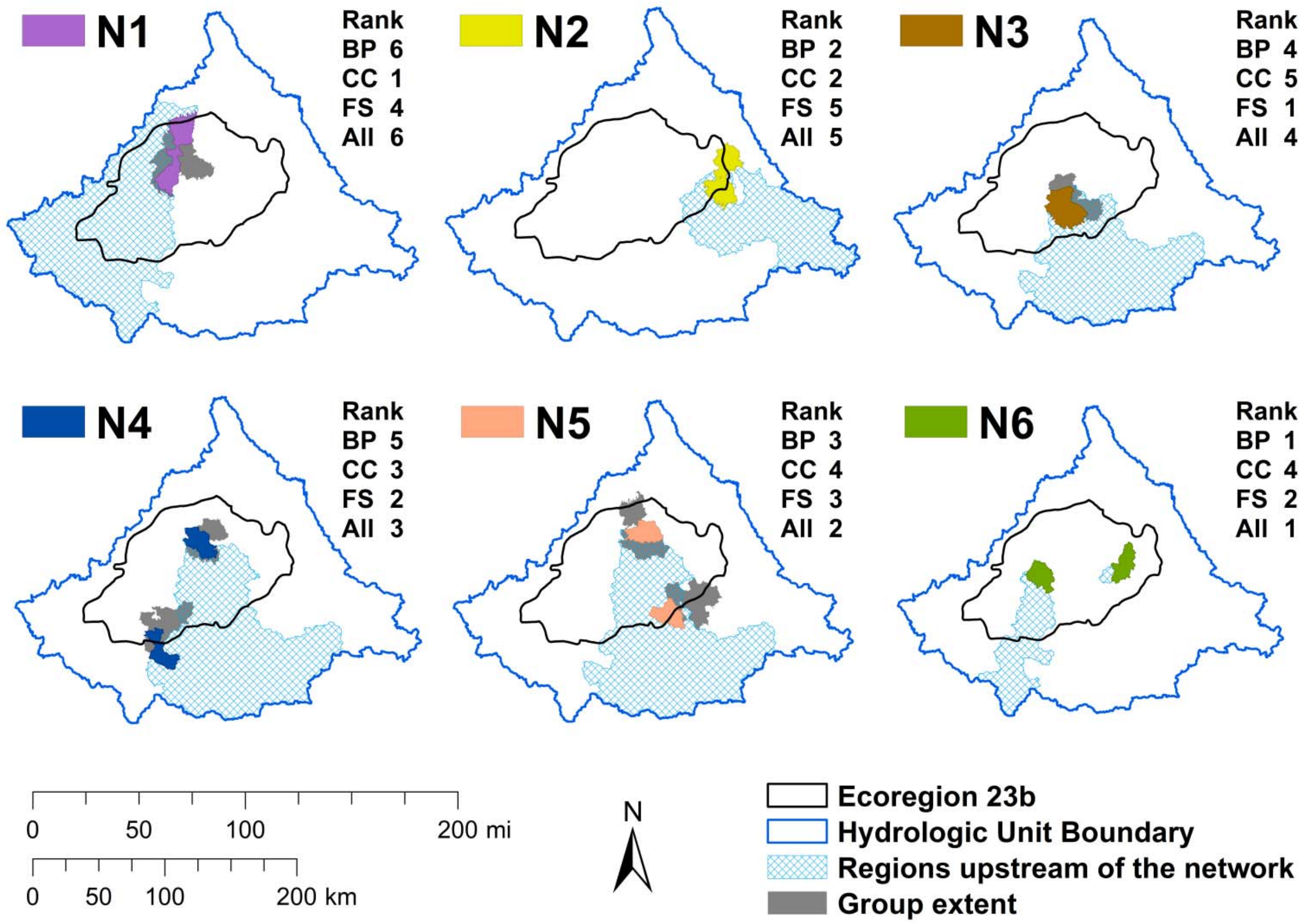

Figure 2: Benchmark networks for ecoregion 23b (N=24) were assigned to 6 spatial groups. The top network selected from each group is shown in color. All networks are comprised of two system-level benchmarks with overlapping benchmarks in N1-3. Catchments upstream of networks are shown in blue cross-hatching. The group extent (grey) is the area covered by all networks in the group. Ranks based on fundamental benchmark properties (BP), resilience to climate change (CC), amount of focal species habitat (FS), and overall rank (ALL) are reported (Tables 3-6).

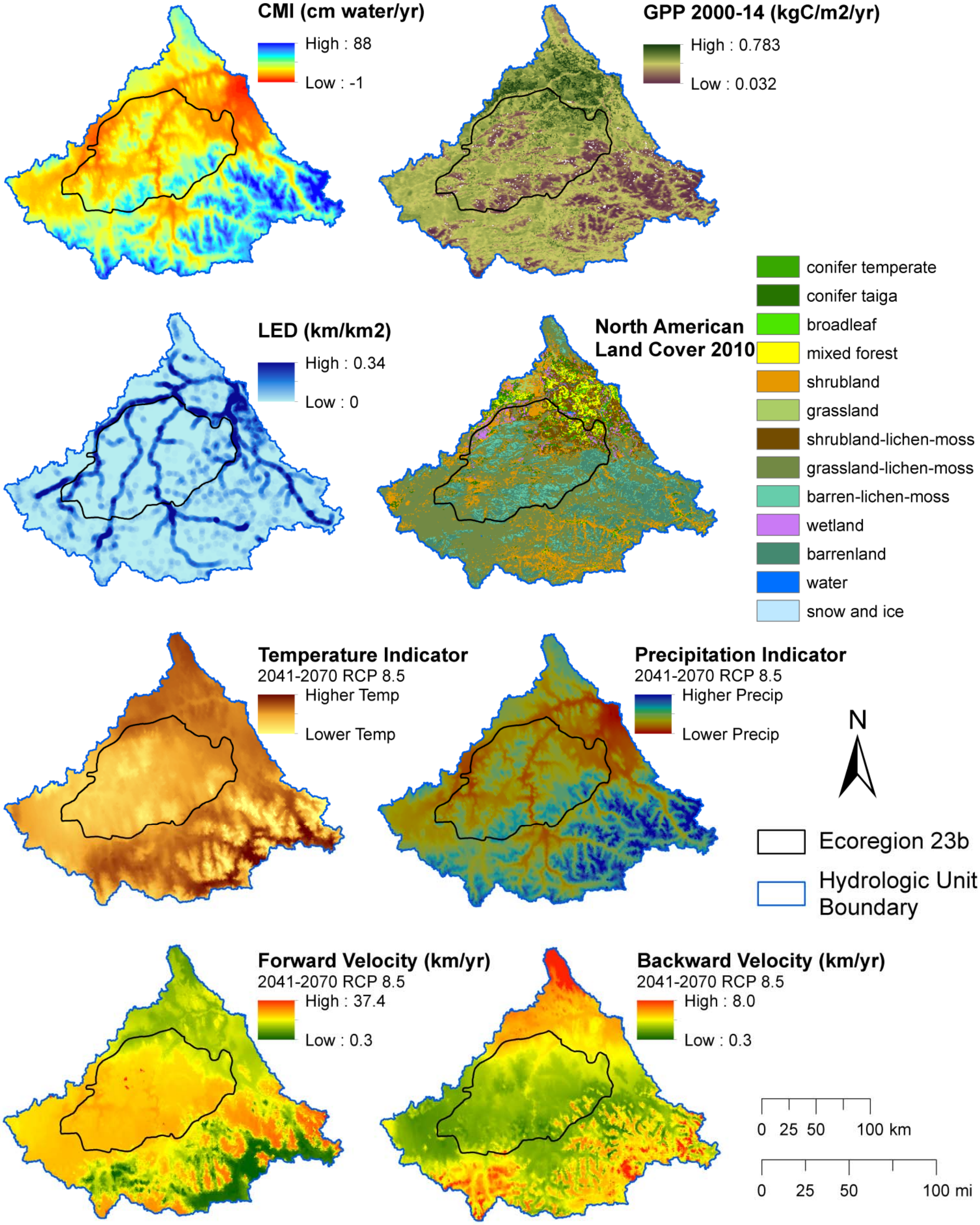

Figure 3: Distribution of the four indicators of environmental variation and four climate change datasets in the ecoregion, which include Climate Moisture Index (CMI, Wang *et al.* 2016), Gross Primary Productivity 2000-14 (GPP, BEACONs 2015), Lake-Edge Density (LED, BEACONs 2015), and North American Land Cover 2010 (CEC 2013), and the climate-projected datasets: Temperature and Precipitation Indicators, and Forward and Backward Velocity (AdaptWest Project 2015).

Benchmark network ranking

Candidate benchmark networks were ranked using three sets of criteria: fundamental benchmark properties (Table 3), resilience to climate change (Table 4), and the amount of focal species habitat (Table 5). Ranks were determined using weighted-rank methods as described in the main report. The ranks across the three sets of criteria were combined to provide an overall rank (Table 6). The results for all benchmark networks (N=24) are available at www.beaconsproject.ca/nwb.

Fundamental Benchmark Properties

In addition to being large and intact, benchmarks are designed to have high internal hydrologic connectivity (*e.g.*, DCI), minimal vulnerability to external and internal disturbances (*e.g.*, Upstream Area), and a compact shape (*e.g.*, Shape Index), and selected to be representative of environmental variation. The 6 candidate networks vary with regards to these properties. While all benchmark networks satisfy MDR-based representation targets, representation varies widely when measured using dissimilarity metrics (DMs). For example, Mean Dissimilarity ranges from 0.096 to 0.226, with higher values indicating greater dissimilarity and poorer representation (Tables 2 & 3). Four of the six networks have moderate to high representation with DM < 0.2 across the four indicators of environmental variation (Table 2). Networks differ widely in the amount of upstream area (3,047 – 11,379 km^2), with all upstream areas largely intact (94 - 100%). Networks are similar with regards to internal vulnerability and shape (1.7-2.2), but differ with regards to internal hydrologic connectivity, with lwDCI ranging from 0.501 to 0.915 (Table 3), with values closer to 1 indicating greater connectivity. The networks with overlapping benchmarks (N1-3) were treated as a single benchmark when calculating Shape and lwDCI.

Table 3: Benchmark networks were ranked using a suite of benchmark properties. **Mean Dissimilarity** is the mean dissimilarity metric for the four indicators of environmental variation, and ranges from 0 to 1, with values closer to 0 indicating better representation, and ranking higher. **Upstream Area** is a measure of vulnerability to external influences via the stream network; lower values rank higher. **Upstream AWI** is the mean area-weighted intactness of catchments upstream of the network; higher values rank higher. **Internal Vulnerability** is the proportion of low (<80%) intact areas within the network; lower values rank higher. **Maximum Shape** is the shape index for the benchmark in the network that most deviates from a circle (shape index = 1); lower values rank higher. **Minimum lwDCI** is the mean length-weighted Dendritic Connectivity Index (0-1; low to high connectivity) for the benchmark with the lowest internal hydrologic connectivity in the network; higher values rank higher. **Benchmark Properties Rank** is based on the network-level mean weighted rank across all properties, shown in (). The highest ranked network within each individual benchmark property is highlighted in grey. All metrics are described in the main report. **Overlapping benchmarks within a network were treated as a single benchmark when calculating Shape and lwDCI.**

Network ID	Mean Dissimilarity	Upstream Area km² (mi²)	Upstream AWI (%)	Internal Vulnerability	Maximum Shape	Minimum lwDCI	Benchmark Properties Rank
N1	0.099	11,379 (4,393)	94	**0.000**	2.2	0.501	6 (0.155)
N2	0.226	5,675 (2,191)	99	0.005	1.9	0.846	2 (0.172)
N3	0.110	9,151 (3,533)	**100**	**0.000**	1.8	0.710	4 (0.167)
N4	0.141	11,074 (4,276)	**100**	**0.000**	2.0	0.513	5 (0.158)
N5	0.109	11,034 (4,260)	**100**	**0.000**	**1.7**	**0.915**	3 (0.169)
N6	**0.096**	**3,047 (1,176)**	95	**0.000**	1.8	0.557	1 (0.176)

Climate Change Resilience

Changes in patterns of environmental variation are expected under climate change. To address this, we ranked benchmark networks based on their ability to maintain representation, as measured by dissimilarity metrics (DM), using climate-projected multivariate indicators of climatic conditions (2041-2070, RCP 8.5[1]; Figure 3), which we refer to as Temperature and Precipitation Indicators given the explanatory power of temperature and precipitation variables in each indicator, respectively. Only one network (N6) maintains representation with moderate to high values for both indicators (DM < 0.2; Table 4), while three other networks (N1, N3 and N5) maintain moderate to high representation of the precipitation indicator. To address the vulnerability of benchmark networks and their support of biodiversity under climate change, we evaluated the ability of species to persist within, and colonize, benchmark networks, using forward and backward climate velocity (2041-2070, RCP 8.5[1]; Figure 3), respectively. Higher velocities indicate greater vulnerability to species loss. Across networks, mean forward and backward velocities range from 6.0 to 7.8 km/yr and 1.4 to 2.3 km/yr, respectively (Table 4). All networks have mean backward and forward velocities similar to the ecoregion-level means of 1.6 km/yr and 7.0 km/yr, respectively. Lower forward velocities indicate higher refugia potential for species, whereas lower backward velocities indicate higher colonization potential. In all networks, mean backward velocity is lower than mean forward velocity. This suggests that the networks favour colonization potential over refugia potential. The output is available such that users have the flexibility to select a subset of climate datasets to rank networks.

Table 4: Benchmark networks were ranked based on their capacity to represent future climatic conditions (temperature and precipitation indicators) and vulnerability to changing climatic conditions (forward and backward velocity). **Temperature and Precipitation Indicators** were assessed using the Kolmogorov-Smirnov (KS) dissimilarity metric, which ranges from 0 to 1; lower values indicate better representation, and rank higher. **Climate Velocities** are calculated as the geometric mean across all benchmarks from each network; lower values rank higher. **Climate Change Rank** is based on the network-level mean of weighted ranks across the four climatic measures, shown in (). The highest ranked network within each indicator/velocity is highlighted in grey. For dataset details, see the main report.

Network ID	KS Dissimilarity Metric		Mean Forward Climate Velocity km/yr (mi/yr)	Mean Backward Climate Velocity km/yr (mi/yr)	Climate Change Rank
	Temperature Indicator	Precipitation Indicator			
N1	0.227	0.114	6.2 (3.9)	2.0 (1.3)	1 (0.173)
N2	0.510	0.286	6.3 (3.9)	1.6 (1.0)	2 (0.171)
N3	0.369	**0.072**	7.8 (4.9)	**1.4 (0.8)**	5 (0.157)
N4	0.340	0.257	**6.0 (3.7)**	2.3 (1.4)	3 (0.169)
N5	0.470	0.116	6.5 (4.0)	1.9 (1.2)	4 (0.164)
N6	**0.105**	0.133	7.3 (4.5)	1.6 (1.0)	4 (0.164)

[1] All climate-projected datasets used to rank networks were for the period 2041-2070 and were created using RCP 8.5, the Representative Concentration Pathway with the highest greenhouse gas emissions from IPCC (2014). Additional rankings based on 2011-2040 and 2071-2100 and RCP 4.5 are available at www.beaconsproject.ca/nwb.

Focal Species

An extensive review of management plans for the NWBLCC did not reveal specific conservation targets for focal species (see focal species report). As such, the objective for all focal species was to maximize the protection of current and future habitat when ranking benchmark networks. For some species, there are multiple datasets (N=2-15). When multiple datasets were used, the network rank for each species (or guild) is a mean of the weighted ranks generated for each dataset. Within each network, ranks vary across species (Table 5). The output is available such that users have the flexibility to select a subset of species datasets to rank networks.

Table 5: Benchmark networks were ranked based on the amount of focal species habitat they capture. Data were not available for Beaver, Broad Whitefish, Chinook Salmon, Chum Salmon and Trumpeter Swan. Values in () are weighted ranks. When multiple datasets were used for a species (*e.g.*, Rusty Blackbird N=3), networks were ranked using the mean of weighted ranks from across datasets. The highest ranked network within each individual species is highlighted in grey. **Focal Species Rank** is based on the network-level mean of weighted ranks across all species. For further details on the datasets and methods see main and focal species reports. Additional information on focal species and datasets is available at www.beaconsproject.ca/nwb.

Network ID	Rank (mean weighted rank)						Focal Species Rank
	Caribou (N=1)	Dall Sheep (N=1)	Moose (N=1)	Old-Forest Birds (N=15)[1]	Rusty Blackbird (N=3)	Waterfowl (N=2)[2]	
N1	1 (0.180)	4 (0.146)	5 (0.132)	4 (0.165)	2 (0.178)	2 (0.168)	4 (0.161)
N2	4 (0.109)	5 (0.136)	3 (0.153)	1 (0.176)	3 (0.170)	4 (0.165)	5 (0.151)
N3	2 (0.178)	3 (0.161)	1 (0.218)	5 (0.148)	4 (0.169)	5 (0.164)	1 (0.173)
N4	1 (0.180)	1 (0.224)	4 (0.152)	3 (0.170)	6 (0.134)	1 (0.169)	2 (0.171)
N5	3 (0.171)	2 (0.194)	4 (0.152)	2 (0.174)	5 (0.153)	3 (0.166)	3 (0.168)
N6	1 (0.180)	5 (0.136)	2 (0.191)	4 (0.165)	1 (0.193)	4 (0.165)	2 (0.171)

[1] Guild composed by Boreal Chickadee, Brown Creeper, Pine Grosbeak, Swainson's Thrush, and White-Winged Crossbill. The weighted rank shown in parenthesis is the mean across 16 datasets (3 per species + 1 that affects all species).

[2] Guild composed by Lesser Scaup (1 dataset), White-Winged Scoter (1 dataset), and Trumpeter Swan (0 datasets). The weighted rank shown in parenthesis is the mean across all species.

Overall Rank

Candidate benchmark networks were assigned an overall rank based on fundamental benchmark properties (Table 3), resilience to climate change (Table 4) and the amount of focal species habitat (Table 5). Attributes were given equal weighting. However, users may wish to prioritize some attributes over others. The results are available in a format that gives users the flexibility to modify and re-rank networks. Additional attributes can also be considered. For example, if the conservation priority is the protection of focal species habitat within the ecoregion, networks with greater overlap with the ecoregion are more likely to achieve this objective. Greater overlap with protected areas may facilitate implementation, given existing protection. Overlap with the ecoregion and existing protected areas ranges from 41-100% and 0% across benchmark networks, respectively (Table 6). While benchmark networks that most overlap with the ecoregion may best reflect the environmental variation of the ecoregion, networks that extend beyond the ecoregion boundary may contribute to the benchmark networks of neighbouring ecoregions, leading to greater efficiency in the design of a protected area networks for the NWBLCC planning region.

Table 6: **Overall Rank** is the network-level mean of weighted ranks for fundamental benchmark properties (Table 3), climate change (Table 4) and focal species (Table 5). Values in () are weighted ranks. **Overlap with ecoregion** and **Overlap with existing PAs** with high levels of protection may be used as additional ranking criteria.

Network ID	Overlap with Ecoregion	Overlap with Existing PAs	Mean Dissimilarity	Benchmark Properties Rank	Climate Change Rank	Focal Species Rank	Overall Rank
N1	89.9%	0.0%	0.099	6 (0.155)	1 (0.173)	4 (0.161)	6 (0.163)
N2	41.4%	0.0%	0.226	2 (0.172)	2 (0.171)	5 (0.151)	5 (0.164)
N3	100.0%	0.0%	0.110	4 (0.167)	5 (0.157)	1 (0.173)	4 (0.165)
N4	64.6%	0.0%	0.141	5 (0.158)	3 (0.169)	2 (0.171)	3 (0.166)
N5	81.3%	0.0%	0.109	3 (0.169)	4 (0.164)	3 (0.168)	2 (0.167)
N6	100.0%	0.0%	0.096	1 (0.176)	4 (0.164)	2 (0.171)	1 (0.170)