Ecoregion 24 – Nulato Hills

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)
58,132 (22,445)	134,167 (51,802)	15,541 (6,000)	0	149	41 (2)

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 24 is defined by the ecoregion and intersecting hydrologic units (HUC8). 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. Two potential PA system-level II benchmarks were identified in ecoregion 24 (Figure 1; Table 1). However, none had 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 24 has high benchmark potential with benchmarks identified over 98% of the ecoregion (Figure 1), which includes areas with existing protection.

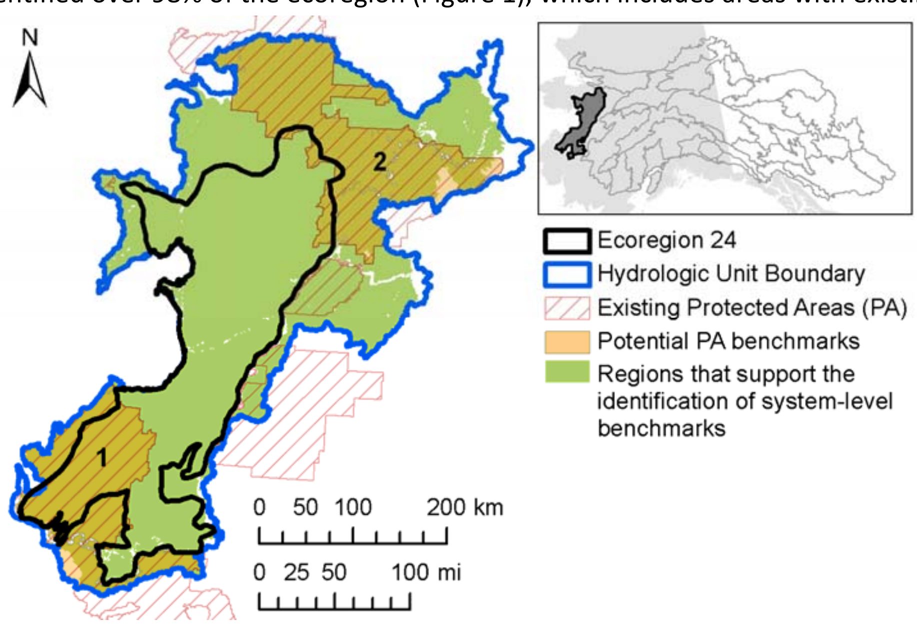

Figure 1: The planning region for ecoregion 24 is defined by the ecoregion (black outline) buffered by HUC8s (blue outline). Potential protected area (PA) system-level II benchmarks are shown in orange; labels correspond to the PA ID in Table 1. Regions that support the identification of new system-level benchmarks (≥80% catchment-intactness) are shown in green.

Table 1: Characteristics of two system-level II protected area (PA) benchmarks evaluated in ecoregion 24 (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	19,134 (7,388)	System-level II	62
PA_2	26,952 (10,406)	System-level II	11

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 (Figure 2a & 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 24, two system-level benchmarks achieve representation targets for all indicator classes except for either one CMI or one landcover class. In total, 41 candidate benchmark networks were identified, and assigned to two spatial groups (Figure 2a). In all networks, the two benchmarks overlap spatially. All networks spatially grouped with N1, fall short in representing CMI class 14 with 81-92% of the target met, while networks grouped with N2 achieve 34-82% of the representation target for shrubland-lichen-moss (Figure 2b). Catchments neighbouring these networks can be added to complete the representation of both classes. 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 two 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	29,868 (11,532)	64,896 (25,056)	0.232	0.088	0.144	0.149	0.153
N2	30,938 (11,945)	49,692 (19,186)	0.246	0.094	0.158	0.232	0.182

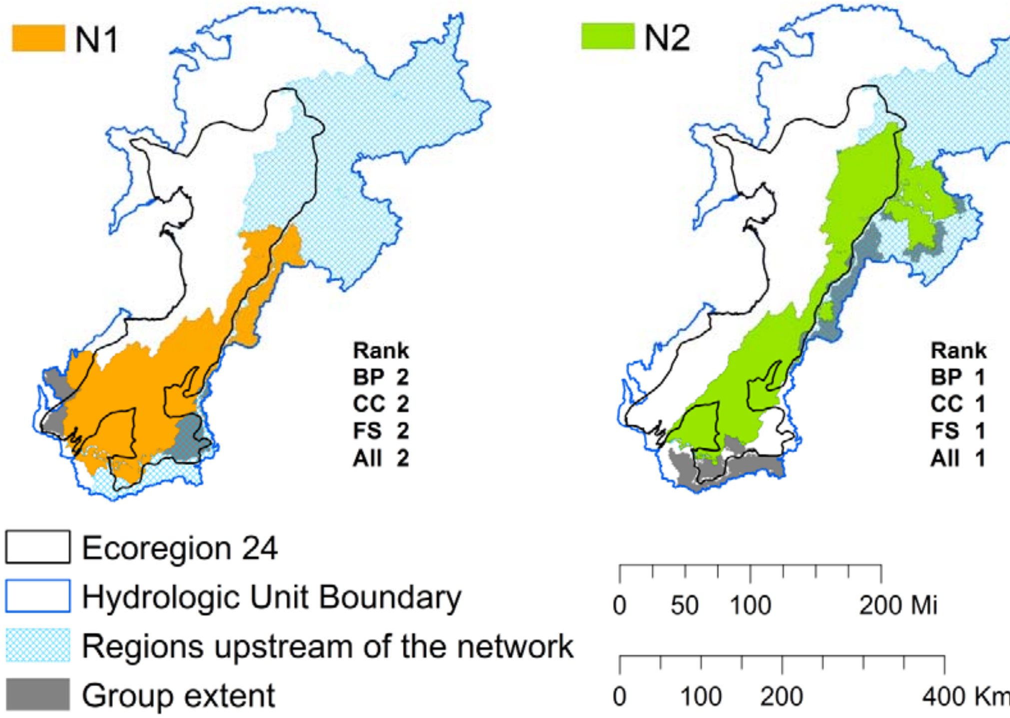

Figure 2a: Benchmark networks for ecoregion 24 (N=41) were assigned to 2 spatial groups. The top network selected from each group is shown in color. Catchments upstream of networks are shown in blue cross-hatching. The group extent (grey) is the area covered by all networks in the group. Ranks based 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).

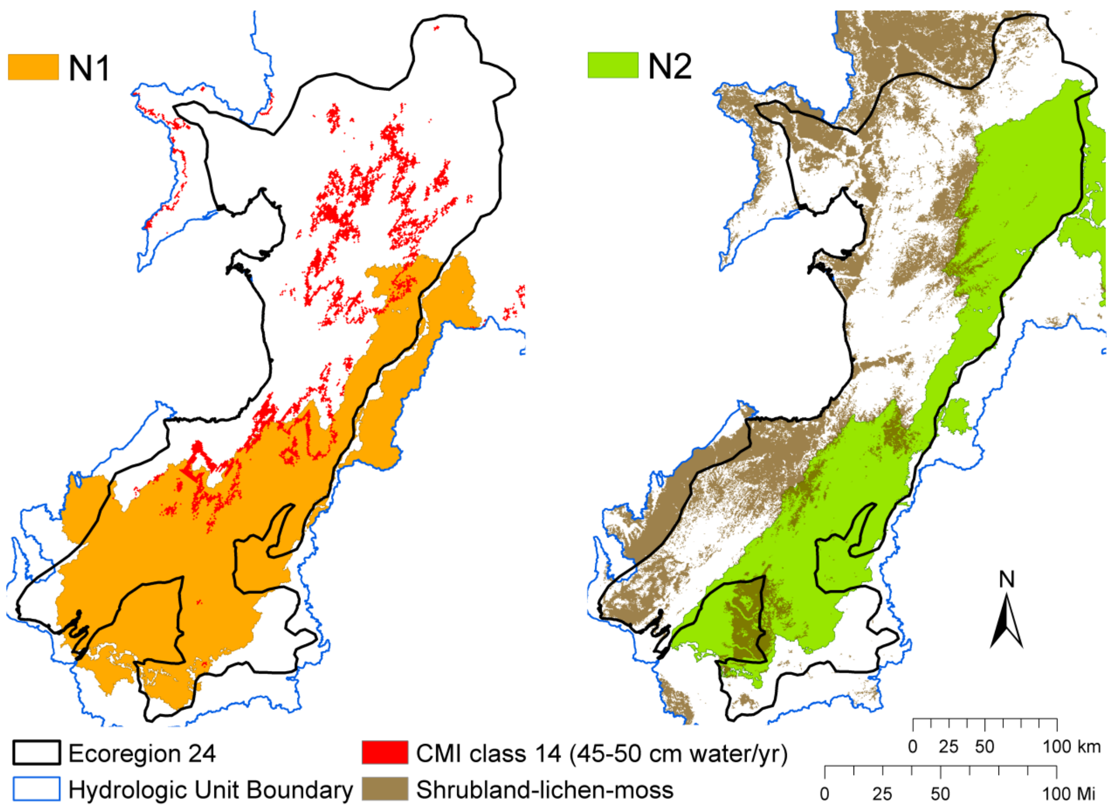

Figure 3b: Benchmark networks N1 and N2 require an additional 91 km^2 of CMI class 14 and 639 km^2 of landcover class shrubland-lichen-moss, respectively, to complete the representation of these indicator classes. In both cases, the classes lie adjacent to network options, and catchments can be added to benchmark networks to complete representation.

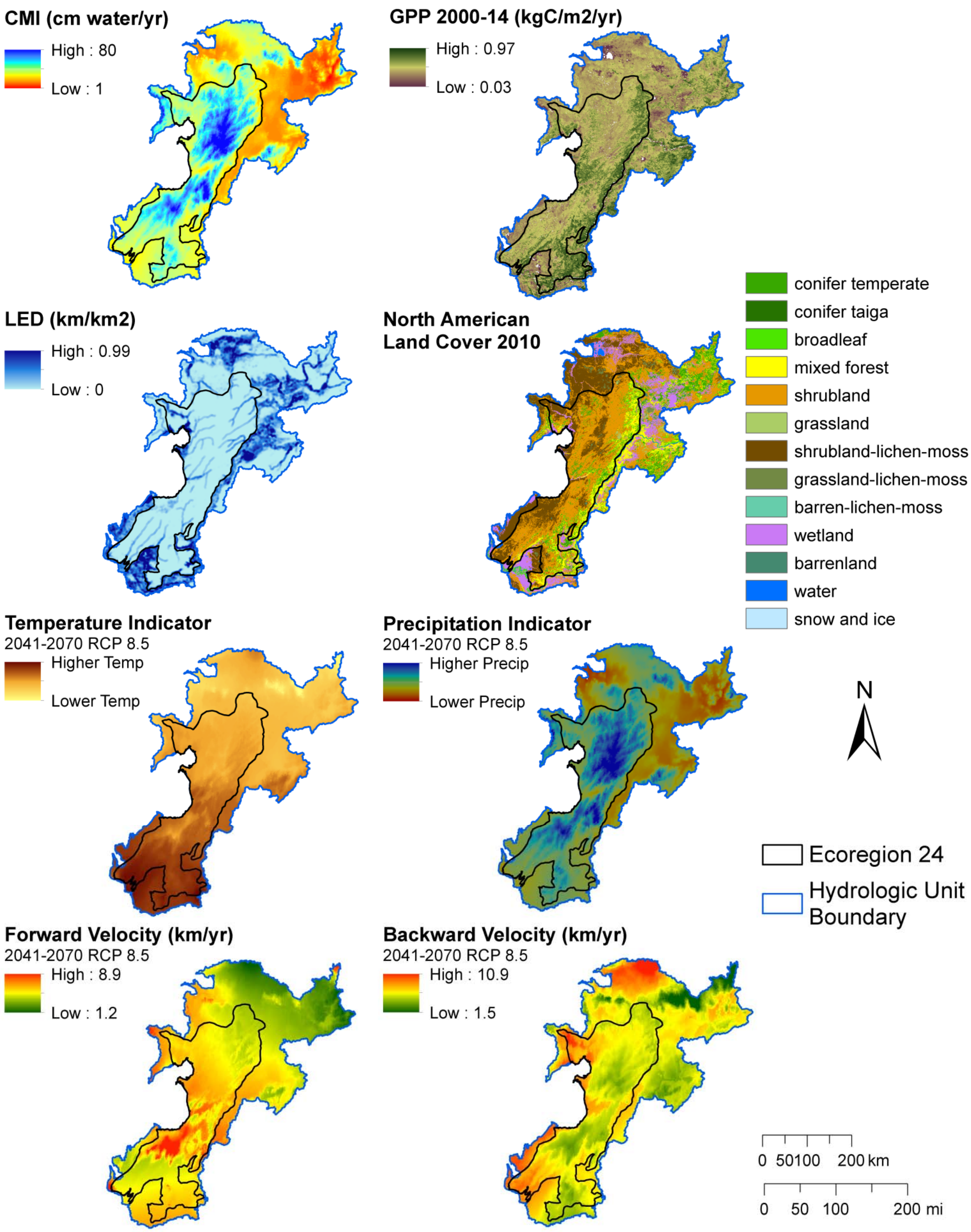

Figure 3: Distribution of the four indicators of environmental variation and four climate change datasets in the ecoregion, which include Climate Moisture Index (CMI, Wang *et al.* 2016), Gross Primary Productivity 2000-14 (GPP, BEACONs 2015), Lake-Edge Density (LED, BEACONs 2015), and North American 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=41) 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. Candidate networks vary with regards to these properties. Both networks require strategic catchment additions in order to achieve MDR-based representation targets. Both networks were similar in terms of representation when measured using dissimilarity metrics (DMs), with moderate mean dissimilarity values (DM < 0.2; Table 3). Network 2 ranked slightly higher overall, largely due to its lower upstream area (Table 3). While the networks differ widely in the amount of upstream area (49,692 – 64,896 km^2), the upstream area is largely intact in both cases (98%; Table 3). Between networks, shape and internal hydrologic connectivity (lwDCI) are also similar. Because the benchmarks within the networks overlap spatially, we treated the network 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. **Shape** is the shape index for the benchmark network, measured as deviation from a circle (shape index = 1); lower values rank higher. **lwDCI** is the mean length-weighted Dendritic Connectivity Index (0-1; low to high connectivity) for the benchmark network; higher values rank higher. **Benchmark Properties Rank** is based on the network-level mean of weighted ranks 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	Shape	lwDCI	Benchmark Properties Rank
N1	**0.153**	64,896 (25,056)	**98**	0.019	5.2	**0.18**	2 (0.479)
N2	0.182	**49,692 (19,186)**	**98**	**0.005**	**5.1**	0.11	1 (0.520)

Climate Change Resilience

Changes in patterns of environmental variation are expected under climate change. To address this, we ranked benchmark networks according to 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. Network 2 maintains representation of the temperature indicator (DM < 0.2), while neither network maintains representation of the precipitation indicator (DM > 0.2; Table 4). 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]; Figure3), respectively. Higher velocities indicate greater vulnerability to species loss. Across networks, climate velocity values are very similar, with mean forward and backward velocities ranging from 5.1 to 5.4 km/yr and 7.0 to 7.4 km/yr, respectively (Table 4). These values are similar to the ecoregion-level mean forward and backward velocities of 5.3 and 7.3 km/yr, respectively. Lower forward velocities indicate higher refugia potential for species, whereas lower backward velocities indicate higher colonization potential. In both networks, forward velocity is lower than backward velocity suggesting that the networks designed for this ecoregion favour refugia potential over colonization 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 weighted rank 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	0.406	0.237	5.4 (3.3)	7.4 (4.6)	2 (0.469)
N2	**0.095**	**0.227**	**5.1 (3.2)**	**7.0 (4.3)**	1 (0.530)

[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.beaconswiki.ca/TBD.

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. Network 2 (N2) captured more habitat than network 1 (N1) for most species, except for moose, old-growth forest birds, and waterfowl (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 Broad Whitefish. Values in () are weighted ranks. When multiple datasets were used for a species (*e.g.*, Caribou N=5), 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 rank across all species. For further details on the datasets and methods, see main and focal species reports. Additional information on each focal species and their datasets is available at www.beaconsproject.ca/nwb.

Network ID	Rank (mean weighted rank)									Focal Species Rank
	Beaver (N=1)	Caribou (N=5)	Chinook Salmon (N=3)	Chum Salmon (N=4)	Dall Sheep (N=2)	Moose (N=2)	Old-Forest Birds (N=15)[1]	Rusty Blackbird (N=3)	Waterfowl (N=3)[2]	
N1	2 (0.377)	2 (0.426)	2 (0.377)	2 (0.377)	1 (0.500)	1 (0.500)	1 (0.513)	2 (0.417)	2 (0.459)	2 (0.438)
N2	1 (0.622)	1 (0.573)	1 (0.622)	1 (0.622)	1 (0.500)	1 (0.500)	2 (0.486)	1 (0.582)	1 (0.540)	1 (0.560)

[1] Guild composed by Boreal Chickadee, Brown Creeper, Pine Grosbeak, Swainson's Thrush, and White-Winged Crossbill. In this case, the weighted rank shown in parenthesis is the mean across 15 datasets (3 per species).

[2] Guild composed by Lesser Scaup (1 dataset), White-Winged Scoter (1 dataset), and Trumpeter Swan (1 dataset). 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. Both networks have similar overlap with the ecoregion, while network N1 has a higher overlap with existing protected areas than network N2 (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 a network-level sum 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	68.4%	48.3%	0.153	2 (0.479)	2 (0.469)	2 (0.438)	2 (0.462)
N2	67.8%	28.0%	0.182	1 (0.520)	1 (0.530)	1 (0.560)	1 (0.537)