Environmentally Significant Areas in Alberta: 2014 Update

FINAL REPORT

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Report Prepared by: Shari Clare (PhD, PBiol), Gillian Holloway (PhD), and Sinisa Vukicevic (PhD).

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1.0

Introduction

1.1. Background

Environmentally Significant Areas (ESAs) are generally defined as areas that are important to the long-term maintenance of biological diversity, physical landscape features and/or other natural processes, both locally and within a larger spatial context (Jennings & Reganold 1991). While the conceptual value of ESAs is clear, the criteria used to identify these resources are of critical importance in terms of what is identified as significant. Identification of ESAs that include multiple criteria (e.g. large habitat patches, occurrences for species of conservation concern, rare habitats) allows for a systematic comparison between ESAs, clearly distinguishing their importance and ranking relative to one another (Smith & Theberge 1987). This information can be incorporated into land-use planning, and provides land managers with additional information that can be used to make informed decisions about areas with environmental significance.

Early work on identifying ESAs in Alberta was conducted by municipalities in the 1980s and 1990s. This work led to the Government of Alberta completing a province-wide consolidation of previously identified ESAs in 1997, followed by an extensive update in 2009. This update took advantage of major advances in Geographic Information Systems (GIS) technology that allowed for a more rigorous and systematic assessment of available biological information. The assessment was based on systematic criteria that defined characteristics that were considered desirable in an ESA, and then identified and mapped areas that contained those defined characteristics based on transparent and repeatable metrics and decision rule-sets (Fiera 2009). The 2009 ESA update was conducted at the provincial scale and was largely focused on terrestrial components.

In 2010, an Aquatic Environmentally Significant Areas (AESA) inventory was completed based on ecological criteria identified by the Alberta Water Council (Fiera 2010).This assessment was exclusively focused on the identification of significant aquatic ecosystem components, and followed the same overall systematic assessment framework that was employed in the 2009 ESA update.

The 2009 ESA update represented the initial work using GIS as a tool to model to identify ESAs. The AESA (2010) project built on this initial work, but focused on augmenting the aquatic component. The current update was initiated to amalgamate the ESA and AESA inventories into a single, comprehensive provincial inventory. This was desired to eliminate overlap between the ESA and AESA products, and to incorporate new information and data that was not available for previous assessments. The 2014 update utilized the most up-to-date and best data available to provide the most comprehensive ESA product produced to-date. It should be noted that ESA delineations continue to change over time as existing data sets improve, new data sources become available for use, and the biophysical conditions of the Province change. As such, the Government of Alberta attempts to make regular updates to the provincial ESA mapping.

1.2. Intended Use of ESAs in Alberta

The primary intended use of the ESA report and associated mapping products is to inform land-use and watershed planning for those areas identified as having high environmental significance, based on the best information available. It should be recognized that there may be environmentally significant areas that have not been identified in this assessment, and these omissions may be due to a lack of inventory and data that documents their location and/or significance. Further, its important to note that all ecosystems in Alberta, including those that fall outside of designated ESAs, should be considered in planning exercises that involve objective setting for environmental and land use criteria. This is of particular importance when considering coarse-filter biodiversity at a landscape scale. For example, habitat connectivity and locations that provide diverse habitat for a variety of species are important considerations in addition to ESAs. It is also important to note that social and economic considerations are key components of land-use planning and other processes (e.g., Municipal bylaws) where ESA information is utilized. While we attempted to include all pertinent data, some data were not suitable for use in this province-wide process; for example, the data did not cover the full study area, did not exist at a useable scale, or existed but were not made available to this project. It is important to note that this project focused on identifying ESAs at the provincial scale. There are many regionally and locally significant sites that are not included in this compilation, but should be identified and considered during finer scale planning.

This report and the resulting mapped areas are available for use by provincial and municipal land-use planners, industry, consultants, environmental organizations, academic institutions, and others, as an information tool to support municipal, regional, and provincial-scale planning initiatives. The identification of significant areas does not consider how these areas are being, or how they should be, managed or conserved. As such, ESAs do not represent natural resource policy, areas requiring specific management objectives, or comprehensive status reporting. Further, ESAs do not represent government policy and do not necessarily require legal protection. They are intended to be an information tool that complements other information sources to inform land-use planning and policy at local, regional, and provincial scales.

This ESA product does not replace other indicator-specific mapping and planning tools, such as wetland inventories, caribou range maps, and species at risk recovery plans. These more detailed information sources must be consulted when planning for projects that may impact specific environmental resources, particularly when dealing with regulatory requirements. ESAs are not intended to be used in the regulatory context.

Section

2.0

ESA & AESA Update & Integration

2.1. Conceptual Framework

This update employed a GIS-based multi-criteria decision analysis (GIS-MCDA) as the foundation for quantifying, weighting, and identifying Environmentally Significant Areas in Alberta. Multi-criteria decision analysis is a method that is commonly used to conceptualize and structure complex decisions or problems that involve multiple criteria, through the development of decision rules that are used to aggregate and rank those criteria (Mendoza and Martins 2006; Malczewski 2006; Greene et al. 2011).

The primary objective of this project was to review, revise, and combine previously selected ESA and AESA criteria, in order to create an updated ESA model for the province. To achieve this, MDCA was employed to help organize the selected criteria into a hierarchy of sub-components that included sub-criteria and indicators. At the highest level, the provincial ESA framework is represented by criteria that were used as categories of conditions or processes that characterize the natural environment, and are representative of specific environmental elements of interest (e.g. water quality, biodiversity, etc.). Each criterion is associated with one or more sub-criterion, which in turn, are represented by one or more specific indicator, which are measureable (quantitative) or descriptive (qualitative) variables. While indicators are characterized as being representative of a specific criterion, in reality, indicators are closely related, and there may be some overlap in what indicators represent or measure. As a result, there is no definitive or "correct" way of categorizing indicators or organizing indicators to a given sub-criterion or criterion.

Once elements (criteria, sub-criteria, and indicators) within the ESA framework were identified, each indicator was quantified and scored. For many of the indicators, scores were determined separately for each Natural Region in the province. The relative importance of each element in the framework was then evaluated by subject matter experts using a rank-sum approach, and each element was assigned a weight to reflect place-based and temporal priorities (Mendoza and Martins 2006; Malczewski 2006; Greene et al. 2011). Weighted indicator scores were then aggregated into individual criterion values using weighted linear combination (Greene et al. 2011), and all criterion values were summed to determine final ESA values. Given that the unit of analysis for this modeling exercise was the quarter section, this update provides information about environmental significance, as measured by the selected indicators, for every quarter section in Alberta. This allows decision makers to better understand the location and extent of areas with environmental significance in Alberta. A more detailed description of the methods used to identify ESAs in Alberta can be found in Section 4.

Section

3.0

2014 ESA Criteria & Indicators

Following a focused literature review and extensive consultation with members of the Government ESA Working Group, a comprehensive list of criteria, sub-criteria, and indicators were selected to identify ESAs in Alberta. Given that a single criteria is unlikely to be representative of all desired components of an ESA, multiple criteria, sub-criteria, and indicators were incorporated into the ESA framework. The objective of this multi-tiered approach was to include a broad set of environmental indicators at a variety of spatial scales, which in turn, allows for the identification of important ecological and evolutionary processes at different levels of organization (Groves et al. 2000; Poiani et al. 2000).

The criteria selected to identify ESAs in Alberta included both coarse-filter and fine-filter indicators. Coarse-filter indicators were developed with the goal of identifying sites that contribute to the maintenance of native biota and natural ecosystem function, while fine-filter indicators were developed to capture environmental features that are required to maintain populations, species, ecosystems, or other special features that are not accounted for under coarse filter criteria (Groves et al. 2000). In total, four criteria, 10 sub-criteria, and 25 indicators were selected to help define, measure, and map terrestrial and aquatic ESAs in Alberta, on the following page.

CRITERION 1.0 Areas that contain focal species, species groups, or their habitats

1a **Sub-criterion 1a: Conservation Hotspots**
1a(i): Rare, Threatened or Endangered Species

1b **Sub-criterion 1b: Focal species groups**
1b(i): Amphibians
1b(ii): Aquatic breeding birds
1b(iii): Fish

1c **Sub-criterion 1c: Focal species habitat**
1c(i): Harlequin duck
1c(ii): Grizzly bear
1c(iii): Woodland caribou (boreal ecotype)
1c(iv): Western burrowing owl
1c(v): Sage grouse
1c(vi): Arctic grayling

CRITERION 2.0 Areas that contain rare, unique, or focal habitat

2a **Sub-criterion 2a: Rare habitats**
2a(i): Vegetation communities
2a(ii): Peatlands

2b **Sub-criterion 2b: Unique habitats and landforms**
2b(i): Natural springs
2b(ii): Nationally and Internationally recognized landforms

2c **Sub-criterion 2c: Focal habitats**
2c(i): Class A and B rivers & streams
2c(ii): Snake and bat hibernacula
2c(iii): Waterfowl staging & foraging areas
2c(iv): Sharp-tailed grouse leks

CRITERION 3.0 Areas with ecological integrity

3a **Sub-criterion 3a: Habitat patch size**
3a(i): Terrestrial habitat patches

3b **Sub-criterion 3b: Habitat intactness & connectivity**
3b(i): Intact landscapes
3b(ii): Lotic (rivers & streams) habitat connectivity
3b(iii): Lentic (wetlands & lakes) habitat intactness

CRITERION 4.0 Areas that contribute to water quality & quantity

4a **Sub-criterion 4a: Rivers and streams**
4a(i): River and stream density
4a(ii): Lotic (rivers & streams) landscape intactness

4b **Sub-criterion 4b: Wetlands and lakes**
4b(i): Wetland landscape composition
4b(ii): Water storage potential

3.1. Rationale for Criteria, Sub-criteria & Indicator Selection

CRITERION **1.0** **Areas that contain focal species, species groups, or their habitats**

An important characteristic of Environmentally Significant Areas in Alberta is the capacity of these locations to support biodiversity. While surrogacy may exist between various measures of biodiversity (e.g., endemism and rarity), previous research has highlighted the importance of combining multiple measures of biodiversity into modeling exercises, such that different dimensions of biodiversity are represented in a conservation network (Ricketts et al. 1999; Caro 2010). As such, Criterion 1 has been divided into three sub-criteria that all represent different aspects of biodiversity:

1a Sub-Criterion 1a: Conservation Hotspots

At-risk, rare, or unique species are those that are recognized as having some level of threat to their long-term persistence because they are naturally rare or endemic to an area, have shown long-term declines in habitat and/or population size as a result of human activities, and/or are at the edge of their distribution or range.

1a(i) Rare, Threatened, or Endangered Species

Given that rare, threatened, or endangered species may require special management consideration to ensure their long-term persistence, elements of provincial, federal, and global conservation concern were included as an indicator under Criterion 1.

1b Criterion 1b: Focal species groups

Focal species groups (guilds) typically have life requisites that encompass other species, ecosystems, and/or processes (Lambeck 1997, Wiens et al. 2008); thus, by considering the habitat needs of focal guilds, a range of ecosystem types, processes, and/or species are represented. Three distinct focal species groups were selected under this criteria to broadly represent important aquatic habitats in the province, including amphibians, aquatic breeding birds, and fish.

1b(i) Amphibians

The amphibian guild serves as an indicator of small, seasonal, or semi-permanent wetlands in the province.

1b(ii) Aquatic breeding birds

The aquatic breeding bird guild serves as an indicator of large semi-permanent or permanent wetlands and lakes. Species represented in this guild tend to aggregate in specific locations to breed and show strong fidelity to these sites.

1b(iii) Fish

The fish guild was selected to represent the diversity of lotic conditions in the province. The occurrence of these species is assumed to represent stream or river conditions that are generally suitable for the persistence of fish that may require different physical (e.g., types of substrates, water temperature) and chemical (e.g., nutrient) conditions.

1c Criterion 1c: Focal species habitat

Focal species habitats are considered critical for fine-filter focal species whose habitat requirements may not be identified by coarse-filter habitat criteria. This criterion considers focal habitat for harlequin duck, grizzly bear, woodland caribou (boreal ecotype), western borrowing owl, sage grouse, arctic grayling, and ferruginous hawk because availability of suitable habitat can severely undermine the survival and reproduction of these high profile species

1c(i) Harlequin duck

Harlequin ducks are migratory sea birds that summer on fast flowing streams in the Foothills and Rocky Mountain subregions of Alberta. Breeding sites may be limiting for this species, as they nest only on the banks of clear and undisturbed mountain streams that have adequate cover for nest concealment (Alberta Sustainable Resource Development 2003). These narrow habitat requirements make Harlequin ducks vulnerable to disturbance and this species is currently listed as Sensitive under the General Status of Alberta Wild Species.

1c(ii) Grizzly bear

Grizzly bears are opportunistic omnivores and habitat use is related to the availability, distribution, and abundance of preferred and seasonally available food items. Major limiting factors for grizzly bears include increased road access into remote areas and road density, human-caused mortality, and habitat loss, alteration, and/or fragmentation. Grizzly bears have been extirpated from a large portion of their range and are currently listed as May Be At Risk in Alberta.

1c(iii) Woodland caribou (boreal ecotype)

Woodland caribou are a wide-ranging species sensitive to habitat alterations due to human industrial activity. Within the last century, woodland caribou have been extirpated from much of their historic range and rapid range contraction continues in Alberta. As a result, the boreal population of woodland caribou have been designated federally as Threatened and provincially as a species At Risk.

1c(iv) Western burrowing owl

The western burrowing owl has experienced recent and dramatic population declines across Canada and major threats to this species includes loss of native prairie habitat and availability of suitable underground burrows for nesting. As a result, this species is listed as Endangered federally, is considered At Risk under the General Status of Alberta Wild Species, and is listed as Threatened under the provincial Wildlife Act.

1c(v) Sage Grouse

The Greater Sage-grouse is federally listed as Endangered, provincially listed as At Risk under the General Status of Alberta Wild Species, and as Endangered under the Provincial Wildlife Act. This species has very specific habitat requirements, and is currently limited to the southwest portion of the province where silver sagebrush persists and has not yet been lost due to land conversion activities.

1c(vi) Arctic grayling

Arctic grayling are native to Alberta and are restricted to the Athabasca, Peace, and Hay River drainages. Ideal habitat conditions include cold, sediment free rivers and streams with consistent flow levels that are free of movement barriers to allow for migration between spring spawning areas and overwintering pools. This fish is listed as Sensitive under the General Status of Alberta Wild Species.

1c(vii) Ferruginous hawk

Ferruginous hawk are migratory birds that prefer open, arid prairie habitat dominated by grass or sagebrush where suitable raised nesting platforms are present. This species has recently experienced rapid population declines due to land conversion and habitat loss and is listed federally as Threatened, and is provincially listed as At Risk under the General Status of Alberta Wild Species and Threatened under the Wildlife Act.

CRITERION 2.0 Areas that contain rare, unique, or focal habitat

Rare, unique, or focal habitats are important components of landscape diversity because they play a significant role in ecosystem functioning, as well as contribute to the aesthetic value of a region. Habitats and landforms identified under this criterion have only a few recorded occurrences in the province, are outstanding examples of that particular habitat or system within the province, or are considered essential for meeting the life requisites of certain species at specific times of the year.

Criterion 2 is divided into three sub-criteria with eight different indicators:

2a Criterion 2a: Rare habitats

Rare habitats are generally considered to be areas that are irreplaceable within an ecological network. As such, the identification of rare habitats is important to ensure that the full range of ecosystems and habitats present in Alberta are represented.

2a(i) Vegetation communities

Rare terrestrial and aquatic vegetation communities offer important habitat to a diverse range of species and populations that may not be captured or represented in more common habitat or community types.

2a(ii) Peatlands

While peatlands cover a substantial portion of the province, many of the peatland types that occur in Alberta are considered rare. These rare peatlands contribute to ecosystem diversity and support a range of important landscape processes, patterns, and structure.

2b Criterion 2b: Unique habitats and landforms

Ecological representation forms the foundation for ensuring the persistence of biodiversity and ecosystem function, and a key component of this is representation of a variety of landscape types, process, patterns, and structure (O'Neil et al. 1995, Noss 1999). Thus, selecting indicators that represent unique or outstanding examples of landscape features is an important component of identifying environmentally significant areas.

2b(i) Natural springs

Springs can be an important aquatic resource to both humans and wildlife. These areas are often relied upon to provide high-quality water supplies to human communities, as well as critical habitat for a variety of flora and fauna.

2b(ii) Nationally & Internationally recognized landforms

These unique landforms are considered to be exceptional examples of landscape diversity and may support important or unique ecological communities, species, and populations.

2c Criterion 2c: Focal habitats

Focal habitats represent areas that provide critical resources to species or populations at distinct times of the year. These habitats are often quite localized and ephemeral, and the availability of these types of habitat can severely undermine the survival and reproduction of the species that depend on them.

2c(i) Class A & B rivers and streams

Class A waterbodies are considered critical fish habitat protection areas, and have habitat that is sensitive enough to be damaged by any type of in-stream activity. Similarly, Class B waterbodies have fish habitat that is considered important to the continued viability of a species, and is sensitive enough to be potentially damaged by any activity within the waterbody.

2c(ii) Snake and bat hibernacula

Hibernacula provide critical overwintering habitat to both snake and bat populations, and the loss of these habitats, or disturbance to populations using these sites during the winter, may have significant negative impacts to populations and species.

2c(iii) Waterfowl staging and foraging areas

Staging areas include large lakes and semi-permanent or permanent wetlands that are used by a large concentration of waterfowl during the spring and fall migration. Many species of waterfowl complete their wing and body molt on staging areas before the start of the fall migration. In addition, staging areas that are ice free early in the season provide important food resources to a wide diversity of species during the spring migration.

2c(iv) Sharp-tail grouse leks

Leks are sites where males and females congregate during the breeding season to carry out courtship displays. These sites are typically located in dry, open areas that are characterized by native prairie or low shrubland habitat, and these lek sites can be used for years or decades. Sharp-tail grouse populations have been declining in Alberta over the last several decades, and this decline has been attributed in part to the loss of suitable lek habitat.

CRITERION

3.0 Areas with ecological integrity

There are both direct (e.g. nutrient and sediment loading) and indirect (e.g. land cover, road density) measures of ecological integrity in aquatic and terrestrial ecosystems, and the links between ecosystem integrity and biodiversity is well established in the scientific literature. In particular, the resilience and ability of ecological systems to maintain core ecological processes and services have been shown to be highly correlated to habitat patch size and intactness (Noss 1990; Anderson 1991). In addition, watershed or catchment connectivity is critical for maintaining natural processes in rivers and wetland communities (Linke et al. 2008; Nel et al. 2009). As such, Criterion 3 is divided into two sub-criteria with four indicators that address both terrestrial and aquatic ecological integrity:

3a Criterion 3a: Habitat patch size

Landscape features such as patch size, heterogeneity, perimeter-area ratio, and connectivity can be major controllers of species composition and abundance, and of population viability for sensitive species (Noss & Harris 1986). The majority of empirical studies conducted to date suggest a strong link between habitat loss and species loss (Fahrig 2003; Fischer & Lindenmayer 2007).

3a(i): Terrestrial habitat patches

Many species require larger tracts of undisturbed habitat to meet their life requisites, and large terrestrial patches generally contain a greater diversity of habitat niches and interior habitat. As a result, larger habitat patches generally support higher species diversity and richness (Environment Canada 2013).

3b Criterion 3b: Habitat intactness and connectivity

Highly intact ecosystems are more resilient to change, and as a result, are more likely to maintain their full range of ecological processes. As a result, more intact ecosystems are considered to be critical to the persistence of a broad range of flora and fauna than highly impacted habitats (Nel et al. 2007; 2009).

3b(i): Intact landscapes

Highly intact ecosystems are more resilient to change, and as a result, are more likely to support and maintain their full range of biodiversity and ecological processes (Nel et al. 2009).

3b(ii): Lotic (rivers & streams) habitat connectivity

Whole catchment connectivity is critical for effective conservation of river and stream networks to ensure natural processes (e.g. upstream connectivity, fish migratory routes, free-flowing rivers) are maintained, along with all elements of biodiversity (Linke et al. 2007a; Nel et al. 2009). Nearly all patterns and processes in freshwater ecosystems are underpinned by connectivity along three spatial dimensions: longitudinal, lateral, and vertical (Nel et al. 2009). Given the importance of habitat connectivity to the function and health of aquatic ecosystems, in-stream habitat connectivity was considered an important indicator in this assessment.

3b(iii): Lentic (wetlands & lakes) habitat intactness

The size and quality of terrestrial habitat on the landscape has been shown to influence aquatic habitat condition, with larger and less fragmented landscapes being of higher quality and condition (Hunsaker & Levine 1995; Linke et al. 2007b). For example, aquatic habitats with high ecological integrity are more likely to be found adjacent to less fragmented upland habitat, and the amount of remaining forest and wetland cover at the watershed scale is a well established indicator of aquatic health (Findlay & Houlahan 1997; Poiani et al. 2000; Nel et al. 2007).

CRITERION

4.0 Areas that contribute to water quality & quantity

The concept of ecological integrity is well established for freshwater ecosystems, and embedded within this is the importance of water quality and quantity to maintain ecohydrological functions and processes that support ecosystems and biodiversity (Linke et al. 2007a; Nel et al. 2009). As such, Criterion 4 is divided into two sub-criteria that consider both lentic and lotic habitats:

4a Criterion 4a: Rivers & streams

4a(i): River & stream density

River and stream network density is closely linked to important ecohydrological processes that support a variety of flora and fauna, and this metric is generally considered a reasonable indicator of the vulnerability of a watershed to land use change (Elmore et al. 2013). In addition, stream and river density has an important influence on water chemistry, as well as the residence time of water in a particular watershed. As such, the density of river and stream networks, particularly the number and length of headwater streams, is an important landscape metric for assessing the environmental significance of an area, and its contribution to both water quality and quantity.

4a(ii): Lotic landscape intactness

Given the geographical context of freshwater systems as receivers on the landscape, the intactness of the surrounding riparian and upland habitat can significantly impact aquatic condition (Linke et al. 2007b; Nel et al. 2007; Norris et al. 2007). In addition, intact riparian areas along rivers and streams serve as important corridors for wildlife, and provide critical functions such as dissipation of flood energy, nutrient and sediment storage, and filtering of non-point source pollution (Jones et al. 2010).

4b Criterion 4b: Wetlands & lakes

Wetlands and lakes play a critical role in a number of ecosystem processes at a variety of spatial scales. These habitats not only support biodiversity by providing important habitat for a variety of species, but also help to moderate the climate system, and serve as critical components of the hydrological system by providing water storage and water purification functions. While the critical role that these ecosystems play in providing water quality and quantity functions and services was recognized in this assessment, ultimately, it was determined that the data were deficient for a number of indicators that could have been included in this sub-criterion. In future ESA updates, consideration should be given to developing indicators that recognize the important contribution that wetlands and lakes make to maintaining water quality and quantity in the province.

Section

4.0

Methods

4.1. Data Assembly & Management

Spatial data for each indicator was gathered and compiled to determine whether the existing and accessible data were appropriate for use in the ESA model. Each data set was reviewed for comprehensiveness, coverage, reliability, and accuracy. If the data set did not meet the criteria for inclusion, it was discarded and alternative data sources were sought. Several indicators were dropped from the model because appropriate data were not available, or the data were not accessible. When a proposed indicator was not used in the analysis, it was documented to allow for consideration in future ESA iterations, should appropriate data become available.

Over 20 different datasets were obtained from a variety of sources for use in this ESA update (Table 1). Data from the Alberta Conservation Information Management System (ACIMS) and the Fish and Wildlife Information Management System (FWMIS) made up the majority of the occurrence and observation records (>2.5 million records) used in the model. All observation and occurrence records in the FWMIS and ACIMS databases for the last 25 years (1987-2013) were included in the model, and these data were combined in a geospatial database. In order to ensure data consistency, the data were normalized and a master species list that included all common and scientific names for each species present in the dataset was created. This master species database was then queried to provide indicator-specific data, as required. All other data were compiled and managed individually for each indicator.

4.2. Unit of Analysis

The Alberta Township System (ATS) grid served as the basis for conducting the analysis to identify ESAs in Alberta. From this grid system, the quarter section (~64 ha) was used as the unit of analysis, because this provided an administratively understandable and functional sampling unit. A total of 1,006,516 quarter sections were analyzed for important environmental values in the province. Depending on the indicator (e.g., focal species habitat), the entire quarter section may have been considered environmentally significant. For other indicators (e.g., occurrences of elements of conservation concern), the quarter section boundary indicates that significant environmental values occur within the area, although the entire quarter section may not be considered environmentally significant.

4.3. Indicator Quantification & Scoring

Given that the topology and geometry of the spatial data for each indicator varied (e.g., point, polygon, raster), we first had to make decisions about whether the indicator was present within a quarter section. Once quarter section membership was determined, the indicator was quantified using methods that were appropriate for the metric being used to quantify each indicator (e.g., area-weighted average habitat value, count, density, total area, etc.).

Once quantified, each indicator was assigned a score ranging between 1 (low score) and 3 (high score) using either Boolean algebra or Jenks Natural Breaks Classification (Jenks 1977).

Boolean algebra was applied in cases where an indicator was quantified by a "presence" or "absence" result (e.g., the quarter section overlapped an Important Bird Area of Canada polygon). In these cases, all "presence" classes were assigned a numerical score of "3", and all other quarter sections were scored zero. For indicators that were quantified using continuous numerical values, a Jenks classification was used to determine quarter section scoring. A Jenks classification statistically breaks data into "natural" classes by minimizing the average deviation from the class mean, and maximizing the deviation from the means of the other groups, thereby reducing variance within classes and maximizing variance between classes (Jenks 1977). For all indicators, a three-category Jenks was used to split the indicator values into scores of 1, 2, or 3. For some indicators, the distribution of values was not normal, and in these cases, the values were transformed using the most appropriate transformation method before running the Jenks analysis. Where appropriate for the indicator, the values were split by Natural Region, and the Jenks analysis was conducted separately for each Natural Region to account for regional differences in indicator occurrence. Detailed rule-sets for how each indicator was quantified and scored are provided in Section 4.3.1.

TABLE 1.

Spatial data used to quantify each indicator included in the 2014 ESA provincial update.

INDICATOR	DATA SOURCE
1a(i) Rare, Threatened, or Endangered Species	ACIMS, FWMIS
1b(i) Amphibians	ACIMS, FWMIS
1b(ii) Aquatic Breeding Birds	ACIMS
1b(iii) Fish	ACIMS, FWMIS
1c(i) Harlequin duck	ACIMS
1c(ii) Grizzly bear	Foothills Research Institute Grizzly Bear Resource Selection Function (RSF) Model
1c(iii) Woodland caribou (boreal ecotype)	Environment Canada (2013) caribou range and anthropogenic disturbance data
1c(iv) Western burrowing owl	Stevens et al. (2011) Western Burrowing Owl Resource Selection Function (RSF) Model
1c(v) Sage Grouse	AESRD Sage Grouse Range
1c(vi) Arctic grayling	AESRD arctic grayling fish suitability index (FSI)
1c(vii) Ferruginous hawk	Ng et al. (2013) Ferruginous Hawk Resource Selection Function (RSF) Model
2a(i) Vegetation communities	ACIMS
2a(ii) Peatlands	Peatland Inventory of Alberta (Vitt et al. 1996), ABMI Human Footprint Map (2010)
2b(i) Natural springs	ACIMS, Alberta Geological Survey Alberta Springs (Stewart 2009)
2b(ii) Nationally & Internationally recognized landforms	ACIMS
2c(i) Class A & B rivers and streams	AESRD Code of Practice management maps
2c(ii) Snake and bat hibernacula	ACIMS
2c(iii) Waterfowl staging and foraging areas	Important Bird Areas of Canada (IBA), NAWMP staging areas, AESRD Trumpeter Swan Waterbodies & Watercourses, AESRD Piping Plover Waterbodies, AESRD Colonial Nesting Birds, Ducks Unlimited Waterfowl Pair Distribution Model, FWMIS, ACIMS
2c(iv) Sharp-tail grouse leks	AESRD Sharp-tail grouse survey data, FWMIS
3a(i) Terrestrial habitat patches	ABMI Human Footprint Map (2010), Provincial base features, Provincial hydrography
3b(i) Intact landscapes	Provincial base features
3b(ii) Intact lotic (stream and river) habitat	Stream single line network, Hydrography points, Provincial base features
3b(iii) Intact lentic (wetlands and lakes) habitat	Provincial hydrography polygons, Terrestrial patch layer [Indicator 3a(i)]
4a(i) River and stream density	Stream single line network
4a(ii) Lotic (river and stream) landscape intactness	Stream single line network, Terrestrial habitat patch layer [Indicator 3a(i)]

Areas that contain focal species, species groups, or their habitats
criterion 1.0

Areas that contain rare, unique, or focal habitat
criterion 2.0

Areas with ecological integrity
criterion 3.0

Areas that contribute to water quality and quantity
criterion 4.0

4.3.1 Indicator Rule-sets

CRITERION 1: Areas that contain rare, unique, or focal species

Areas that contain focal species, species groups, or their habitats

criterion 1.0

1a **Criterion 1a: Conservation Hotspots**

1a(i) Rare, Threatened, or Endangered Species

Data source:

- ACIMS, FWMIS

Quantification:

- Species with a ranking of S1, S1?, S2, S2?, S1S2, S2S3, G1?, G2?, G1G2, G2G3, or a Provincial/Federal ranking of Special Concern, Threatened, At Risk, or Endangered were identified
- For all points and/or polygons that touched a quarter section, an occurrence ('1') was assigned
- The number of occurrences were summed by quarter section
- Data were summarized by Natural Region and the distribution was log transformed
- A Jenks analysis was run by Natural Region

Indicator Scoring:

- 3 = QS with the highest count of rare, threatened, or endangered species
- 2 = QS with moderate count of rare, threatened, or endangered species
- 1 = QS with low count of rare, threatened, or endangered species

TABLE 2.

Final log transformed rare, threatened, or endangered species scores by Natural Region.

NATURAL REGION	NUMBER OF SPECIES OF CONSERVATION CONCERN (COUNT/QUARTER SECTION)		
	Class 1	**Class 2**	**Class 3**
Boreal/Shield	<3	3-11	>11
Grassland	<4	4-15	>15
Parkland	<4	4-22	>22
Rockies	<3	3-16	>16
Foothills	<4	4-21	>21

1b Criterion 1b: Focal species & focal species groups

1b(i) Amphibians

Data source:

- ACIMS, FWMIS

Quantification:

- Amphibian guild included Boreal chorus frog, Boreal toad, Canadian toad, Columbia spotted frog, Leopard frog, Long-toed salamander, Plains spadefoot, Wood frog, and Tiger salamander
- FWMIS points were buffered by 250m to create polygons (consistent with ACIMS data)
- For each quarter section, the percent cover of each species polygon was quantified
- A Jenks analysis was completed for each species to rank species occurrence by QS
- For each QS, the sum of rank scores for all species was determined
- Data was log transformed and a Jenks was performed on the re-classified data

Indicator Scoring:

- 3 = QS with the highest combination of % cover and number of species present
- 2 = QS with a moderate combination of % cover and number of species present
- 1 = QS with a low combination of % cover and number of species present

TABLE 3.

Final log transformed scores for amphibian guild occurrence by quarter section

Class	Total Quarter Section Score
Class 3	>1.386
Class2	0.694–1.386
Class 1	< 0.694

1b(ii) Aquatic Breeding Birds

Data source:
- ACIMS

Quantification:
- Quarter sections that touched any polygon identified by ACMIS as "bird colony" in the "EOTYPE" column were identified

Indicator Scoring:
- Score of 3 assigned to all quarter sections touching a Bird Colony polygon

1b(iii) Fish

Data source:
- ACIMS, FWMIS, Strahler stream order

Quantification:
- Fish guild included bull trout, cutthroat trout, walleye, and goldeye
- Streams & rivers with Strahler Order ≥ 3 were selected
- All indicator fish occurrence records were buffered by 5 kilometers, and this buffered occurrence layer was used to select all streams/rivers with Strahler Order ≥3
- All quarter sections touching occurrence/observation within the 5 km upstream and downstream buffers were selected

Indicator Scoring:
- 3 = Quarter sections with a focal fish occurrence/observation record
- 2 = Quarter sections touching overlapping buffers (i.e., >1 buffer)
- 1 = Quarter sections touching a single buffer

1c

Criterion 1c: Focal species habitat

1c(i) Harlequin duck

Data source:
- ACIMS

Quantification:
- Quarter sections that touched any Harlequin duck occurrence polygon

Indicator Scoring:
- 3 = Quarter sections touching a Harlequin duck polygon

1c(ii) Grizzly bear

Data source:
- Foothills Research Institute Grizzly Bear Resource Selection Function (RSF) Model

Quantification:
- RSF scores (30m resolution) were re-sampled to the quarter section scale by calculating an area weighted average RSF value
- A Jenks analysis was performed on the re-classified RSF values

Indicator Scoring:
- 3 = Quarter sections with high average RSF values
- 2 = Quarter sections with moderate average RSF values
- 1 = Quarter sections with low average RSF values

TABLE 4.

Final area-weighted average habitat scores by quarter section for grizzly bear derived using the Foothills Research Institute grizzly bear resource selection function model.

Class	Area-weighted Average Habitat Quality Score by Quarter Section
Class 3	>7.12
Class 2	3.84–7.12
Class 1	>3.87

1c(iii) Woodland caribou (boreal ecotype)

Data source:
- Environment Canada (2013)

Quantification:
- Quarter sections touching boreal caribou ranges were selected and the type of disturbance within each quarter section was characterized

Indicator Scoring:
- 3 = Quarter sections within boreal caribou range with undisturbed habitat
- 2 = Quarter sections within boreal caribou range with habitat impacted by fire
- 1 = Quarter sections within boreal caribou range with habitat impacted by anthropogenic disturbance
- Quarter sections containing >1 scoring class received the lower score (e.g., if a quarter section contained both undisturbed and fire disturbed habitat, the quarter section received a score of 2)

1c(iv) Western burrowing owl

Data source:
- Stevens et al. (2011) Western Burrowing Owl Resource Selection Function (RSF) Model

Quantification:
- RSF scores (30m resolution) were re-sampled to the quarter section scale by calculating an area weighted average RSF value
- A Jenks analysis was performed on the re-classified RSF values

Indicator Scoring:
- 3 = Quarter sections with high average RSF values
- 2 = Quarter sections with moderate average RSF values
- QS with a score of 1 (low average RSF value) were dropped from the analysis to eliminate study boundary effects

TABLE 5.

Final area-weighted average habitat scores by quarter section for western burrowing owl derived using the resource selection function model developed by Stevens et al. (2011).

Class	Area-weighted Average Habitat Quality Score by Quarter Section
Class 3	>7.43
Class 2	4.37–7.43

1c(v) Sage grouse

Data source:
- AESRD

Quantification:
- Quarter sections that touched sage grouse habitat or known lek locations

Indicator Scoring:
- 3 = Quarter sections containing sage grouse leks
- 2 = Quarter sections containing sage grouse habitat only

1c(vi) Arctic grayling

Data source:
- AESRD arctic grayling fish suitability index (FSI), Strahler stream order

Quantification:
- Suitability for arctic grayling was estimated using adult density values at the tertiary watershed scale
- All watersheds for which government fisheries experts felt grayling were unlikely to have ever occurred in recent historic times were removed
- Watersheds that have not been sampled, but where government fisheries experts strongly suspect arctic grayling occur, were placed in the moderate Adult FSI category
- All other watersheds were classified based on adult density values derived from field sampling. The Adult FSI categories included: none detected, very low, low, moderate, high, very high
- Quarter sections with streams/rivers with a Strahler Order ≥3 overlapping a watershed in the FSI model were selected and re-classified to a score of 1-3
- Where more than one watershed polygon was present within a quarter section, the quarter section was assigned the highest score

Indicator Scoring:
- 3 = Quarter section intersecting streams/rivers in watersheds rated as Very High or High
- 2 = Quarter sections intersecting streams/rivers in watersheds rated as Moderate
- 1 = Quarter sections intersecting streams/rivers in watersheds rated as None Detected, Very Low, or Low

1c(vii) Ferruginous hawk

Data source:
- Ng et al. (2013) Ferruginous Hawk Resource Selection Function (RSF) Model

Quantification:
- RSF scores (1600m resolution) were re-sampled to the quarter section scale by calculating an area weighted average RSF value
- A Jenks analysis was performed on the re-classified values

Indicator Scoring:
- 3 = Quarter sections with high average RSF values
- 2 = Quarter sections with moderate average RSF values
- QS with a score of 1 (low average RSF value) were dropped from the analysis to eliminate study boundary effects

TABLE 6.

Final area-weighted average habitat scores by quarter section for ferruginous hawk derived using the resource selection function model developed by Ng et al. (2013).

Class	Area-weighted Average Habitat Quality Score by Quarter Section
Class 2	4.2–5.0
Class 3	>5.0

CRITERION 2: Areas that contain rare, unique, or focal habitat

Areas that contain rare, unique, or focal habitat
criterion
2.0

2a Criterion 2a: Rare habitats

2a(i) Vegetation communities

Data source:
- ACIMS

Quantification:
- Quarter sections that touch any vegetation communities tracked by ACIMS

Indicator Scoring:
- 3 = Quarter section touching an ACIMS polygon

2a(ii) Peatlands

Data source:
- Peatland Inventory of Alberta (Vitt et al. 1996), ABMI Human Footprint Map (2010)

Quantification:
- Human footprint was overlaid and subtracted out of the peatland inventory to account for recent anthropogenic disturbance to peatlands
- A representation analysis was completed for each peatland type as a measure of rarity (Table 7)
- A rarity rating was assigned to each peatland type based on representation, as follows:
- <5% = Very Rare
- >5 to 11% = Rare
- >11% = Common
- Rarity ratings were re-assigned to an indicator score

Indicator Scoring:
- 3 = Quarter sections touching a Very Rare habitat polygon
- 2 = Quarter sections touching a Rare habitat polygon
- 1 = Quarter sections touching a Common habitat polygon
- Where more than one habitat polygon was present within a quarter section, the quarter section was assigned the highest score, regardless of the coverage of the quarter section by each habitat type

TABLE 7.

Results of a representation analysis conducted for peatlands in Alberta.

Peatland Type	Area (ha)	Area (%)	Rating
FTNI	17,316.03	0.22	Very Rare
STNN	21,522.93	0.27	Very Rare
BOVC	97,325.30	1.23	Very Rare
SOWN	130,799.30	1.65	Very Rare
BTNI	144,258.82	1.82	Very Rare
SONS	184,374.71	2.33	Very Rare
FTNR	191,230.33	2.42	Very Rare
BTNR	216,736.63	2.74	Very Rare
MONG	239,056.99	3.02	Very Rare
FOPN	442,038.82	5.59	Rare
BTNN	596,043.11	7.53	Rare
FONS	836,555.34	10.57	Rare
FONG	1,410,966.74	17.83	Common
BTXC	1,498,497.19	18.94	Common
FTNN	1,886,935.13	23.84	Common

2b Criterion 2b: Unique habitats and landforms

2b(i) Natural springs

Data source:
- ACIMS, Alberta Geological Survey Springs (Stewart 2009)

Quantification:
- Count of the total number of springs contained within each quarter section
- Score the quarter section based on the total number of springs present

Indicator Scoring:
- 3 = Quarter sections with 3 natural springs
- 2 = Quarter sections with 2 natural springs
- 1 = Quarter sections with 1 natural spring

2b(ii) Nationally & Internationally recognized landforms

Data source:
- ACIMS

Quantification:
- QS that touch any nationally or internationally recognized landform polygons

Indicator Scoring:
- 3 = QS touching a Nationally or Internationally recognized landform polygon

2c Criterion 2c: Focal habitats

2c(i) Class A & B rivers and streams

Data source:
- AESRD Code of Practice management maps

Quantification:
- Quarter sections that touch a Class A or Class B stream or river

Indicator Scoring:
- 3 = Quarter sections touching a Class A river or stream
- 2 = Quarter sections touching a Class B river or stream
- Quarter sections with both a Class A and Class B designation take on the highest score

2c(ii) Snake and bat hibernacula

Data source:
- ACIMS

Quantification:
- Quarter sections that touch any snake or bat hibernacula polygon

Indicator Scoring:
- 3 = Quarter section touching a snake or bat hibernacula polygon

2c(iii) Waterfowl staging and foraging areas

Data source:
- Important Bird Areas of Canada (IBA), NAWMP staging areas, AESRD Trumpeter Swan Waterbodies and Watercourse, AESRD Piping Plover Waterbodies, AESRD Colonial Nesting Birds, Ducks Unlimited Canada Waterfowl Pair Distribution Model, FWMIS, ACIMS

Quantification:

Layer 1: Combine and dissolve the following layers:
- IBA
- NAWMP Staging Areas
- AESRD Trumpeter Swan Waterbodies and Watercourse,
- AESRD Piping Plover Waterbodies
- AESRD Colonial Nesting Birds

Layer 2:
- Using Ducks Unlimited Canada Waterfowl Pair Distribution Model (30m resolution), calculate an area weighted average pair density for each quarter section
- Select all quarter sections with an average value ≥5.5

Layer 3:
- Create an aquatic bird foraging guild layer using FWMIS and ACIMS observation/occurrence data (see Table 8 for species list)
- Select quarter sections with a count of ≥2 UNIQUE species
- Combine and dissolve Layers 1, 2, and 3

Indicator Scoring:
- 3 = Quarter sections touching the waterfowl staging and foraging area layer

TABLE 8.

Species included in the aquatic bird foraging guild that were used in combination with other spatial layers to create the waterfowl staging and foraging areas layer .

Diving Carnivores	
Common loon *(Gavia immer)*	Horned grebe *(Podiceps auritus)*
Common merganser *(Mergus merganser)*	Pied-billed grebe *(Podilymbus podiceps)*
Double-crested cormorant *(Phalacrocorax auritus)*	Red-necked grebe *(Podiceps grisegena)*
Eared grebe *(Podiceps nigricollis)*	Western grebe *(Aechmophorus occidentalis)*
Diving Omnivores	
Bufflehead *(Bucephala albeola)*	Redhead *(Aythya americana)*
Canvasback *(Aythya valisineria)*	Ring-necked duck *(Aythya collaris)*
Common goldeneye *(Bucephala clangula)*	Ruddy duck *(Oxyura jamaicensis)*
Harlequin duck *(Histrionicus histrionicus)*	White-winged scoter *(Melanitta fusca)*
Lesser scaup *(Aythya affinis)*	
Dabbling Omnivores	
American coot *(Fulica americana)*	Gadwall *(Anas strepera)*
American wigeon *(Anas americana)*	Green-winged teal *(Anas crecca)*
Blue-winged teal *(Anas discors)*	Mallard *(Anas platyrhynchos)*
Canada goose *(Branta canadensis)*	Northern pintail *(Anas acuta)*
Cinnamon teal *(Anas cyanoptera)*	Trumpeter swan *(Cygnus buccinator)*
Surface-foraging Carnivores	
American bittern *(Botaurus lentiginosus)*	Bonaparte's gull *(Larus philadelphia)*
American dipper *(Cinclus mexicanus)*	Common tern *(Sterna hirundo)*
American white pelican *(Pelecanus erythrorhynchos)*	Forster's tern *(Sterna forsteri)*
Belted kingfisher *(Ceryle alcyon)*	Franklin's gull *(Larus pipixcan)*
Black tern *(Chlidonias niger)*	Great blue heron *(Ardea herodias)*
Black-crowned night-heron *(Nycticorax nycticorax)*	Osprey *(Pandion haliaetus)*
Shoreline Omnivores	
American avocet *(Recurvirostra americana)*	Solitary sandpiper *(Tringa solitaria)*
Black-necked stilt *(Himantopus mexicanus)*	Sora *(Porzana carolina)*
Greater yellowlegs *(Tringa melanoleuca)*	Spotted sandpiper *(Actitis macularia)*
Lesser yellowlegs *(Tringa flavipes)*	Virginia rail *(Rallus limicola)*
Marbled godwit *(Limosa fedoa)*	Willet *(Catoptrophorus semipalmatus)*
Sandhill crane *(Grus canadensis)*	Wilson's phalarope *(Phalaropus tricolor)*
Riparian Omnivores	
Marsh wren *(Cistothorus palustris)*	
Red-winged blackbird *(Agelaius phoeniceus)*	
Yellow-headed blackbird *(Xanthocephalus xanthocephalus)*	

2c(iv) Sharp-tail grouse leks

Data source: • AESRD Sharp-tail grouse survey data, FWMIS

Quantification: • Quarter sections that touch sharp-tail grouse lek point or polygon

Indicator Scoring: • 3 = Quarter sections touching a sharp-tail grouse lek point or polygon

CRITERION 3: Areas with ecological integrity

3a **Criterion 3a: Habitat patch size**

Areas with ecological integrity

criterion 3.0

3a(i) Terrestrial habitat patches

Data source:

- ABMI Human Footprint Map (2010), Provincial base features, Provincial hydrography

Quantification:

- An ESA human footprint layer was created by combining the following data:
  - Heavy Industrial or Urban Anthropogenic Features from the ABMI Human Footprint layer were combined and buffered by 100m to account for edge effects. The footprint types included were: Mine Sites, High Density Livestock Operation, Industrial Site Rural, Wind Generation Facility, Municipal (water and sewage).
  - Rural, Forestry, Agricultural, and Lower Impact Industrial footprint types from the ABMI Human Footprint layer were combined and buffered by 25m to account for edge effects. The footprint types included were: Rural features (homestead and farmyards, Well sites, Peat mines, Human-created water bodies, Cultivation (crop, pasture, bare ground), Managed forest (i.e., cutblocks)
  - Roads, rail lines, power lines, and pipelines were derived from the provincial base feature layers and were buffered by 25m. Paved roads were buffered by 100m.
- The ESA human footprint layer was "subtracted" from the provincial boundary
- Waterbodies (Provincial hydrography layer) were removed to create a terrestrial habitat patch layer
- Given the use of multiple data sources to create the layer, small slivers existed due to boundary inconsistencies. Slivers were removed if they met the following criteria:
  - Very small polygons (<0.05 ha)
  - Very narrow polygons with a length to width ratio of 25:1 (0.04)
- The cleaned layer was split into Natural Regions and the data were square root transformed

- Quarter sections intersecting the boundary of a waterbody were identified, and the total terrestrial area of the quarter section was recalculated by subtracting the waterbody area from the quarter section area
- A Jenks analysis was conducted by Natural Region to determine terrestrial patch area classes
- Patch size scores were assigned to each quarter section by touch; where >1 terrestrial patch was present in a quarter section, an area-weighted average patch score was calculated
- The percentage of the quarter section covered by a terrestrial patch was calculated, and the average patch score for each quarter section was weighted by the percent cover value
- The final quarter section score was determined through Jenks analysis using the area-weighted patch scores by Natural Region

Indicator Scoring:

- 3 = QS with extensive coverage of terrestrial patches
- 2 = QS with moderate coverage of terrestrial patches
- 1 = QS with low coverage of terrestrial patches

TABLE 9.

Final terrestrial habitat patch scores by Natural Region. Values are the product of the average patch score, multiplied by the percent of the quarter section covered by a terrestrial patch.

NATURAL REGION	TERRESTRIAL PATCH SCORE BY QUARTER SECTION		
	Score 1	**Score 2**	**Score 3**
Boreal/Shield	≤1.206	>1.206-2.428	>2.428
Grassland	≤ 0.855	>0.855-2.134	>2.134
Parkland	≤0.651	>0.651-1.923	>1.923
Rockies	≤1.348	>1.348-2.472	>2.472
Foothills	1.094	1.094-2.268	>2.268

3b Criterion 3b: Habitat intactness

3b(i) Intact landscapes

Data source:

- Provincial base features (roads, rail lines, pipelines, power lines, seismic lines)

Quantification:

- Calculate density (km/km^2) of linear features contained within each quarter section
- Jenks analysis by Natural Region to determine intactness categories (zero values excluded)

Indicator Scoring:

- 3 = Fully intact quarter sections (no linear features)
- 2 = Quarter sections with high intactness (low linear feature density)
- 1 = Quarter sections with moderate intactness (moderate linear feature density)
- Quarter sections with high linear feature density were excluded from the scoring

TABLE 10.

Final intact landscape scores by Natural Region. Quarter sections with the highest linear feature density by natural region were excluded from the scoring.

NATURAL REGION	LINEAR FEATURE DENSITY (KM/KM²) BY QUARTER SECTION			
	No Score	**Class 1**	**Class 2**	**Class 3**
Boreal/Shield	>3.54 – 20.35	>1.18 - 3.54	>0 - 1.18	0
Grassland	>5.22 – 28.04	>2.32 - 5.22	>0 - 2.32	0
Parkland	>5.60 – 27.26	>2.35 - 5.60	>0 - 2.35	0
Rockies	>4.55 – 17.22	> 1.93 - 4.98	>0 - 1.88	0
Foothills	>4.98 – 18.26	>1.97 – 4.55	>0 - 1.18	0

3b(ii) Lotic (rivers & streams) habitat connectivity

Data source:
- Stream single line network, Hydrography points, Provincial base features (roads & rail lines), Strahler stream order

Quantification:
- Select quarter sections touching streams and rivers with Strahler Order 2, 3, or 4
- Calculate length (km) of stream/river segment unimpeded by a road, rail line, dam, or control structure
- Jenks analysis by Natural Region and stream order to determine unimpeded stream length categories

Indicator Scoring:
- 3 = Quarter sections with longest unimpeded stream length segments
- 2 = Quarter sections with moderate unimpeded stream length segments
- 1 = Quarter sections with low unimpeded stream length segments

TABLE 11.

Final lotic habitat connectivity scores by Natural Region and Strahler stream order.

NATURAL REGION	STREAM ORDER	UNIMPEDED STREAM LENGTH (KM) BY QUARTER SECTION		
	No Score	**Class 1**	**Class 2**	**Class 3**
Boreal/Shield	2	<1.036	1.036 - 3.81	>3.81
	3	<1.921	1.921 - 7.84	>7.84
	4	<3.814	3.814 - 16.925	>16.925
Grassland	2	<0.371	0.371 - 1.44	>1.44
	3	<0.546	0.546 - 2.415	>2.415
	4	<0.949	0.949 - 4.528	>4.528
Parkland	2	<0.376	0.376 - 1.357	>1.357
	3	<0.524	0.524 - 1.994	>1.994
	4	<0.736	0.736 - 3.233	>3.233
Foothills	2	<0.687	0.687 - 2.241	>2.241
	3	<1.471	1.471 - 5.341	>5.341
	4	<2.326	2.326 - 8.567	>8.567
Rockies	2	<0.548	0.548 - 1.769	>1.769
	3	<1.059	1.059 - 3.916	>3.916
	4	<1.585	1.585 - 6.906	>6.906

3b(iii) Lentic (wetlands & lakes) riparian habitat intactness

Data source:
- Provincial hydrography polygons, ESA terrestrial patch layer [Indicator 3a(i)]

Quantification:
- Extract all wetland and lake features from provincial hydrography polygon layer
- Buffer features by waterbody size (Alberta Environmental Protection 1994):
  - <1ha = 30m buffer
  - 1 to 4ha = 60m buffer
  - >4ha = 100m buffer
- Select quarter sections touching lentic buffers and calculate the total buffer area
- Calculate proportion of the buffer covered by a terrestrial patch
- Jenks by Natural Region to determine buffer intactness score
- Re-assign buffer intactness score to quarter sections contained within the water body polygon

Indicator Scoring:
- 3 = Quarter sections within waterbodies with high shoreline intactness
- 2 = Quarter sections within waterbodies with moderate shoreline intactness
- 1 = QS within waterbodies with low shoreline intactness

TABLE 12.

Final lentic riparian habitat intactness scores by Natural Region. The values presented are based on the percentage of the lentic buffer covered by a terrestrial patch.

PROPORTION (%) OF LENTIC BUFFER COVERED BY TERRESTRIAL PATCH

	Score 1	Score 2	Score 3
Boreal/Shield	≤39.2	>39.2 – 80.4	>80.4
Grassland	≤27.6	>27.6 – 67.6	>67.6
Parkland	≤17.5	>17.5 – 54.2	>54.2
Rockies	≤32.5	>32.5 – 80.9	>80.9
Foothills	≤46.8	> 46.8 – 78.3	>78.3

Areas that contribute to water quality and quantity

criterion

4.0

CRITERION 4: Areas that contribute to water quality and quantity

4a Criterion 4a: Rivers and streams

4a(i) River and stream density

Data source:

- Stream single line network

Quantification:

- Remove lentic features using provincial hydrography layer (all wetland and lake categories)
- Calculate density (km/km²) of streams and rivers contained within each quarter sections
- Jenks analysis by Natural Region to determine river and stream density score, treating Jasper & Banff as a separate "Region" given the paucity of stream data in this area of the province

Indicator Scoring:

- 3 = Quarter sections with high river and stream density
- 2 = Quarter sections with moderate river and stream density
- 1 = Quarter sections with low river and stream density

TABLE 13.

Final river and stream density scores by Natural Region.

RIVER AND STREAM DENSITY (KM2) BY QUARTER SECTION

	Class 1	Class 2	Class 3
Boreal/Shield	< 1.085	1.085–2.352	> 2.352
Grassland	< 1.237	1.237–2.816	> 2.816
Parkland	< 1.078	1.078–2.362	> 2.362
Rockies	< 1.261	1.261-2.669	> 2.669
Foothills	< 1.120	1.120–2.372	> 2.372
Jasper/Banff	< 0.965	0.965–2.076	> 2.076

4a(ii) Lotic (river and stream) riparian habitat intactness

Data source:
- Stream single line network, ESA terrestrial habitat patch layer [Indicator 3a(i)]

Quantification:
- Select quarter sections intersecting a stream or river
- Calculate proportion of the quarter section covered by a terrestrial patch
- Jenks analysis by Natural Region, treating Jasper & Banff as a separate "Region" given the paucity of stream data in this area of the province

Indicator Scoring:
- 3 = Quarter sections adjacent to rivers & streams with high terrestrial patch coverage
- 2 = Quarter sections adjacent to rivers & streams with moderate terrestrial patch coverage
- 1 = Quarter sections adjacent to rivers & streams with low terrestrial patch coverage

TABLE 14.

Final lotic riparian habitat intactness scores by Natural Region. The values presented are based on the percentage of adjoining quarter sections covered by a terrestrial patch.

PROPORTION (%) OF ADJOINING QUARTER SECTIONS COVERED BY TERRESTRIAL PATCH			
	Class 1	**Class 2**	**Class 3**
Boreal/Shield	<34.2	4.2–76.9	>76.9
Grassland	<27.7	27.7–68.8	>68.8
Parkland	<19.2	19.2–58.1	>58.1
Rockies	<39.8	39.8–77.9	>77.9
Foothills	<37.7	37.7–74.5	>74.5
Jasper/Banff	<51.7	51.7–85.0	>85.0

4.4 Indicator, Sub-criterion, and Criterion Weighting

A weighting is a value that indicates the importance of a particular variable, relative to others that are under consideration (Malczewski 1999), and the application of multi-criteria decision analysis and weighting of criteria is becoming increasingly common in modeling exercises (Mendoza and Martins 2006; Malczewski 2006; Greene et al. 2011). In any weighting exercise, there is a certain amount of subjectivity applied to the ranking of variables, and this subjectivity is used to better reflect the place-based values that underlie the identification of important environmental resources (Greene et al. 2011).

A ranking method, where all attributes under consideration are ranked according to the decision maker's preference, was used to prioritize criteria, sub-criteria, and indicators because it is one of the simplest methods for calculating weights (Drobne and Lisec 2009; Greene et al. 2011). Members of the government ESA Working Group compiled a list of subject matter experts from the Government of Alberta, and these experts were invited to participate in the ranking exercise. In order to capture the full range of subjective opinions about ESAs in Alberta, participants were selected from a broad range of government departments and areas of expertise. In total 34 people were invited to participate in the ranking exercise in September of 2013, and 12 responses were received (35% response rate). These responses were used to determine the ranking for the criteria, sub-criteria, and indicators included in the ranking exercise. Subsequent to the ranking exercise, one additional indicator was added to the ESA model under Criterion 3. In order to integrate the new indicator into the ESA framework, members of the government ESA Working Group were asked to provide a rank for the new indicator, relative to the existing indicators included in Criterion 3. Once the final ranking for all indicators, sub-criteria, and criteria was determined, a rank sum approach was used to calculate the final weights. Rank sum weights were calculated using the following formula:

$$\omega_i = \frac{n - r_j + 1}{\sum(n - r_k + 1)}$$

where:

ω_i	=	normalized weight for the j^{th} criterion or indicator
n	=	the number of criteria or indicators under consideration
r_j	=	the rank position of the criterion
$\sum$(n-r_k+1)	=	sum of all weights

All calculated weights were organized in accordance with the analytic hierarchy process method (AHP) to ensure mathematical consistency throughout the framework (Drobne and Lisec 2009). To achieve system consistency, all criteria, sub-criteria and indicator weights obtained from the ranking exercise were normalized, meaning that the sum of all indicator values related to a sub-criterion were equal to the weight of that sub-criterion, and the sum of all sub-criterion weights were equal to the criterion weight. Finally, the sum of all criteria weights was equal to 1 (Figure 1).

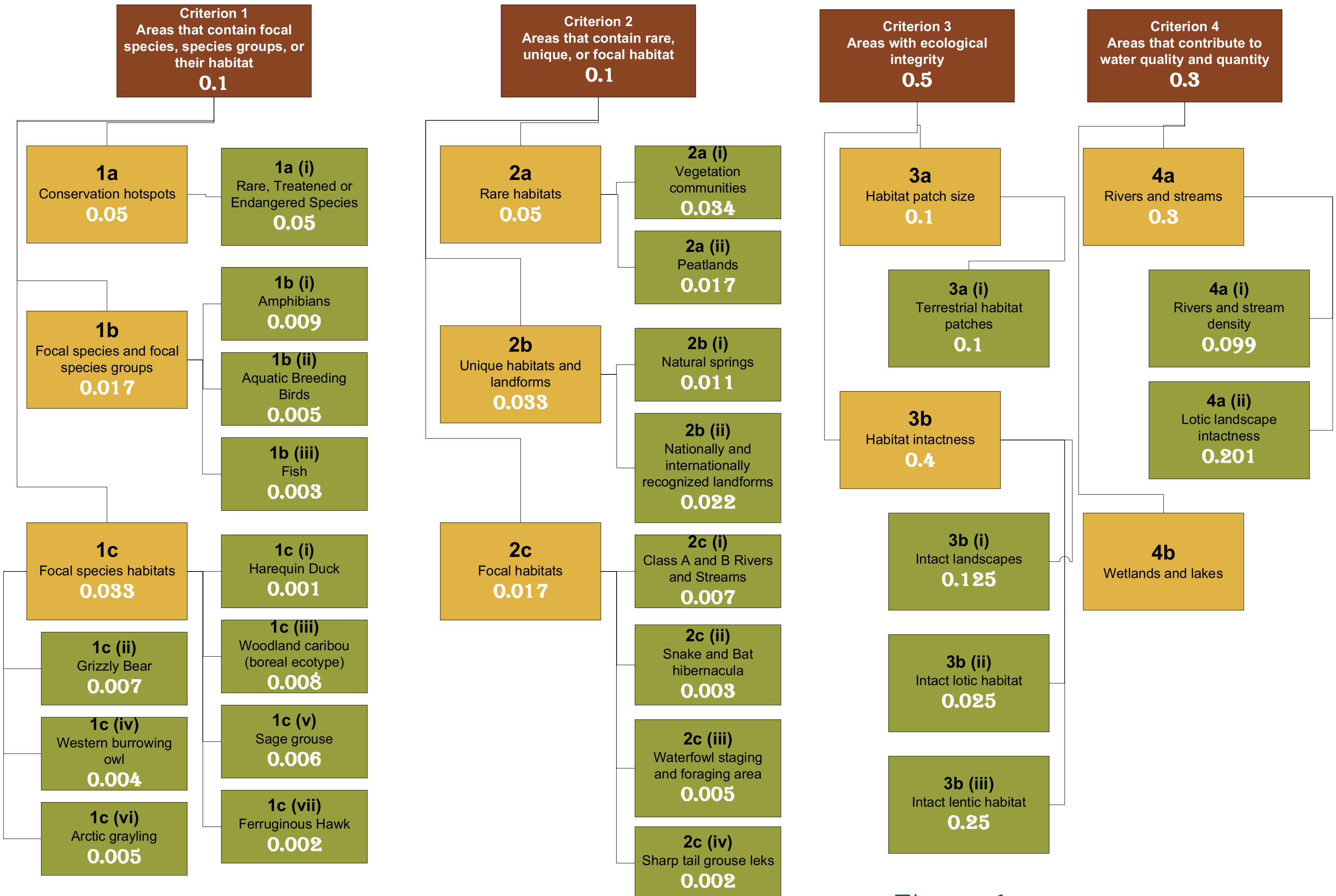


Figure 1

Final weightings for all criteria, sub-criteria, and indicators used to identify Environmentally Significant Areas in Alberta as part of the 2014 update.

4.5 Indicator and Criteria Aggregation

Once indicators were quantified and a weighting determined, final values for each indicator were calculated using weighted linear combination. This approach, also referred to as simple additive weighting, first involves normalizing indicator scores into a common numeric range (Greene et al. 2011). This was done using linear scale transformation, which is one of the most frequently used GIS-based methods for standardizing indicator scores (Drobne and Lisec 2009). A number of different linear scale transformations exist, but this analysis employed a score range procedure that standardized scores into values that ranged between 0 and 1. Specifically, indicator scores were normalized as follows: Class 1 = 0.15; Class 2 = 0.35; Class 3 = 0.50. Indicator scores and weightings were then combined using the following mathematical expression (Drobne and Lisec 2009):

$$Iv = \sum w_i \; x_i$$

where:

Iv	=	Indicator value
w_i	=	Indicator weight
x_i	=	Indicator score

For each quarter section in the province, weighted indicator values were aggregated for each criteria to determine a final criteria value. Criteria values were then summed by quarter section to calculate a final ESA value. This resulted in a provincial map with a continuous ESA value surface, with values that ranged between 0 and 0.5.

4.6 Assigning ESA Score

Once final ESA values were calculated, and a continuous ESA value surface was produced, the Government Working Group was consulted to determine an ESA cut-off value. The distribution of ESA scores was examined and a variety of methods were explored to objectively assign an ESA cut-off value, including Jenks and percentile ranks. Ultimately, professional judgement was used to determine a cut-off value of >0.189 for designating quarter sections as Environmentally Significant Areas in the province.

Section 5.0

Results

criterion 1.0

CRITERION 1: Areas that contain rare, unique, or focal species

Criterion 1 received a final weighting of 0.1 (10%) in the Provincial ESA model. Final criteria values ranged between 0 and 0.037, with a mean value of 0.002. This criterion covered a total of 333,942 km² (50% of the province), with the greatest proportion of this area located in the Boreal Natural Region (Figure 2; Table 15). In terms of coverage by Natural Region, Criterion 1 covered large portions of the Rocky Mountain, Foothills, and Grassland Natural Regions (Table 15).

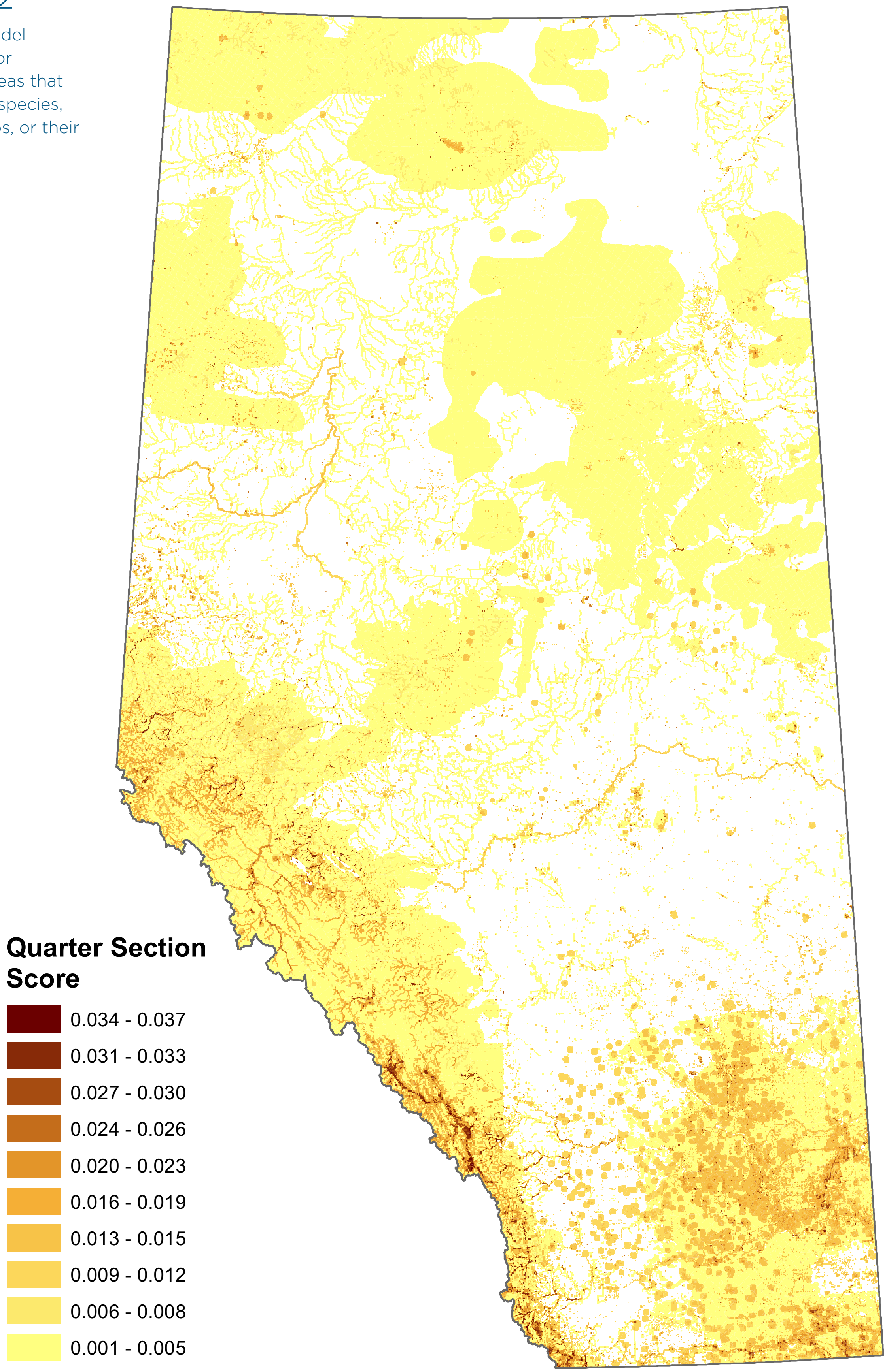
TABLE 15.

Total provincial coverage of Criterion 1, and the total area and proportion of coverage by Natural Region.

	Area Coverage (km²)	Proportion (%) of Criterion Coverage	Criterion Coverage by Natural Region (%)
Boreal	171,539	51.4	45.0
Canadian Shield	1,660	0.5	17.1
Foothills	45,689	13.7	68.8
Grassland	62,516	18.7	65.4
Parkland	5,500	1.6	9.1
Rocky Mountain	47,037	14.1	95.9
TOTAL	**333,942**	-	-

Figure 2

Final 2014 model output map for Criterion 1: Areas that contain focal species, species groups, or their habitats.



criterion
2.0

CRITERION 2: Areas that contain rare, unique, or focal habitat

Criterion 2 also received a final weighting of 0.1 (10%) in the Provincial ESA model (Figure 1). Final criteria values ranged between 0 and 0.031, with a mean value of 0.002. Criterion 2 covered 192,209 km² (29% of the province), with the greatest proportion of the total criterion area located in the Boreal Natural Region (Figure 2; Table 16). The greatest coverage by Natural Region for Criterion 2 included the Boreal and the Foothills (Table 16).

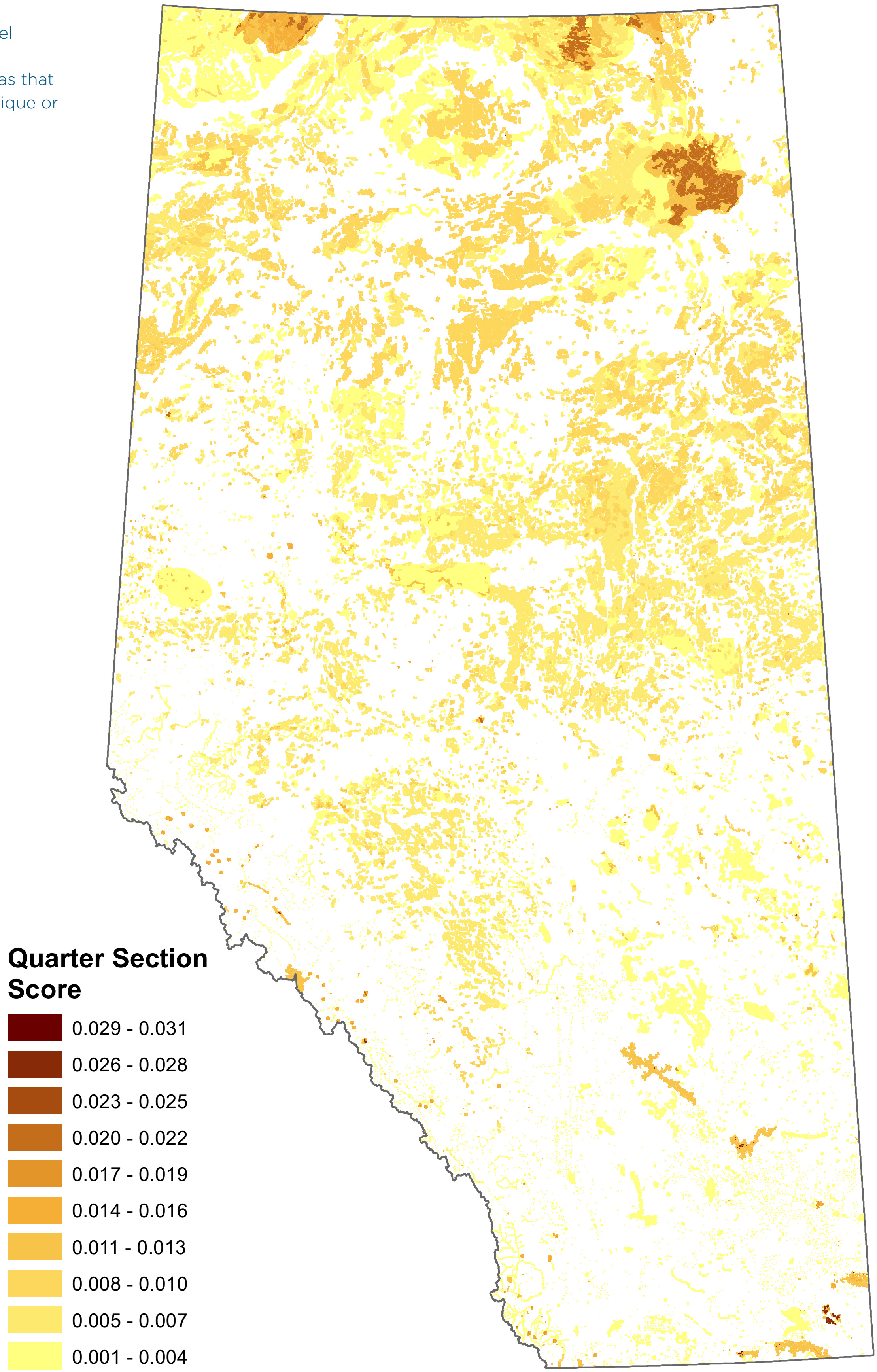
TABLE 16.

Total provincial coverage of Criterion 2, and the total area and proportion of coverage by Natural Region.

	Area Coverage (km²)	Proportion (%) of Criterion Coverage	Criterion Coverage by Natural Region (%)
Boreal	154,908	80.6	40.7
Canadian Shield	1,741	0.9	17.9
Foothills	13,410	7.0	20.2
Grassland	10,647	5.5	11.1
Parkland	7,856	4.1	12.9
Rocky Mountain	3,648	1.9	7.4
TOTAL	**192,209**	**-**	**-**

Figure 3

Final 2014 model output map for Criterion 2: Areas that contain rare, unique or focal habitat.



criterion

3.0

CRITERION 3: Areas with ecological integrity

Criterion 3 received a weighting of 0.5 (50%), which was the highest weighting value of all criteria included in the ESA model (Figure 1). Final criteria values ranged between 0 and 0.251, with a mean value of 0.106. Criterion 3 covered 658,157 km^2 (99% of the province), with the greatest proportion of the total criterion area located in the Boreal Natural Region (Figure 4; Table 17). Coverage by Natural Region for Criterion 3 was extensive, with coverage exceeding 98% for all Natural Regions in the province (Table 17).

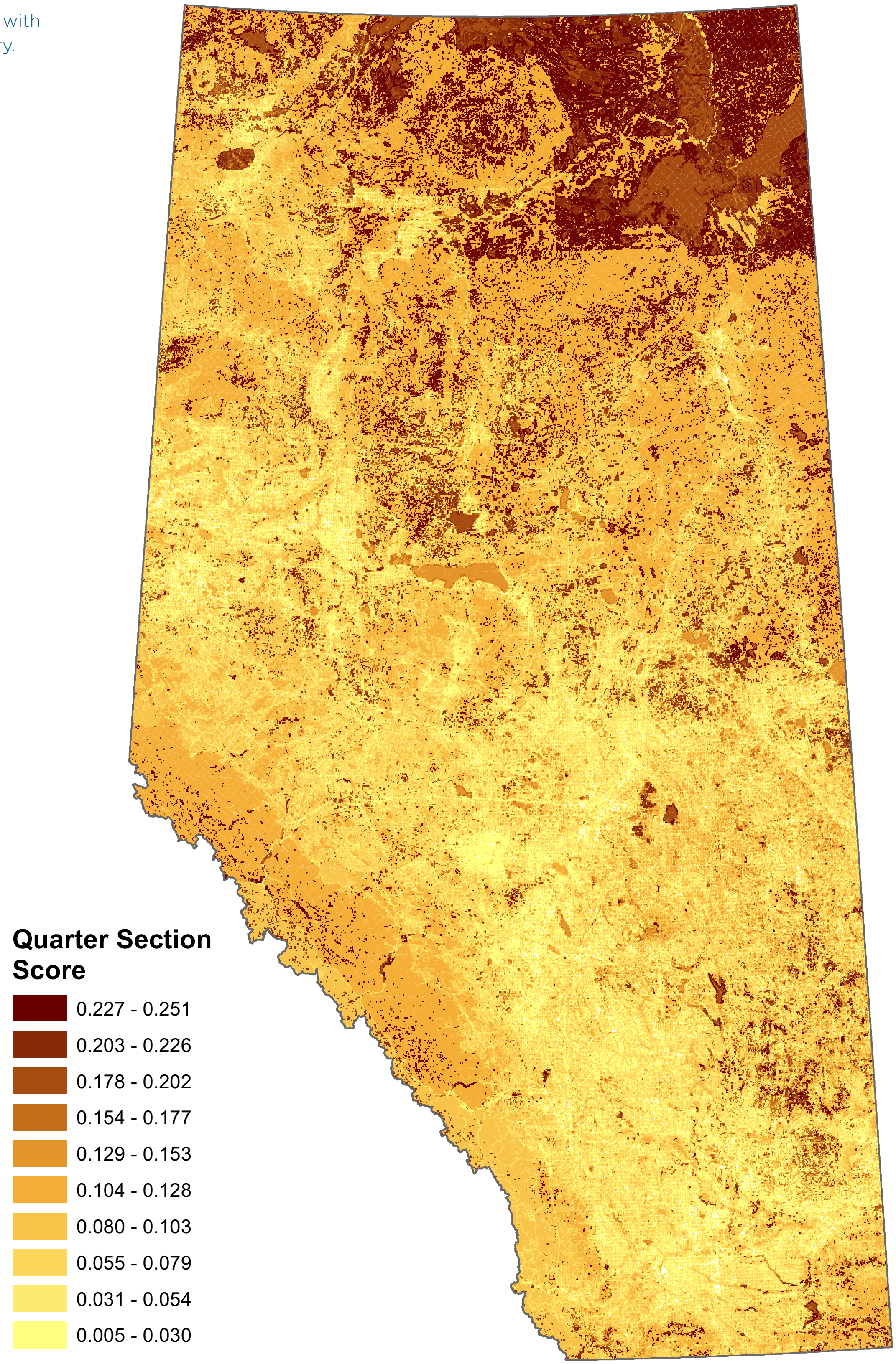
TABLE 17.

Total provincial coverage of Criterion 3, and the total area and proportion of coverage by Natural Region.

	Area Coverage (km^2)	Proportion (%) of Criterion Coverage	Criterion Coverage by Natural Region (%)
Boreal	379,359	57.6	99.6
Canadian Shield	9,710	1.5	100.0
Foothills	66,390	10.1	99.9
Grassland	93,914	14.3	98.3
Parkland	59,739	9.1	98.4
Rocky Mountain	49,046	7.5	100.0
TOTAL	**658,157**	-	-

Figure 4

Final 2014 model output map for Criterion 3: Areas with ecological integrity.



criterion 4.0

CRITERION 4: Areas that contribute to water quality and quantity

Criterion 4 received a weighting of 0.3 (30%), which was the second highest weighting value of all criteria included the ESA model (Figure 1). Final criteria values ranged between 0 and 0.150, with a mean value of 0.062. Criterion 4 covered a total of 372,904 km^2 (56% of the province), with the greatest proportion of the total criterion area located in the Boreal Natural Region (Figure 5; Table 18). The greatest coverage by Natural Region for Criterion 4 included the Rocky Mountains and Foothills (Table 18).

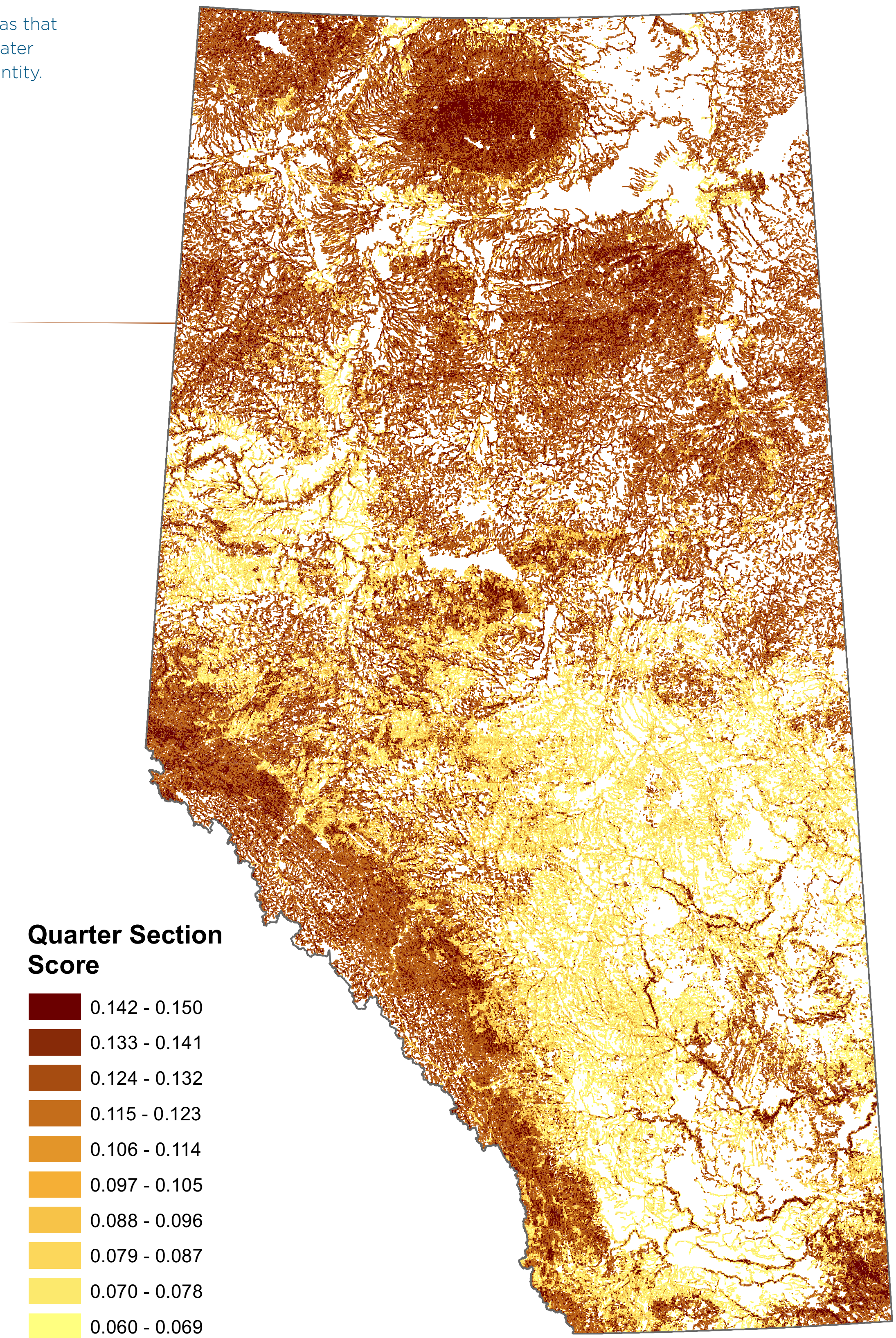
TABLE 18.

Total provincial coverage of Criterion 4, and the total area and proportion of coverage by Natural Region.

	Area Coverage (km^2)	Proportion (%) of Criterion Coverage	Criterion Coverage by Natural Region (%)
Boreal	207,074	55.5	54.3
Canadian Shield	4,162	1.1	42.9
Foothills	47,722	12.8	71.8
Grassland	46,101	12.4	48.2
Parkland	28,743	7.7	47.3
Rocky Mountain	439,100	10.5	79.7
TOTAL	**372,904**	-	-

Figure 5

Final 2014 model output map for Criterion 4: Areas that contribute to water quality and quantity.



5.5. Environmentally Significant Areas

Final provincial ESA values ranged between 0 and 0.4375, with a mean value of 0.172. When the ESA cut-off value of 0.189 was applied, a total of 294,926 km² (~45% of the province) was identified as an Environmentally Significant Area, with the greatest proportion of this area located in the Boreal Natural Region (Figure 6; Table 19). ESA coverage by Natural Region was highest for the Canadian Shield (89%) and the Rocky Mountains (71%), with ESA coverage in the Parkland (~11%) being the lowest of all Natural Regions (Table 19).

TABLE 19.

Total provincial coverage of ESAs (>0.189), and the total area and proportion of coverage by Natural Region.

	Area Coverage (km²)	Proportion (%) of Criterion Coverage	Criterion Coverage by Natural Region (%)
Boreal	197,713	67.0	51.9
Canadian Shield	8,634	2.9	88.9
Foothills	25,302	8.6	38.1
Grassland	21,751	7.4	22.8
Parkland	6,629	2.2	10.9
Rocky Mountain	4,896	11.8	71.1
TOTAL	**294,926**	-	-

The proportion of the province identified as an ESA in this update increased by just over 4%, as compared to the combined area of the previous ESA (2009) and AESA (2010) products (Table 20). When the updated 2014 ESA model results were overlaid on previously identified ESAs and AESAs, the area of overlap was approximately 60% (Figure 7). The greatest proportion of new ESAs added with the 2014 update were located in the Boreal Natural Region, with the smallest proportion of new areas added in the Rocky Mountain Natural Region (Table 21).

TABLE 20.

Comparision of the total area and proportion of the province covered by ESAs as identified through different modeling exercises.

	Provincial Area Coverage (km²)	Proportion (%) of Province Covered
ESA (2009)	190,711	28.8
AESA (2010)	201,128	30.4
ESA (2009) & AESA (2010) combined area	266,050	40.2
ESA (2014)	294,926	44.5

TABLE 21.

The total area and proportion of new ESAs identified in each Natral Region in the 2014 update.

	New ESA Area (ha)	Proportion (%) of New ESA Area (ha)
Boreal	87,519.96	73.6
Canadian Shield	5,252.93	4.4
Foothills	13,451.49	11.3
Grassland	7,950.51	3.0
Parkland	3,527.98	10.9
Rocky Mountain	1,256.81	1.1
PROVINCIAL TOTAL	**118,959.68**	-

Figure 6

Final 2014 model output map identifying Environmentally Significant Areas (quarter sections with a score of >0.189), as well as scores for all other quarter sections.

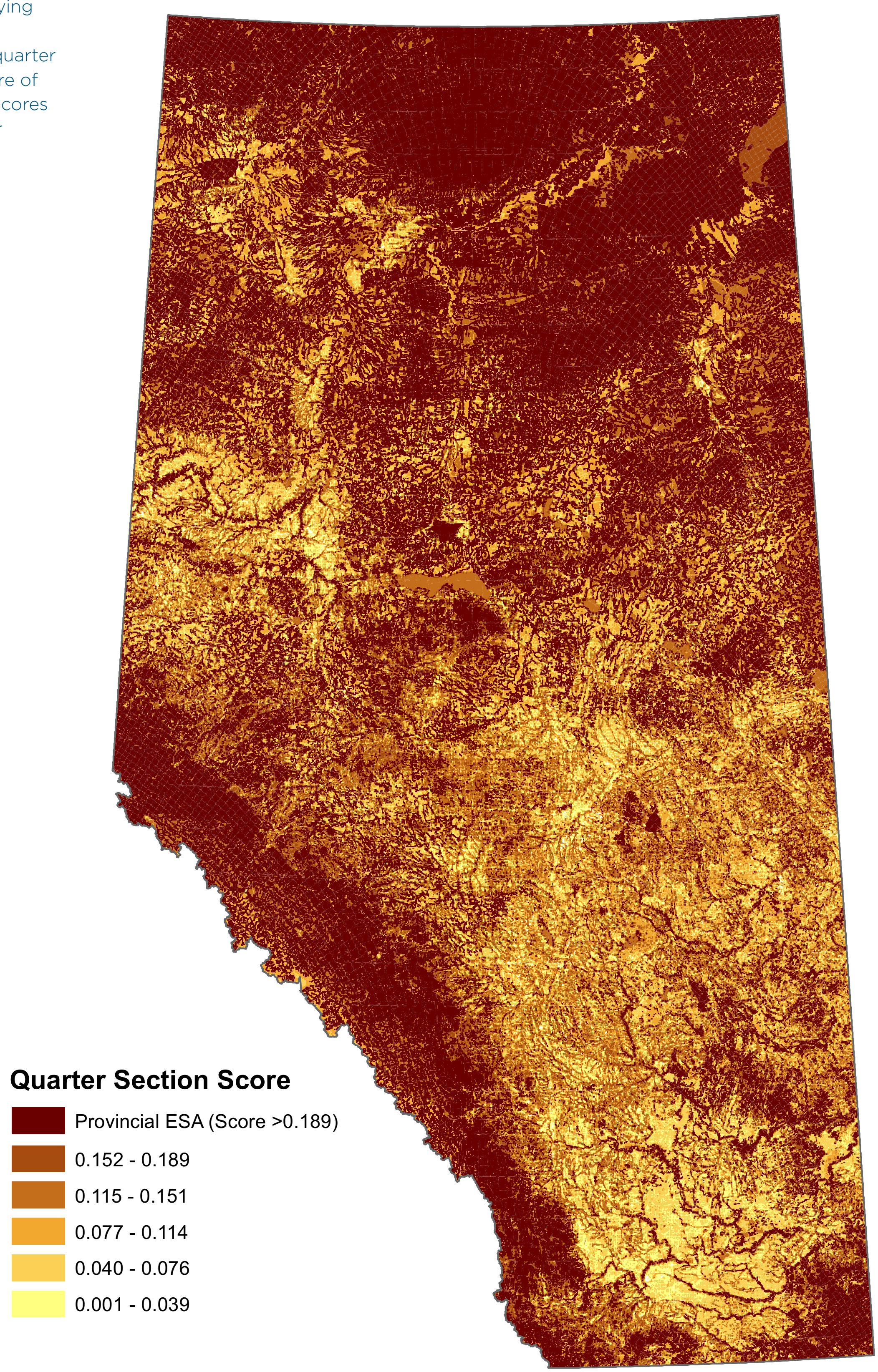
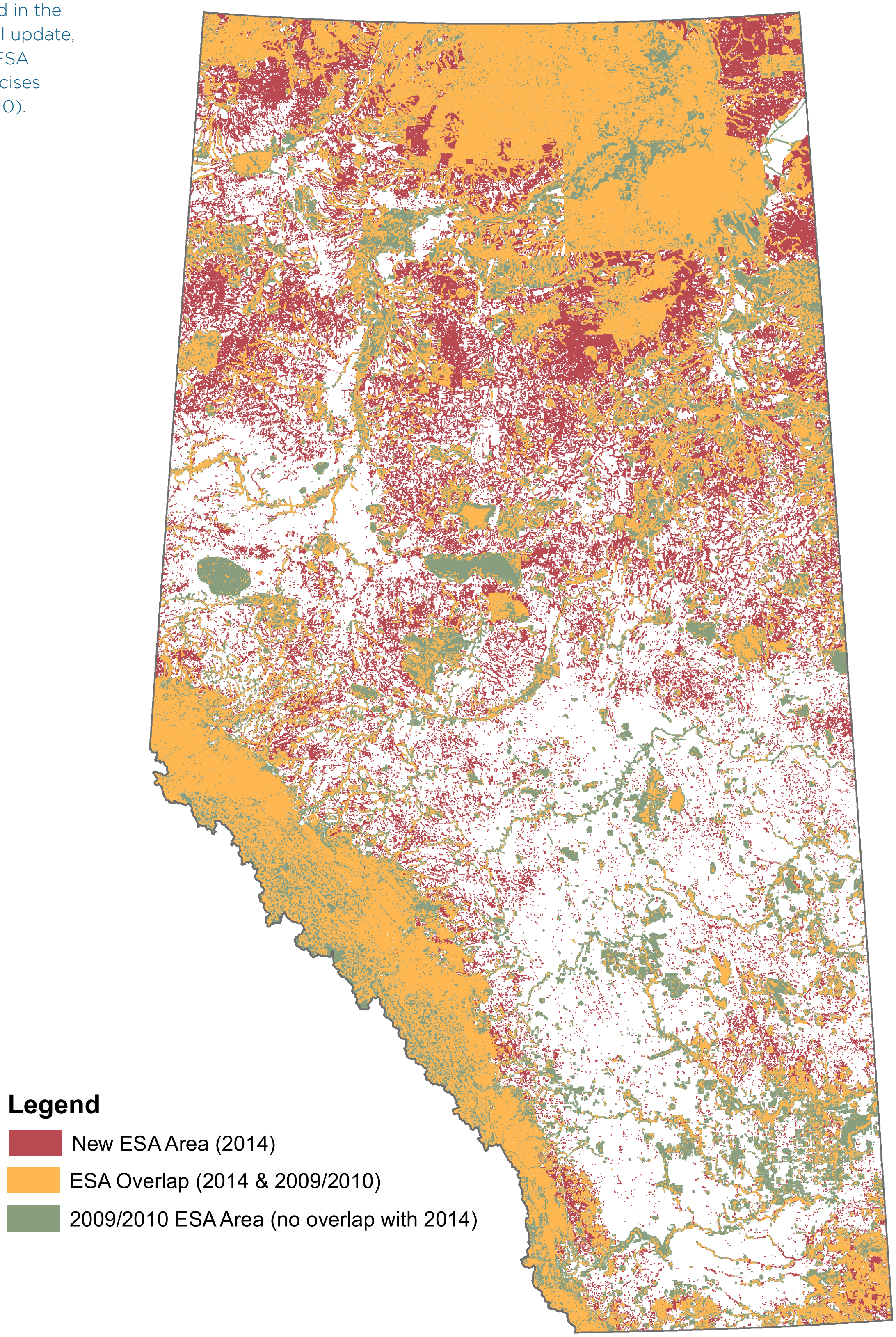


Figure 7

Similarities and differences between ESAs identified in the 2014 provincial update, and previous ESA modeling exercises (2009 and 2010).



Section

6.0

Discussion

The ESA network is not evenly distributed across the province, with the majority of ESAs (67%) located in the Boreal Natural Region. In terms of the proportion of ESA coverage by Natural Region, the Rocky Mountain and Boreal Natural Regions have the highest coverage (Table 19). These results are driven primarily by the fact that both of these Natural Regions have a relatively high degree of ecological integrity (Figure 4), and contain elements that are considered to positively contribute towards the maintenance of water quality and quantity (Figure 5). Given that these two criteria received the highest weightings in the calculation of final quarter section values, large portions of the Boreal and the Rocky Mountain Natural Regions were identified as ESAs. In contrast, the Parkland Natural Region is one of the most fragmented regions of the province, and as a result, both the proportion of ESAs identified in this region, as well as the total coverage by Natural Region, is very small.

6.1. Data Gaps and Model Limitations

While every effort was made to create the most comprehensive and up-to-date ESA model possible, there are several important data gaps and model limitations that should be understood when considering the final results of this update:

1. While there have been past efforts to map the extent of riparian lands in the province, to date, there has been no systematic measurement of the aerial extent of intact riparian habitat in Alberta. Further, while there are various methods that have been used in Alberta to quantify riparian health, there is a lack of commonly applied assessment methods, and the extent of riparian health surveys is limited to small portions of the province (Clare and Sass 2012). While this ESA update used proxies to approximate the location and condition of riparian habitat in Alberta, the model would certainly be improved if a more comprehensive provincial inventory of riparian habitat existed.
2. At present, the provincial wetland inventory consists of a compilation of different inventories that were produced using a variety of methods and mapping techniques. The result is an inventory with inconsistent accuracy across different regions of the province. In some regions, the level of accuracy was considered by the Working Group to be unacceptably low, and thus, the provincial inventory was not used as a data input in this model. As a result, any indicator that required a wetland inventory was removed. Given the environmental importance of wetlands, the inability to reliably identify wetlands in Alberta was considered a major gap in this assessment.
3. ESAs were identified at a very coarse scale (provincial) using the quarter-section as the unit of analysis. As such, this model provides a coarse-scale assessment of environmental values in the province, and the resulting ESA map highlights

general areas that contain environmentally significant elements. Finer-scale planning processes are required if the objective is to identify and delineate specific areas of environmental significance at scales finer than the quarter section (e.g., a single wetland or a tree stand). Further, the identification of ESAs at finer scales allows for region-specific prioritization and weighting of criteria and indicators; for example, higher priority may be placed on water quality and quantity indicators in water-scarce regions of the province, as compared to the provincial weighting.

4. Several of the indicators used to identify ESAs relied on species observation and occurrence records, which represents "presence only" data. The use of presence-only data can be problematic because there is no reliable information about where a particular species is not found, and these types of data often exhibit strong spatial bias related to survey effort. While there are various statistical ways of accounting for and dealing with this spatial bias (e.g., Pearce and Boyce 2006; Phillips et al. 2009), applying these techniques to the datasets used in this assessment was outside the scope of work. As a result, indicators that are solely based on presence only data should be interpreted cautiously, and likely do not represent the full extent of species distribution in Alberta.

5. The final values assigned to each quarter section in the province are relative values, and for many of the indicators, the Class score determination (i.e., assigning scores of 1, 2, or 3) were based on cut off values that were statistically determined, rather than determined through application of ecological thresholds. As a result, it is conceivable that for some indicators, quarter sections that received a high score represent areas where ecological integrity thresholds have already been exceeded for a particular species or habitat.

6. While this process identified ESAs across the province, neither the designation of the quarter section as an ESA, nor the final value assigned to that quarter section should be considered synonymous with pristine or undisturbed habitat. It is conceivable that areas identified as ESAs in this update have been negatively impacted by direct or indirect disturbance, and may require some level of restoration. Future updates should include criteria to measure intactness of ESAs to better account for human footprint on the land base and the vulnerability of ESAs to current and future developments. This information would inform decision-makers about threats to individual ESAs and management actions that may be required to maintain or restore their environmental values

Section
7.0

Conclusions

The primary objective of this project was to review, revise, and combine previously selected ESA and AESA criteria, in order to update the portfolio of ESAs in the province. To achieve this, we employed a GIS-based multi-criteria decision analysis (GIS-MCDA) as the foundation for quantifying, weighting, and identifying Environmentally Significant Areas in Alberta. This update represents a major advance in the approach and methods used to identify ESAs in the province. Specifically, this update provides a continuous ESA value surface for the province, allowing for a more comprehensive understanding of the location of elements that are considered to be environmentally significant based on the criteria and indicators included in this update. In addition, this update includes criteria weights that are reflective of existing priorities as expressed by subject matter experts in the Government of Alberta.

The criteria selected to identify ESAs in Alberta represented a broad range of important environmental elements, and included both coarse-filter and fine-filter indicators. Coarse-filter indicators were developed with the goal of maintaining native biota and natural ecosystem function, while fine-filter indicators were developed to capture environmental features that are required to maintain populations, species, ecosystems, or other special features that are not accounted for under coarse filter criteria (Groves et al. 2000). In total, four criteria, 10 sub-criteria, and 25 indicators were selected to help define, measure, and map terrestrial and aquatic ESAs in Alberta. The application of objective, well-defined criteria to systematically identify significant aquatic ecosystems has resulted in a transparent and repeatable process that can be easily updated with new data and/or new criteria and indicators.

Ultimately, land-use planning for the province of Alberta must incorporate social, economic, cultural, and environmental values to produce a multifunctional landscape supporting all of these functions (Lovell and Johnston 2009). This ESA mapping product represents scientifically defensible options for future land-use planning, providing relevant and flexible information on the location of environmentally significant elements. Consideration of important environmental values as part of a larger planning process will increase the probability that these values can be maintained over the long-term.

Section

8.0

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CONTACT US

Suite 200, 10318-82 Avenue
Edmonton, Alberta T6E 1Z8

Email: info[at]fieraconsulting[dot]ca
Telephone: 780-466-6554

UTM Coordinates
12U E 334537, N 5932815 (NAD 83)