Ecoregion 171 – Selwyn 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)
72,426 (27,964)	199,198 (76,910)	4,761 (1,838)	1	348	23 (7)

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 benchmark properties, climate change, and focal species, as done below.

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

The planning region for ecoregion 171 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 benchmark was identified in ecoregion 171 (Figure 1; Table 1). This PA benchmark had sufficient overlap with the ecoregion (≥ 80% MDR) to be included in the design of benchmark networks. While this single PA benchmark is sufficient to achieve environmental representation, we identified new benchmarks to provide land managers with additional options. Ecoregion 171 has high benchmark potential with benchmarks identified over 97% of the ecoregion (Figure 1), which includes areas with existing protection.

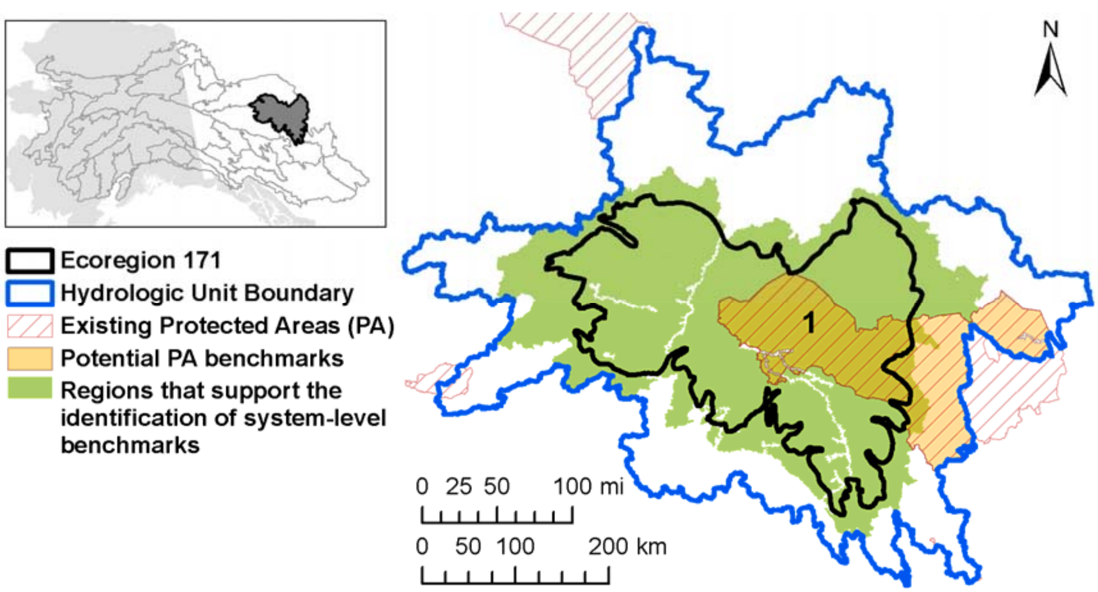

Figure 1: The planning region for ecoregion 171 is defined by the ecoregion (black outline) buffered by FDAs (blue outline). Potential protected area (PA) system-level II benchmarks are shown in orange; labels correspond to the PA ID in Table 1. Regions that support the identification of new system-level benchmarks (≥80% catchment-intactness) are shown in green.

Table 1: Characteristics of the system-level II protected area (PA) benchmark identified in Ecoregion 171 (Figure 1). To be included in the design of benchmark networks, the ecoregion portion of the PA benchmark must be ≥ 80% MDR in size.

PA ID	Area km² (mi²)	Benchmark Type	% MDR area intersecting ecoregion
PA_1	29,400 (11,351)	System-level II	326 (3.3 x MDR)

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 171, the existing protected area benchmark achieves representation targets for all indicator classes (N1; Figure 2). Only the ecoregion portion of N1 (comprised of PA_1) is needed to achieve representation and satisfy the size and intactness requirements of a system-level benchmark. As such, only the ecoregion portion of N1 was used to assess fundamental benchmark properties and resilience to climate change. However, the full extent of N1 was used when evaluating the representation of focal species habitat. Networks were also identified from new benchmarks only. Networks designed from two new system-level benchmarks achieve all representation targets. In total, 23 candidate benchmark networks were identified, and assigned to seven spatial groups (Figure 2). For reporting, the set of candidate benchmark networks was reduced to the top network from each spatial group (N2-N7; 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 network selected from each of the seven 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*	15,520 (5,992)	1,760 (680)	0.114	0.026	0.112	0.140	0.098
N2	9,521 (3,676)	2,459 (949)	0.231	0.081	0.118	0.233	0.166
N3	9,223 (3,561)	7,264 (2,805)	0.118	0.024	0.076	0.091	0.077
N4	9,265 (3,577)	7,221 (2,788)	0.076	0.017	0.057	0.090	0.060
N5	8,951 (3,456)	865 (334)	0.065	0.046	0.081	0.130	0.080
N6	9,526 (3,678)	199 (77)	0.027	0.024	0.066	0.071	0.047
N7	9,525 (3,678)	4,358 (1,683)	0.023	0.057	0.025	0.116	0.055

*N1 is the protected area system-level II benchmark PA_1 (Figure 1, Table 1).

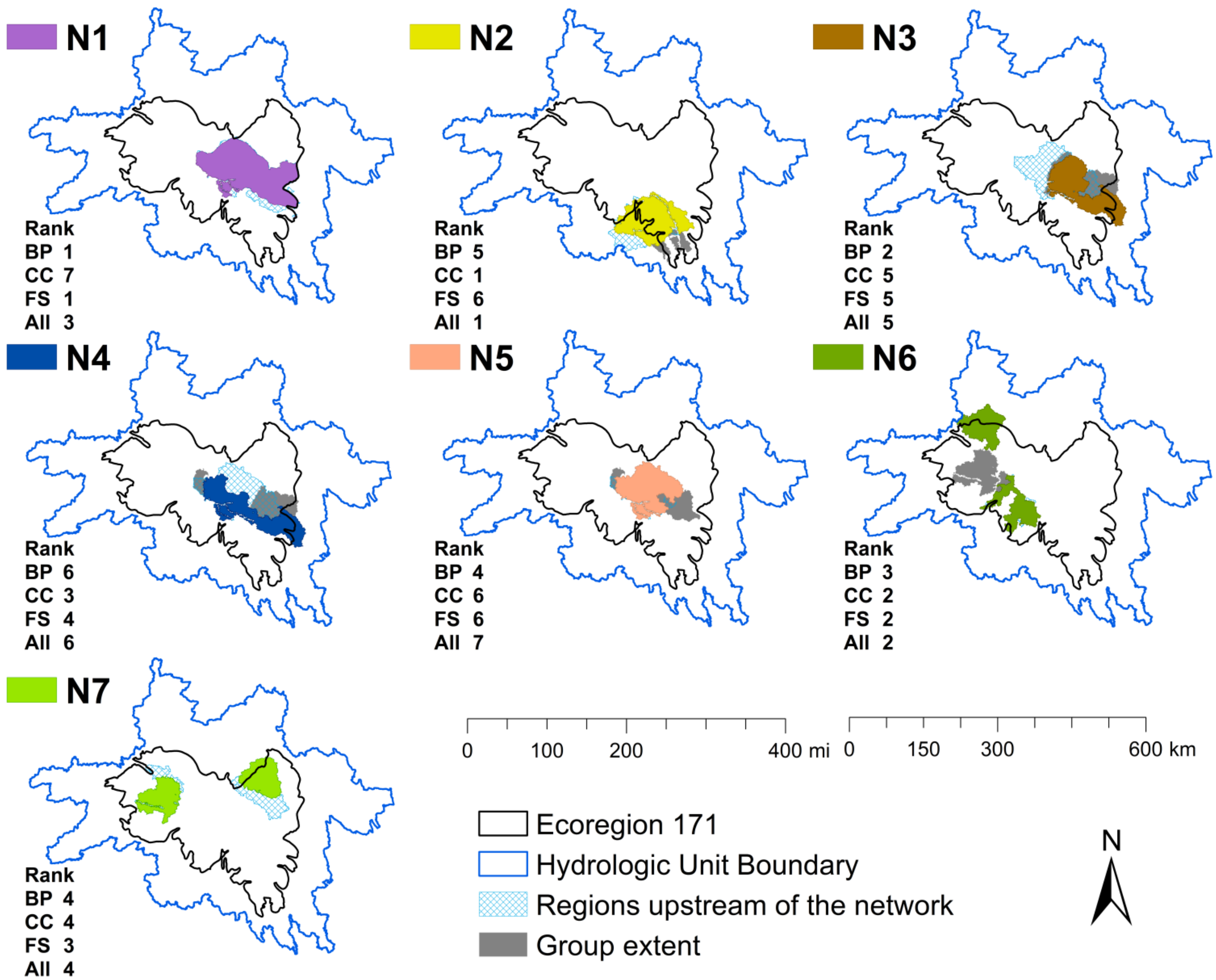

Figure 2: Benchmark networks for ecoregion 171 (N=23) were assigned to seven spatial groups. The top network selected from each group is shown in color. N1 is the protected area system-level II benchmark PA_1 identified in Figure 1. N2-N7 are benchmark networks comprised of two new system-level benchmarks; the benchmarks overlap in N2-N5. 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).

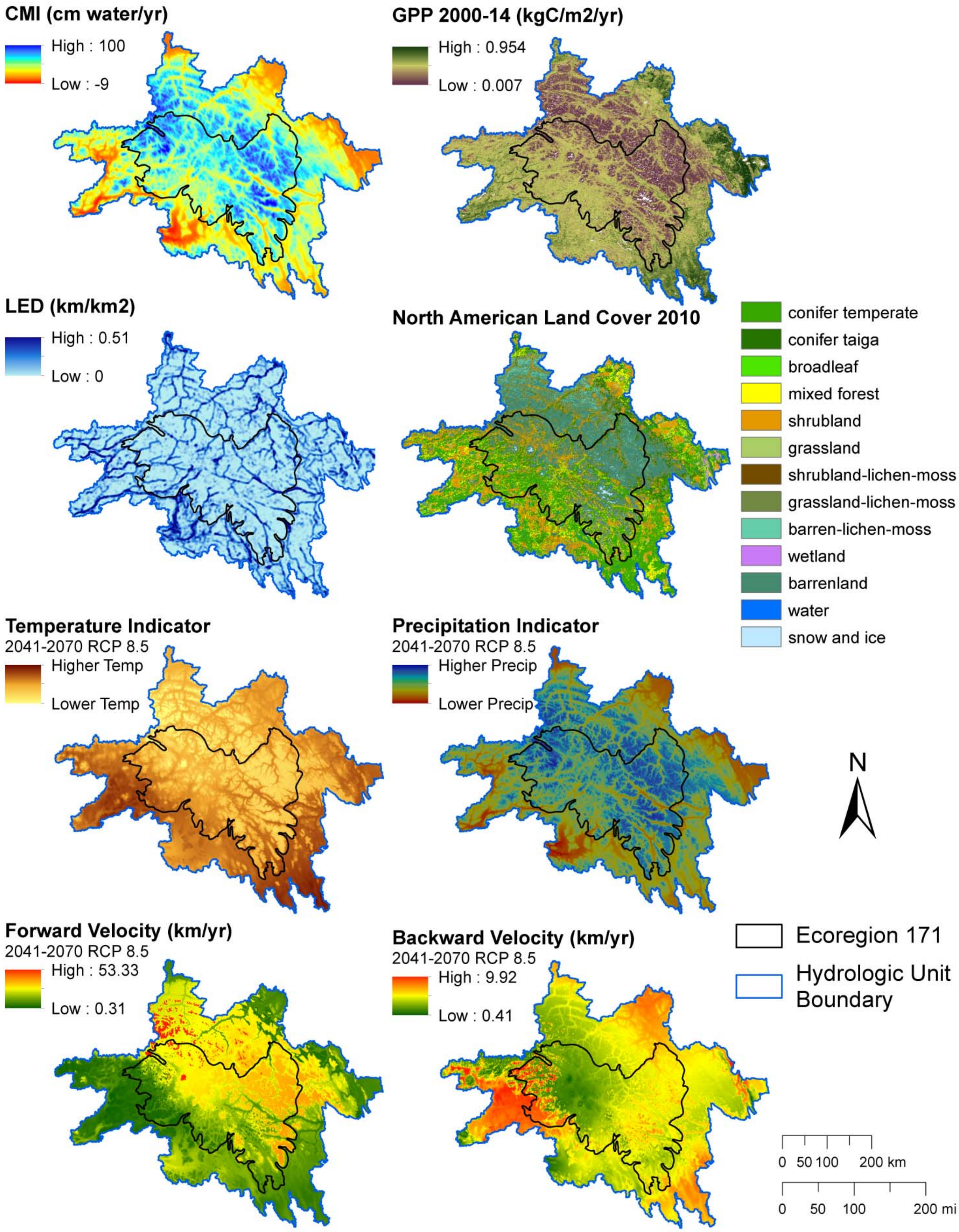

Figure 3: Distribution of the four indicators of environmental variation and four climate change datasets in the ecoregion, which include Climate Moisture Index (CMI, Wang *et al.* 2016), Gross Primary Productivity 2000-14 (GPP, BEACONs 2015), Lake-Edge Density (LED, BEACONs 2015), and North American 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 5a). 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=23) 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 seven candidate networks vary with regards to these properties. While all benchmark networks satisfy MDR-based representation targets, representation varies when measured using dissimilarity metrics (DMs). Mean Dissimilarity ranges from 0.047 to 0.166, with higher values indicating greater dissimilarity and poorer representation (Tables 2 & 3). All networks (except N2) have moderate to high representation across the four indicators of environmental variation with DM < 0.2 (Table 2). Networks differ widely in the amount of upstream area (199 – 7,264 km^2), although in all cases the upstream area is moderately to largely intact (77-98%; Table 3). Networks vary with regards internal vulnerability, shape (2.8-4.3), and internal hydrologic connectivity, with minimum lwDCI ranging from 0.184 to 0.584 (Table 3), with values closer to 1 indicating greater connectivity. The networks with overlapping benchmarks (N2-N5) 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 km^2 (mi^2)	Upstream AWI (%)	Internal Vulnerability	Maximum Shape	Minimum lwDCI	Benchmark Properties Rank
N1	0.098	1,760 (680)	91	0.003	**2.8**	**0.584**	1 (0.158)
N2	0.166	2,459 (949)	81	0.029	4.1	0.184	5 (0.133)
N3	0.077	7,264 (2,805)	97	0.**001**	2.9	0.498	2 (0.148)
N4	0.060	7,221 (2,788)	**98**	0.014	4.3	0.498	6 (0.131)
N5	0.080	865 (334)	84	0.013	4.2	0.549	4 (0.141)
N6	**0.047**	**199 (77)**	77	0.**001**	3.7	0.448	3 (0.146)
N7	0.055	4,358 (1,683)	**98**	0.006	3.5	0.274	4 (0.141)

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. All networks (except N2) maintain representation with moderate values for both indicators (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]; Figure 3), respectively. Higher velocities indicate greater vulnerability to species loss. Across networks, mean forward and backward velocities range from 6.9 to 11.1 km/yr and 2.2 to 3.8 km/yr, respectively (Table 4). Lower forward velocities indicate higher refugia potential for species, whereas lower backward velocities indicate higher colonization potential. In all networks, backward velocity is lower than forward velocity. Most networks have mean forward velocities higher than the ecoregion-level mean of 8.5 km/yr (except N2), whereas mean backward velocities are similar to the ecoregion-level mean of 2.9 km/yr. This suggests that 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 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 Metrics		Mean Forward Climate Velocity km/yr (mi/yr)	Mean Backward Climate Velocity km/yr (mi/yr)	Climate Change Rank
	Temperature Indicator	Precipitation Indicator			
N1	0.108	0.118	11.1 (6.9)	3.4 (2.1)	7 (0.115)
N2	0.321	0.266	**6.9 (4.3)**	3.4 (2.1)	1 (0.200)
N3	0.122	0.119	9.3 (5.8)	3.8 (2.3)	5 (0.129)
N4	0.098	0.099	8.9 (5.5)	3.5 (2.2)	3 (0.141)
N5	**0.083**	0.063	10.5 (6.5)	3.3 (2.0)	6 (0.123)
N6	0.107	0.085	9.9 (6.1)	**2.2 (1.4)**	2 (0.150)
N7	0.136	**0.033**	10.4 (6.5)	2.6 (1.6)	4 (0.137)

[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=3-15). When multiple datasets were used, the network rank for the species (or guild) is a mean of the weighted ranks generated for each dataset. Within each network, ranks vary across species (Table 5a). **For this evaluation, Network N1 includes the full extent of the PA benchmark PA_1 (Figure 1), not just the ecoregion portion (Figure 2).** The top-rank of the protected area benchmark N1 is likely due to its size, which is twice or three times that of the other networks. To remove the influence of the large network N1 on the weighted rank values, the ranking process with focal species was repeated with N1 excluded (Table 5b). The relative ranks of networks may differ from Table 5a, as differences masked by the large network N1 are revealed. The output is available such that users have the flexibility to select a subset of species datasets to rank networks.

Table 5a: Benchmark networks were ranked based on the amount of focal species habitat they capture. Data were not available for Broad Whitefish, Beaver, Chinook Salmon and Chum Salmon. 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. **Focal Species Rank** is based on the network-level mean weighted rank across all species. The highest ranked network within each individual species is highlighted in grey. 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	Area km² (mi²)	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=3)[2]	
N1	29,400 (11,351)[3]	1 (0.195)	3 (0.129)	1 (0.189)	4 (0.141)	1 (0.158)	2 (0.145)	1 (0.159)
N2	9,521 (3,676)	6 (0.121)	3 (0.129)	7 (0.115)	1 (0.166)	7 (0.131)	3 (0.140)	6 (0.133)
N3	9,223 (3,561)	4 (0.137)	3 (0.129)	3 (0.143)	3 (0.142)	6 (0.132)	4 (0.139)	5 (0.137)
N4	9,265 (3,577)	2 (0.147)	3 (0.129)	2 (0.152)	2 (0.146)	5 (0.136)	6 (0.136)	4 (0.141)
N5	8,951 (3,456)	7 (0.118)	3 (0.129)	5 (0.131)	5 (0.139)	3 (0.146)	5 (0.138)	6 (0.133)
N6	9,526 (3,678)	5 (0.133)	1 (0.213)	4 (0.142)	7 (0.128)	4 (0.142)	6 (0.136)	2 (0.149)
N7	9,525 (3,678)	3 (0.146)	2 (0.140)	6 (0.125)	6 (0.136)	2 (0.153)	1 (0.162)	3 (0.143)

[1] Guild composed of 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 of 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.

[3] The area reported for N1 differs from Table 2 because for the focal species analysis N1 includes the full extent of PA_1 (Figure 1), not just the ecoregion portion (Figure 2).

Table 6b: Benchmark networks were ranked based on the amount of focal species habitat they capture. Data were not available for Broad Whitefish, Beaver, Chinook Salmon and Chum Salmon. 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. **Focal Species Rank** is a network-level mean weighted rank across all species. The highest ranked network within each individual species is highlighted in grey. 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
	Caribou (N=1)	Dall Sheep (N=1)	Moose (N=1)	Old-Forest Birds (N=15)[1]	Rusty Blackbird (N=3)	Waterfowl (N=3)[2]	
N2	5 (0.130)	3 (0.148)	6 (0.124)	1 (0.193)	5 (0.162)	3 (0.163)	6 (0.153)
N3	3 (0.174)	3 (0.148)	2 (0.183)	3 (0.165)	6 (0.157)	2 (0.164)	4 (0.165)
N4	1 (0.205)	3 (0.148)	1 (0.205)	2 (0.170)	4 (0.163)	5 (0.160)	2 (0.175)
N5	6 (0.124)	3 (0.148)	4 (0.158)	4 (0.162)	2 (0.174)	4 (0.162)	5 (0.154)
N6	4 (0.163)	1 (0.244)	3 (0.181)	6 (0.149)	3 (0.164)	6 (0.159)	1 (0.176)
N7	2 (0.201)	2 (0.161)	5 (0.144)	5 (0.159)	1 (0.178)	1 (0.190)	3 (0.172)

[1] Guild composed of 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 of 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 5a). 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 69-100% and 0-100% 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 areas network for the NWBLCC planning region.

Table 7: **Overall Rank** is based on the network-level mean weighted rank for fundamental benchmark properties (Table 3), climate change (Table 4) and focal species (Table 5a). 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[1]	Overall Rank
N1	100.0%	100.0%	0.098	1 (0.158)	7 (0.115)	1 (0.159)	3 (0.144)
N2	68.6%	0.0%	0.166	5 (0.133)	1 (0.200)	6 (0.133)	1 (0.155)
N3	85.2%	84.1%	0.077	2 (0.148)	5 (0.129)	5 (0.137)	5 (0.138)
N4	85.2%	83.8%	0.060	6 (0.131)	3 (0.141)	4 (0.141)	6 (0.137)
N5	100.0%	97.1%	0.080	4 (0.141)	6 (0.123)	6 (0.133)	7 (0.132)
N6	76.2%	0.0%	0.047	3 (0.146)	2 (0.150)	2 (0.149)	2 (0.148)
N7	88.6%	0.0%	0.055	4 (0.141)	4 (0.137)	3 (0.143)	4 (0.140)

[1] Focal Species Rank is from Table 5a.