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Terrestrial Analysis of Ecological Representation
WWF-Canada

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Overview

In this briefing document, the criteria for a national gap analysis is described. This gap analysis builds on the principles developed during WWF-Canada's *Endangered Spaces* campaign and further work to translate these principles into a tool. The original tool by Iacobelli et al. (2006) was used as a decision-support tool for conservation planners and resource managers. Adjustments to criteria, introduction of new data, and integrating high priority considerations makes the tool applicable for conservation planning today. A description of the calculations of criteria are provided in this document.

For further details on the guiding principles of this tool, please see Iacobelli et al. (2006).

Assessment of Ecological Representation

The Assessment of Ecological Representation (AOR) is a gap analysis methodology to assess the ecological representation of a core terrestrial reserve network. The assessment is based on physical habitat types as a surrogate for the distribution of biodiversity. Ecological representation is the idea that an ecosystem should “represent” all ecosystem types, maintain all populations of native species, ecological and evolutionary processes, and allow for natural environmental change. An existing protected areas network or any number of scenarios for future protection can be tested against the conservation criteria of the representation assessment.

In 2006, WWF developed an automated calculation to assess ecological representation and developed the AOR. In 2019, WWF-Canada has taken the core principles and metrics and redeveloped the AOR tool – making adjustments and bringing in additional information, including species at risk and carbon storage. A gap analysis is a method of identifying areas in need of conservation – areas currently lacking protection yet needed for biodiversity to thrive. The AOR is a landscape-based gap analysis to inform ecoregional conservation planning by testing reserve design options that have been developed by multi-criteria methods.

Ecological representation is measured using several metrics including: 1) size requirements to maintain viable populations of native species and sustain ecological processes, 2) environmental gradients (elevation), 3) important habitat types (shoreline), and 4) habitat quality (fragmentation due to transportation networks). In addition, information on risk species, climate refugia, forest biomass and carbon storage can be utilized to identify priority areas for conservation.

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Natural disturbance zones

In this assessment, a natural region, similar to an ecozone, is mainly characterized by climate and delineated by common landscape types. Natural regions can be grouped together into larger disturbance zones based on similar disturbance regimes (Figure 1). Disturbance zones are congruent with natural regions in that they are also characterized by climate and landscape, but can be easily quantified using known data, such as fire disturbance events.

Natural disturbance zones provide the basis for generating size guidelines for protected areas. For further information on delineating natural disturbance zones as well as specific characteristics of each zone, refer to Appendix 2 in Iacobelli et al (2006).

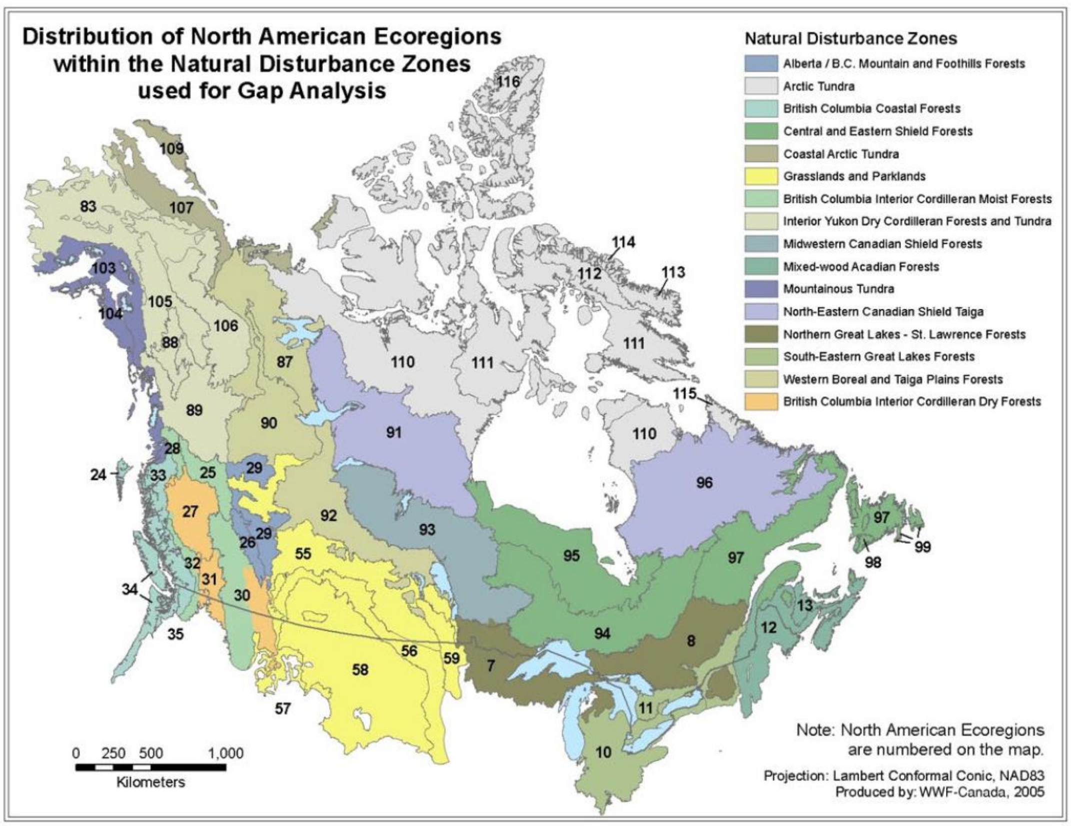


Figure 1: Natural disturbance zones used to define size and connectivity recommendations for protected areas

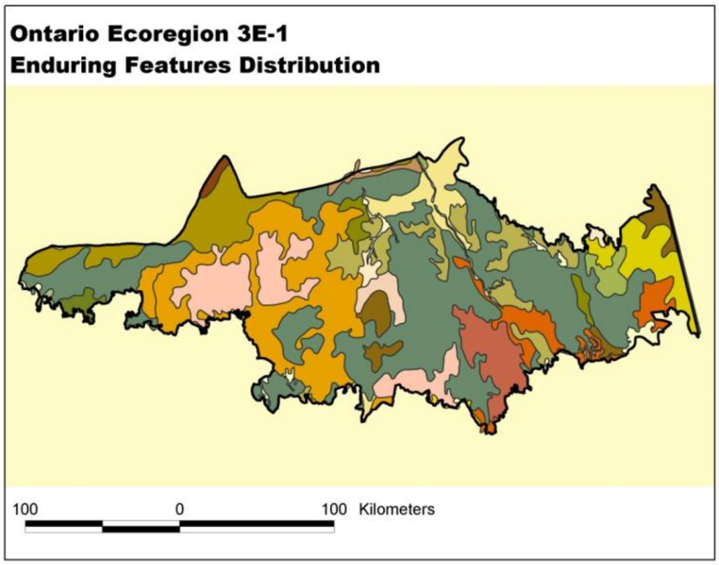
Enduring features

Enduring features, also referred to as physical habitats, are areas of similar soils, geology, landforms and climate. Enduring features are known to influence biodiversity and persist through time. Enduring features are similar to natural regions but are much more specific. These features account for regional geology, terrain, and topography. They are embedded into the natural region framework (i.e. ecodistricts) designated by each jurisdiction. There can be many enduring features within a natural region.

Beginning in 1992, WWF-Canada along with the Canadian Council on Ecological Areas (CCEA) coordinated pilot studies to delineate enduring features. Working with academic partners as well as Geomatics

International Inc (1994), these studies helped develop a framework for a nation-wide delineation. Based on results of these pilot studies, WWF-Canada developed a method to identify enduring features using the Soil Landscapes of Canada. Each soil landscape was differentiated by its landform, using a combination of topography, texture, and surficial deposits. With this database and using the framework by Geomatics International Inc (1994), an enduring feature map was created for all of Canada.

The enduring features (physical habitats) are the spatial units to which the assessment is completed.



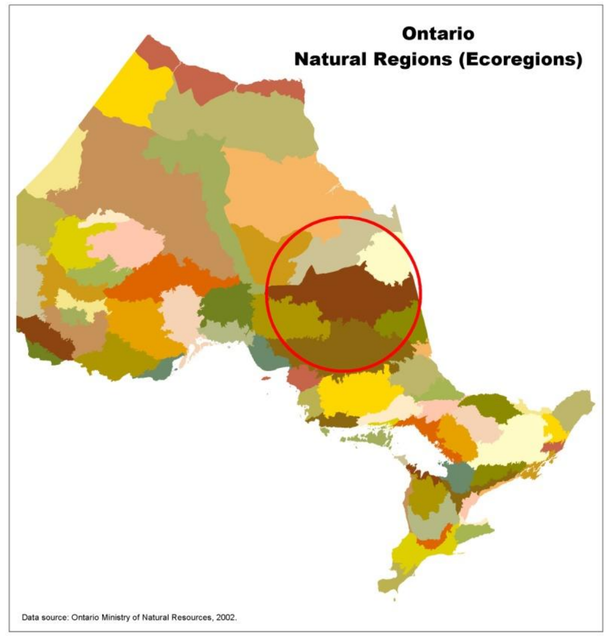


Figure 2 Example enduring features in Ontario. Enduring features are nested within provincial ecodistricts.

Protected areas

A network of conservation areas provides benefits for biodiversity and natural regimes. These areas can also be significant for cultural values and recreation. This assessment focuses on protected areas for biodiversity conservation and climate change mitigation.

For this analysis, protected areas are defined as areas that contribute to the Convention on Biological Diversity (CBD) goals. The current protected areas in Canada were obtained from the CCEA dataset – Conservation Areas Reporting and Tracking System (CARTS). While this dataset is from 2017, where possible, more recent dataset from each jurisdiction was obtained. This included protected areas for Quebec, Nova Scotia, Alberta and for the Northwest Territories. Areas contributing to Aichi Target 11 were included, including both designated and interim areas. Only terrestrial protected areas were included in this assessment.

Ecological representation criteria

There are currently six sets of criteria built into assessing our current protected area network. Each enduring feature is evaluated by assessing the degree of protection within the region. A common method for ecological representation is based on a calculation of proportions; for example, the percent of the spatial unit that is protected.

For an understanding of ecological representation, the criteria focus on size guidelines, connectivity, environmental variation, shorelines, and intactness. Explanations of each criterion are provided below.

Largest Protected Area Score (%)

Size guidelines for adequate protection were developed for enduring features. These guidelines were derived to meet two guiding principles: 1) to accommodate for spatial differences of ecological processes and 2) to be able to maintain viable populations of species. Primarily driven by natural disturbance events (forest fires) and focal species data, ecological integrity size thresholds equations were derived. Each natural disturbance zone has a unique log-log equation which accounts for a for recommended minimum protected area size for that specific zone. While this briefing document does not go into detail of the development of these equations, the full methods and rationale can be found in Iacobelli et al (2006).

Based natural disturbance zones and size threshold equations, each enduring feature was given a recommended protected size. Using the protected area boundary, the largest contiguous protected area clipped to each enduring feature was identified. The largest contiguous protected area was compared to the protected size guideline and a percent in relation to the guideline was computed. Limits were set to range between 0% and 100%. These scores were then reclassified based on the rubric found in Table 1.

Protected Area Coverage Score (%)

Using the same equations for each natural disturbance zone described above, each enduring feature was given a recommended protected size. The total area of the protected areas in each enduring feature was calculated. The protected area size was compared to the protected size guideline in that natural disturbance zone and a percent in relation to the guideline was computed. Limits were set to range between 0% and 100%. These scores were then reclassified based on the rubric found in Table 1.

Connectivity Score (%)

This criterion is made to assess whether protected areas connect multiple landscape habitats. A variety of different physical habitats can support a higher diversity of wildlife. A protected areas capability to cross many enduring features or physical habitat types also ensures wildlife can move freely between different regions for mating and resources. Larger sites that are more connected are able to maintain ecological integrity better in comparison to smaller, unconnected sites.

The largest protected area that intersects the enduring feature was identified. This value was then compared to the connectivity value, which was predetermined by the natural disturbance zone. Ecological rationale for connectivity values can be found in Appendix 7 of Iacobelli et al. (2006). Limits were set to range between 0% and 100%. These scores were then reclassified based on the rubric found in Table 1.

Shorelines (%)

Shorelines are an indication of important community types for wildlife and ecological processes. Needed for both terrestrial species and aquatic species, as well as the interaction between the two, these are features of interest. Calculations for important community types are based on portion protected in relation to the enduring feature. Canada's abundance of freshwater makes it difficult to receive a high score for shorelines in this assessment. Protections should be prioritized to areas where stress to freshwater is highest. WWF-Canada's *Watershed Reports* has done a national survey of freshwater health and threats that can help identify those areas.

This calculation was modified from the original calculation by Iacobelli et al. (2006). Shoreline and stream habitat are assessed based on proportional representation for each enduring feature. The amount of shoreline in a protected area was compared to the total amount of shoreline in an enduring feature. Limits were set to range between 0% and 100%. These scores were then reclassified based on the rubric found in Table 1.

Environmental Gradients (%)

This criterion quantifies the variation in topography in an enduring feature as a way of predicting ecological communities. Elevations changes provide insight into the varying drainage and soil conditions.

The range of elevation within the enduring feature was calculated to determine how well represented the range of elevation is for the protected portion within the enduring feature. This required the input of a Digital Elevation Model (DEM), from which the summary statistics for mean and standard deviation were calculated for the total enduring feature and the respective protected areas. Using these values, a modified variance test was run for each enduring using the following equation:

$$ModVar_{EF} = \frac{|\mu_{ef} - \mu_{pa}|}{(\sigma_{ef} - \sigma_{pa})/2}$$

Where:

μ_{ef} is the mean elevation in the enduring feature
μ_{pa} is the mean elevation if the protected area
σ_{ef} is the standard deviation in the enduring feature
σ_{pa} is the standard deviation in the protected area

Limits were set to range between 0% and 100%. A larger modified variance implies less similar elevation ranges between the entire enduring feature and the protected portion. Hence, a smaller value indicates better protection. These scores were then reclassified based on the rubric found in Table 1.

Intactness (%)

Intactness provides a measure of habitat quality. By looking at human disturbance, an enduring feature can be assessed for its naturalness. Areas with less human footprint will benefit landscapes and wildlife within them.

This calculation was modified from the original calculation in Iacobelli et al. (2006). To establish the level of intactness, the density of road networks and human disturbances within an enduring feature's protected area were evaluated. The Global Forest Watch's access roads dataset was combined with road layers from the National Road Network, Statistics Canada, and Open Street Map to create a comprehensive human impact layer. The intactness proportion was calculated based on area of undisturbed land within the total protected area. Limits were set to range between 0% and 100%. Lower proportions values imply less habitat fragmentation. These scores were then reclassified based on the rubric found in Table 1.

High priority considerations

Key considerations are necessary to highlight high conservation value areas. Identifying areas for prioritization are based on current gaps in the protected area network, as well as additional criteria. The main goal for this assessment was to identify areas that would provide benefit for at-risk species, as well as mitigate climate change. For these reasons, we looked at the criteria listed below.

Number of at-risk species

COSEWIC-assessed 'at-risk' species ranges were retrieved from Environment and Climate Change Canada (ECCC), and data was cleaned by the University of Ottawa to remove duplicates. Ranges included spatial data files for 188 populations of COSEWIC-assessed at-risk species (special concern threatened endangered and extirpated). In addition to ranges, habitat associations collected from individual COSEWIC status reports were provided by the University of Ottawa. Using European Space Agency land cover data from 2015 at 300m resolution, land cover data was reclassified to match with habitat associations. Species ranges were reduced by land cover constraints and overlaid to identify areas of overlap. For each enduring feature, the maximum number of species at-risk was calculated. Results were then reclassified based on five quantiles to range from very low to very high.

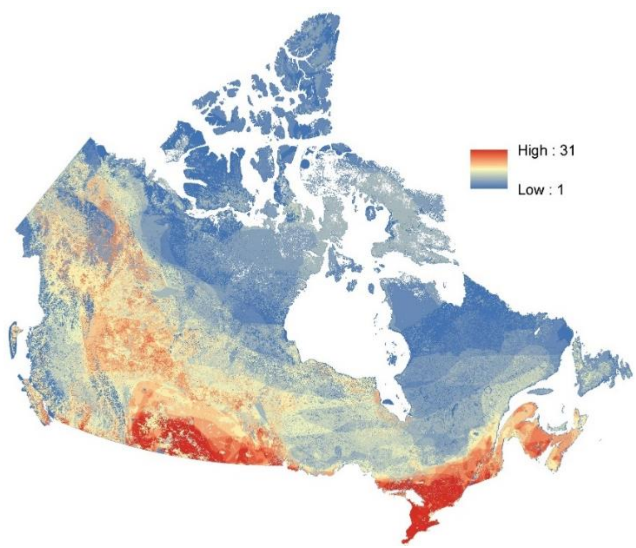


Figure 3 Number of COSEWIC-assessed at risk species. Range maps were reduced by habitat requirements and overlaid.

Climate refugia

Potential climate refugia and locations were identified by Michalak et al. (2018). These locations represent rare climatic regions on the landscape that provide stability and the ability to support biodiversity under climate change. In addition to using range boundaries for 1000 North American mammal, bird, amphibian and tree species, Michalak et al. (2018) identified areas with less climate sensitivity under different climate change models. For our analysis, results from all models under the 2050 prediction were used. Enduring features with more than 5% area of potential climate refugia were identified.

Average Soil Carbon (tons/ha)

Global Soil Carbon Map (GSOC) dataset, developed by the Food and Agriculture Organization of the United Nation, was used. This dataset, produced in 2017 at a 1km resolution, displays carbon storage for all soil types. Canadian contributors to the map include Agriculture and Agri-Foods Canada, British Columbia Ministry of Forests, Lands and Natural Resources, Ministère des Forêts, de la Faune et des Parcs (Québec), Natural Resources Canada, and Simon Fraser University. For each enduring feature, the average soil carbon (tons/ha) was found. Results were then reclassified based on five quantiles to range from very low to very high.

Forest Biomass

An aboveground forest biomass dataset was created and retrieved from the Group on Earth Observations Biodiversity Observation Network (GEO BON). Data was harmonized for both boreal and pan-tropical biomass. Boreal biomass, depicted in mg/ha, was developed by Santoro et al. (2015) and harmonized by Avitabile et al. (2014). For each enduring feature, the average aboveground forest biomass was calculated. Results were then reclassified based on five quantiles to range from very low to very high.

Priority areas

To identify areas of priority for conservation, gaps in the current network were layered in with high priority considerations. Using the criteria for ecological representation, an overall score was determined for each enduring feature (Table 1 and Figure 5). Enduring features with no protection or very poor protection are large gaps in the network. Additionally, areas with high or very high key considerations are areas to prioritize. The map below shows the areas with no protection or very poor protection, and the number of high priority considerations. For example, and areas with 4 overlapping key considerations means that the area is has a high number of at-risk species, is high in soil carbon and in forest biomass, and has the potential to be climate refugia. All regions on this map are considered a priority for the designation of new protected areas in Canada. The color gradient depicts the relative prioritization of these priority regions across Canada based on the number of overlapping key considerations within a physical habitat.

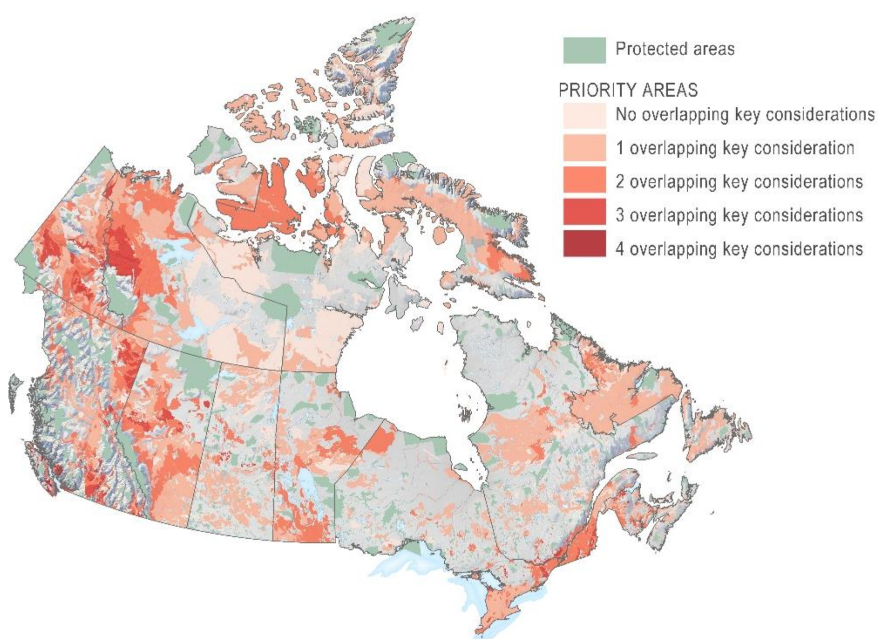


Figure 4 Priority areas in Canada. Red areas are where there are currently no protections or very poor protections and fall within high areas of the priority considerations

Data inputs

The table below summaries all data inputs used into the assessment.

Input	Type	Source
Enduring Features	WWF Canada Publication date: 2005 Validity date: 1995	Vector (Polygon)
Digital Elevation Model	Science (EROS) 2013 Publication date: November 2010 Updated: August 2014	Raster (DEM)
Shorelines/Rivers	Atlas of Canada National Frameworks 1:1 000 000 scale Includes rivers and lakes Vector https://open.canada.ca/data/en/dataset/87bb794c-eabf-5eea-bdb3-61d0338d9594	Vector (Polyline)
Protected Areas	CCEA Canadian Council on Ecological Areas Publication: Unknown Updated: December 2017 Quebec: March 2018 Alberta Alberta Parks, Government of Alberta Updated: April 2019 Nova Scotia Protected Areas and Wetlands Branch, Nova Scotia Environment, Updated: 2018	Vector (Polygon)
Road Network	Developed by Schuster and Ray (2018) Data from: Global Forest Watch Canada Access Dataset Updated:2010 Statistics Canada road network National Road Network Updated: 2016 Open Street Maps road network	Vector (Polygon)

	Updated: 2018	
COSEWIC assessed species at risk	Environment and Climate Change Canada Range of 188 populations 2017	Vector (Polygon)
Land Cover	European Space Agency 300 m resolution 2015	Raster
Soil Carbon	Global Soil Carbon Map Food and Agriculture Organization of the United Nation 1 km Resolution Updated: 2014	Raster
Forest Biomass	Avitabile et al, 2014 Data retrieved from LUCID	Raster
Climate Refugia	Michalak et al, 2018 Data retrieved from Adapt West	Raster

References

Avitabile, V., Herold, M., Lewis, S.L., Phillips, O.L., Aguilar-Amuchastegui, N., Asner, G. P., Brienen, R.J.W., DeVries, B., Cazzolla Gatti, R., et al., (2014). Comparative analysis and fusion for improved global biomass mapping. Global Vegetation Monitoring and Modeling, 3 – 7 February 2014, Avignon (France) https://colloque.inra.fr/gv2m

Avitabile, V., Herold, M., Heuvelink, G. B. M., Lewis, S. L., Phillips, O. L., Asner, G. P., Armston, J., Ashton, P. S., Banin, L. et al., (2016). An integrated pan-tropical biomass map using multiple reference datasets. Global Change Biology, 22, pp. 1406–1420.

Environment and Climate Change Canada (ECCC). 2017. Range map extents, species at risk, Canada. Retrieved in 2018 from: http://donnees.ec.gc.ca/data/species/protectrestore/range-map-extents-species-at-risk-canada/?lang=en

Iacobelli, A., Alidina, H., Blasutti, A., & Kavanagh, K. (2006). A landscape-based protected areas gap analysis and GIS tool for conservation planning. *World Wildlife Fund, Toronto*.

Michalak, J. L., Lawler, J. J., Roberts, D. R. and Carroll, C. (2018), Distribution and protection of climatic refugia in North America. Conservation Biology. doi: 10.1111/cobi.13130

Schuster, R., Ray, J. 2018 Industrialized human impact for Canada and Alaska. Layer created for report on "Identifying and delineating Key Biodiversity Areas for Criterion C in Canada". Wildlife Conservation Society Canada.

Santoro, M., Beaudoin, A., Beer, C., Cartus, O., Fransson, J.E.S., Hall, R.J., Pathe, C., Schmullius, C., Schepaschenko, D., Shvidenko, A., Thurner, M. and Wegmüller, U. (2015). Forest growing stock volume of the northern hemisphere: Spatially explicit estimates for 2010 derived from Envisat ASAR. Remote Sensing of Environment, Vol. 168, page. 316-334

Table 1 Representation Scores and classes

Representation Criteria		Scoring Guidelines for Representation Criteria (scores are indicated in brackets)						Maximum Possible Score
Protected Areas Size & Connectivity	A - Largest single protected area block on enduring feature	Meets size guideline ≥ 95% of recommended size is protected) **(5)**	Meets size guideline ≥ 75% of recommended size is protected) **(4)**	Is ≥ 50% of the recommended size **(3)**	Is ≥ 25% of the recommended size **(2)**	Is < 25% of the recommended size **(1)**	If no protected area exists (area = 0) **(0)**	5
	B - Total area protected on enduring feature	Meets size guideline (≥ 95% of recommended size is protected) **(5)**	Meets size guideline ≥ 75% of recommended size is protected) **(4)**	Is ≥ 50% of the recommended size **(3)**	Is ≥ 20% of the recommended size **(2)**	Is < 25% of the recommended size **(1)**	If no protected area exists (area = 0) **(0)**	5
	C - Size of largest contiguous protected area complex intersecting the enduring feature (Connectivity)	Meets ≥ 95% of recommended Connectivity Value and size score A is met **(5)**	Meets size guideline≥ 75% of recommended Connectivity Value **(4)**	Is ≥ 50 of recommended Connectivity Value **(3)**	Is ≥ 25 of recommended Connectivity Value **(2)**	Is < 25% of recommended Connectivity Value **(1)**	If no protected area exists (area = 0) **(0)**	5
Environmental Gradients	Surrogate for capturing habitat or community variability within the enduring feature	If the calculated mean difference over the average standard deviation (MODVAR) < 0.05 and size score A is met **(5)**	If the calculated mean difference over the average standard deviation (MODVAR) < 0.25 **(4)**	If the calculated mean difference over the average standard deviation (MODVAR) ≥ 0.25 **(3)**	If the calculated mean difference over the average standard deviation (MODVAR) ≥ 0.50 **(2)**	If the calculated mean difference over the average standard deviation (MODVAR) ≥ 0.75 **(1)**	If no protected area exists (area = 0) **(0)**	5
Shoreline & Stream Habitats	Proportion of shoreline in an enduring feature that is protected	The shoreline habitat in the protected portion ≥95% of shoreline habitat in the enduring feature and size score A is met **(5)**	The shoreline habitat in the protected portion ≥75% of shoreline habitat in the enduring feature **(4)**	The shoreline habitat in the protected portion ≥50% of shoreline habitat in the enduring feature **(3)**	The shoreline habitat in the protected portion ≥25% of shoreline habitat in the enduring feature **(2)**	The shoreline habitat in the protected portion <25% of shoreline habitat in the enduring feature **(1)**	If no protected area exists (area = 0) **(0)**	5
Intactness	Proportion of protected area in an enduring feature that is considered intact.	The intact land in the protected portion is ≥75% of the protected area size and size score A is met **(5)**	The intact land in the protected portion is ≥75% of the protected area size **(4)**	The intact land in the protected portion is ≥50% of the protected area size **(3)**	The intact land in the protected portion is ≥25% of the protected area size **(2)**	The intact land in the protected portion is < 25%of the protected area size **(1)**	If no protected area exists (area = 0) **(0)**	5
Overall Score								**See below**

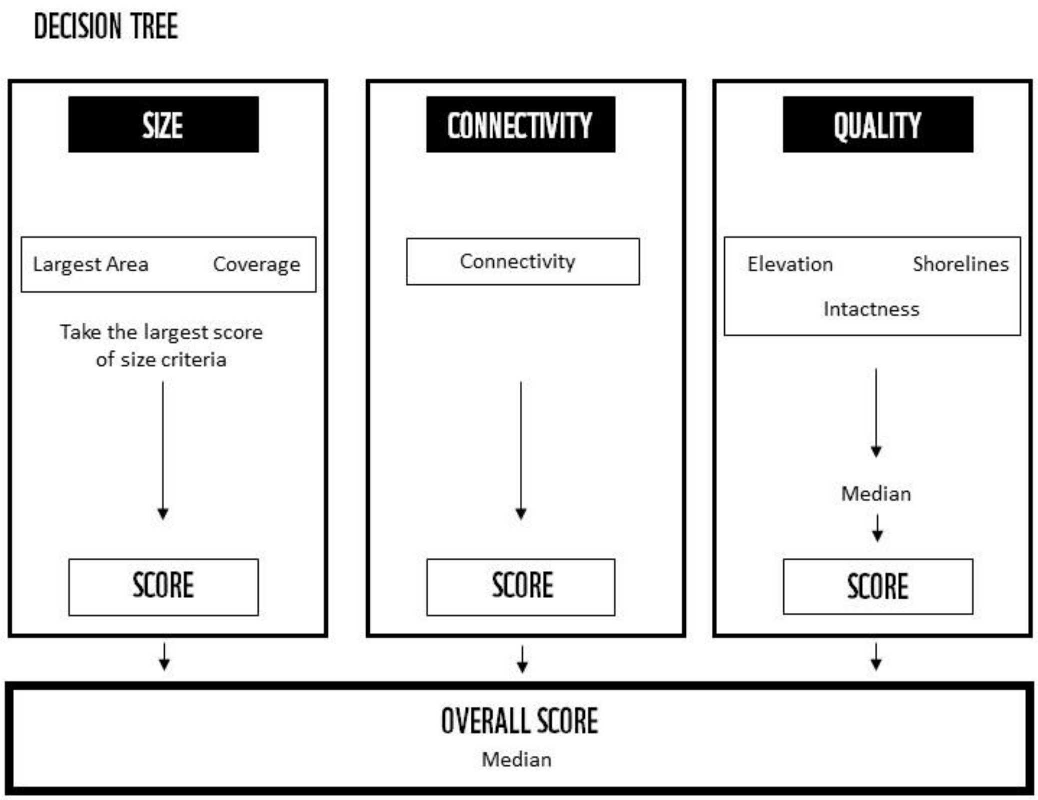


Figure 5 Decision tree used for an overall score for ecological representations. Areas of very poor, poor, fair and no protection are categorized as inadequate. Areas of good and very good protection are categorized as adequate