A Terrestrial Biodiversity Assessment for the Northwest Territories

Prepared by: Wayne Condon, Manager, GIS Programs, Aurora Research Institute, Fort Smith, Northwest Territories
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This document is also available at www.nwtresearch.com.

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1.0 Plain Language Summary

Biodiversity consists of the diversity of life at the genetic, species and ecosystem levels of organization. As it is not possible to identify all species, genes, and ecosystems in the Northwest Territories, other measures must be used to evaluate where diversity is high or low. A commonly used measure of biodiversity is species richness or the total number of species in a given area. In this report, bird, bird **species-at-risk** and mammal species richness were assessed for the Northwest Territories. Both mammal and bird species had high diversity in the southwest and south-central portion of the territory and along the Mackenzie, Liard and Slave River valleys. Higher diversity is associated with mixed wood forests in the southern part of the territory and the major river valleys (Mackenzie, Liard and Slave Rivers). Bird **species-at-risk** diversity was also higher in the southwest and south-central portions of the territory, along the Mackenzie River valley and near the northern coast. Plant cover and other land cover (e.g. water, rock or soil) diversity were also assessed for the territory. This type of diversity is highest east of Great Slave Lake, along the Slave River valley and the Mackenzie Delta.

2.0 Introduction

The 2009 Science Agenda for the Northwest Territories (NWT) identified a need for baseline biodiversity work for the NWT (Government of the Northwest Territories, 2009). Noss and Cooperrider (1994) define biodiversity as “the variety of life and its processes; it includes the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting.” Since it is not currently possible to quantify all genes, species and ecosystems present in the Northwest Territories, this document will use surrogate indicators to identify biodiversity hot spots or areas where there is high diversity. Noss states that “Conservation plans that identify and protect centers of species richness, endemism, and vegetative diversity complement approaches based on qualities of individual species” (Fiedler and Jain, 1992). An analysis of individual species has already been completed for the Northwest Territories (Working Group on General Status of NWT Species, 2011) and endemic and rare species are being mapped (Carriere, 2012). Thus, this assessment will focus on bird, mammal and bird species-at-risk richness, and vegetative (land cover) diversity surrogates as indicators of biodiversity.

The Global Biodiversity Outlook 3 (Convention on Biological Diversity, 2010) identifies five factors that threaten to reduce biodiversity: habitat loss, exploitation, pollution, invasive species, and climate change. The loss of biodiversity is linked to human urbanization, agriculture, fishing, and industrial activities (e.g., oil and gas development, exploration and mining development, and forestry), which have fragmented terrestrial environments (Expert Panel on Biodiversity Science, 2010). Habitat fragmentation poses the greatest threat to biodiversity worldwide (Noss and Cooperrider, 1994).

3.0 Biodiversity and Biodiversity Assessment

Biodiversity includes diversity at genetic, species, ecosystem and landscape biological levels of organization. Rowe (1993) has argued that to maintain biodiversity, a top down approach to conservation is necessary, starting with ecosystem-level diversity or eco-diversity. Other authors have argued that lower level genetic and species diversity in the biodiversity hierarchy are constrained by higher-level ecosystem and landscape diversity patterns (Gaines, et. al., 1999). Numerous researchers have attempted to assess biodiversity at different spatial and temporal scales (Caldecot, et. al., 1994; Kavanagh and Iacobelli, 1995; ; Zochler, 1998; The Natural History Museum, 2000). The different approaches used have been a reflection of the complexity of biodiversity assessment, the lack of complete information with which to assess biodiversity, and the spatial and temporal scales at which biodiversity analyses may be conducted. Individual species perceive and use their environment at different scales and ecosystem processes like nutrient and energy cycling may occur over larger areas.

Methods to measure diversity at the different organizational levels are described in detail by several authors (Krebs, 1978; Brown and Gibson, 1983; McGarigal and Marks, 1995; Gaines, et. al., 1999). Gaines and others (1999) have listed several methods to measure landscape-level diversity using geographical information systems (GIS).

Landscape ecology assessment deals with analyzing landscape composition and configuration, as these factors affect diversity (McGarigal and Marks, 1995). Landscape composition, in the form of ecoregional vegetation mapping is being assessed by the GNWT (Groenewegen, 2011). A landscape may be defined as a unique association of ecosystems and the interactions that occur between them. Important attributes that affect species diversity within a landscape include core area, edge density, landscape area, interspersion and juxtaposition, and patch density, size and variability and depend on the species or ecosystem under study. Detailed descriptions of the landscape metrics may be found in the Fragstats and Patch Analyst GIS tool manuals (McGarigal and Marks, 1995; Carr, et. al., 1999).

Ecosystem diversity operates on a community scale and includes the variation in ecosystems based on unique living and non-living associations. Several ecosystem classification systems have been developed to describe these unique associations in different regions of the world. In the Northwest Territories, ecosystems have been classified at four different levels, ecoregion levels I-IV (Ecosystem Classification Group, 2008 and 2010).

Species diversity has been assessed using measures of species richness, or the total number of different species in a given area. Species richness may be calculated for a given region using ArcGIS's Spatial Analyst extension by adding species range maps together with the Map Calculator (ESRI, 2000). Shannon and Simpson diversity and evenness indices incorporate an assessment of the number of species and their evenness (Krebs, 1978). These indices have been criticised for their inability to consider species composition, or which species are found in a particular area; however, they do provide a useful measure of species diversity. Fragstats is a GIS tool that calculates these and other indices and, in the case of satellite imagery data, provides a list of land cover types within a given landscape unit (ecoregion). Land cover mapping, broken down by ecoregion, is currently being completed by the GNWT so this will not be included in this report (Groenewegen, 2011).

Genetic diversity refers to the genetic make-up of individuals within species populations and meta-populations. Gaines and others (1999) describe methods used to assess diversity at the genetic level. Detailed information at this fine scale is limited in availability, thus, it will not be incorporated into this report. Currently, there is an on-going biomonitoring 2.0 project that is collecting samples at the genetic level (Rosolen, 2012) in the Fort Smith region.

In addition to the previously defined levels of biodiversity, some bird species operate on a continental level, breeding in North America, staging in other areas and migrating to Central and South American wintering sites. This level of diversity may be called hemispheric or inter-continental biodiversity. Although this is a critical component to address for migratory bird conservation, it is beyond the scope of this report.

3.1 Scale of Biodiversity Assessment

On a global scale, biodiversity is highest in equatorial regions and declines with increasing latitude. A report assessed biodiversity at a global level using a variety of biodiversity indicators (Groombridge and Jenkins, 2002). Global assessments are important to identify large, biodiversity hot spots; however, national and regional efforts are required to address biodiversity over smaller areas.

A biodiversity assessment for conservation in Canada identified four priority locations in southern Canada through a national scale complementary analysis approach (Freemark, et. al., 1999). However, by conducting regional scale biodiversity assessments, areas not identified at the national level may also be prioritized for protection by provincial and territorial governments.

Important aspects of scale include grain and extent (McGarigal and Marks, 1995). Grain is the minimum resolution of the data. It is important to consider grain size for the organism being studied as species respond differently to grain size based upon their perceptual abilities (Mcgarigal and Marks, 1995). For example, birds of prey may be sensitive to a coarser grain size than an insect. Extent refers to the overall size of the landscape unit and is delimited by the landscape or study area boundary. The extent and grain size are limited by the data used, which have implications for biodiversity assessments. As such, biodiversity assessments need to be conducted on a variety of spatial scales to accommodate species whose habitat requirements are perceived from micro to macro scales.

Satellite imagery has a variety of spatial resolutions and more data are becoming freely available in Canada as time passes. Currently, LANDSAT 7 enhanced thematic mapper images (with a 25 metre spatial resolution) have been classified for forested areas of Canada (Wulder, et.al., 2004). Prior to this new development, the Global Land Cover 2000 project classified 1 kilometre spatial resolution imagery from the French SPOT satellite (European Commission, 2000). With the freely available satellite imagery, biodiversity assessment in Canada is now possible at a variety of spatial scales at low cost. Historical to present-day LANDSAT satellite imagery is available on-line at the USGS GLOVIS site (http://glovis.usgs.gov/).

3.2 Ecological Factors Affecting Biodiversity Trends

Several well-established diversity trends have been observed including those based upon area, ecosystem isolation, latitude, elevation, vertical and horizontal habitat complexity and ecosystem productivity (Bernhardt, undated; Brown and Gibson, 1983; Krebs, 1978).

3.2.1 Island Biogeography Theory

The equilibrium theory of island biogeography, as proposed by MacArthur and Wilson (1967) has illuminated three general relationships regarding species diversity on islands as follows:

- The area–species relationship predicts larger islands will have more species than smaller islands up to a point.
- The distance–species relationship, predicts islands further from the mainland will have fewer species.
- The immigration-emigration equilibrium is a determining factor in island species richness based upon an equilibrium between immigration and emigration/extinction.

This theory has been extended to include habitat “islands” surrounded by developed areas (Coila, 2009).

3.2.2 Area and Species Richness

According to biogeographical theory, larger areas are predicted to contain more species up to a point (Shafer, 1990). As Bernhardt (undated) points out, this could be a function of habitat diversity, with larger areas containing higher habitat variety, sampling effects, or due to a balance between immigration and emigration as suggested by the theory of island biogeography.

3.2.3 Edge Effects

It has long been thought that species diversity was higher in edge habitats (i.e. those areas where two or more differing adjacent habitat types meet) or transitional areas between ecosystems (i.e. ecotones). These areas contain species that specialize in edge habitats and those from adjacent habitats, which may result in higher diversity in edge areas due to more complex spatial variety; however, some species require core areas in a habitat's interior that are away from edges.

Species respond to edge habitats differently. Numerous studies on birds show differing responses. For example, many forest-nesting neotropical migrant birds require interior habitats, away from edge habitats, while other species such as parasitic Brown-headed Cowbirds, exploit edge areas (Temple, 1986 in McGarigal and Marks, 1995). Thus, when analyzing the effects of edges on diversity it is important to consider the species and context involved. For example, Canada Warbler, Northern Waterthrush, Ovenbird, Hermit Thrush and Hairy Woodpecker are forest interior nesting species.

3.2.4 Polar versus Equatorial Regions

Biodiversity is highest at the equator and decreases as latitude increases (Kimmins, 1996). Arctic regions, such as the Northwest Territories, have lower productivity, harsher and more variable climates, more recent catastrophic disturbances (i.e. glaciation), and less complex ecosystems when compared to equatorial regions. In the last ice age portions of the NWT were ice-free and served as refugia for some species. These areas have different species compositions and there are endemic plant species in these areas (Northwest Territories Protected Areas Strategy, 2009).

3.2.5 Elevation Gradients

High elevations are also associated with lower diversity. A 1000 metre increase in elevation results in an average 6º C drop in temperature, which is the equivalent of 500 to 750 kilometre of movement towards the pole (Bernhardt, undated). Harsher climate and glacial influences at higher elevations are the main reasons for decreased biodiversity, especially so in barren and ice-covered Arctic regions. Varied topography, with different elevations, in general, lead to increased diversity as a variety of habitats occur in close proximity to one another over relatively short distances. As Johnson, et.al

(2003) point out, "Topographic complexity is positively related to species diversity in many ecological communities (MacArthur & MacArthur 1961; McCormick 1994; Kostylev 1996; Petren & Case 1998)."

3.2.6 Habitat Complexity

Increases in habitat complexity lead to increased biodiversity, as there are greater resources for potential species to exploit. Theoretically, habitats that are not subjected to catastrophic disturbances have evolved over a longer period of time. Arctic regions like the NWT have been subjected to recent glaciations, which have limited their ability to increase in complexity. Habitat complexity is greater in areas where both vertical and horizontal vegetative structures and species are varied.

Ecological theory suggests that areas having high vertical heterogeneity (variety) will provide a greater number of niches for species to fill than those that are structurally less complex (Krebs, 1978). For example, forested ecosystems, which contain a variety of tree, shrub and herb layers, should be more diverse than lichen/rock tundra ecosystems. Horizontal habitat diversity, called spatial heterogeneity, also will lead to an increase in species diversity. Regions that have several different habitat types adjacent to one another may have a higher number of species because there are a greater number of niches to fill in adjacent habitats.

3.2.7 Ecosystem Productivity

Nutrient deficient soils, cold temperatures and a shortage of water limit terrestrial plant productivity in the Arctic tundra regions of the NWT. Ecosystems that have low plant productivity are predicted to have lower diversity. Thus, terrestrial Arctic regions, although they have high productivity in summer months have low productivity at other times of the year. This is related to the cold temperatures in arctic regions. In addition to limiting productivity on an annual basis, cold temperatures slow down nutrient cycling processes and limit potential tree and shrub growth as well as soil development (AMAP, 1997). This results in less complex ecosystems with correspondingly less biodiversity.

3.2.8 Climate Change

Natural Resources Canada (2007) discussed the impact of climate change on biodiversity as follows:

> *"Climate change is expected to affect Arctic biodiversity through changes in the distribution of ranges and habitats of species, the abundance of species, the genetic diversity and behaviour of migratory species, and the introduction of non-native species (Usher et al., 2005)".*

4.0 Methodology

Included in this analysis is an assessment of bird species richness or an indication of how many birds are present in different parts of the Northwest Territories. Typically, there are more bird species present in areas with high habitat diversity as there are more niches for them to occupy. A correlation was found between vertical foliage diversity and bird diversity (Abbott, 1976 in Doherty, et. al., 2000) and the vertical distribution of birds was observed by Dickson and Noble (1978).

Range maps for NWT bird species were obtained from the Canadian Wildlife Service (2010) and Ridgley, et. al. (2007). Bird species richness was assessed by adding together range maps for 236 of 241 regularly occurring bird species of the NWT in ArcGIS using the Spatial Analyst extension to arrive at a sum of species across the territory. This map of bird species richness was then grouped into 10 categories containing approximately 18 species per class to arrive at a bird diversity index map for the whole NWT to show broad trends in bird diversity. A drawback of species richness assessments is that they do not identify areas where species-at-risk are located.

Thus, an analysis of bird species-at-risk was completed to see how these species are distributed across the Northwest Territories. Range maps of 47 species of birds considered to be **at risk, may be at risk** and **sensitive** (Working Group on General Status of NWT Species, 2011) were added together in ArcGIS to arrive at a bird species-at-risk diversity index map. This map was created to see if trends in species-at-risk were different from the bird diversity index map.

Another surrogate used to measure biodiversity was mammal species richness for the mainland ecoregions of the NWT. Mammal range maps were created from Microsoft Excel tables (Chowns, et. al., 2011) with relative mammal species abundance (ranging from 0 to 5) in each level IV ecoregion (Ecosystem Classification Group, 2008 and 2010). They were then converted to Dbase files for use in ArcView GIS software. Finally, the Dbase files were joined to an ecological land classification shapefile for visual display in map form in ArcView. These were then converted to raster layers with occurrences either present (a value of 1) or absent (a value of 0) in ArcGIS. Finally, the maps for 73 mammal species and sub-species were added together and grouped into 10 classes to arrive at a mammal species diversity index map.

Mammal relative abundance ranged from 0 (absent) to 5 (abundant). The relative abundance codes for all mammals were added together and grouped into 10 groups to arrive at a mammal productivity map, another measure of diversity. This map represents areas that have high productivity based on mammal abundances for each ecoregion.

Land cover diversity was assessed using satellite imagery to measure the variety of different land cover types (e.g. vegetation types, soil, water, rock) across the NWT. This surrogate indicator assesses the horizontal spatial variety of land cover classes at different scales. Land cover diversity was assessed using circular neighbourhood analyses of classified Landsat and SPOT satellite imagery. Classified Landsat imagery, with a 25 metre resolution, was obtained from the Earth Observation for Sustainable Development of Forests (EOSD) project that classified the land cover types for all forested regions across Canada (Wulder, et.al, 2004). This data was aggregated into half hectare areas by Government of the Northwest Territories Protected Areas Strategy staff (Gah, 2010). Thus, unforested areas of the NWT mainland in the northeast part of the territory were not assessed nor the Arctic Archipelago at this spatial resolution. The classified SPOT satellite imagery, at a 1 kilometre resolution, was downloaded from the Internet (European Commission, 2000). This classified imagery included the entire NWT.

5.0 Results

The bird diversity index map (Figure 1) shows those areas with the higher bird diversity in dark areas and lower diversity areas in lighter shades. These categories are based on approximately 18 bird species per category. Areas of high bird diversity appear to be correlated with complex habitats in forested areas (Figure 2). Specifically, the area in the south-central and south-west portions of the NWT consist of mixed forests that contain both deciduous and coniferous trees. Thus, these areas have structurally diverse habitats in both horizontal and vertical planes. Forested areas have a diverse vertical structure that may be composed of many layers (e.g. moss, herb, low shrub, tall shrub and tree canopy). Having mixed forests means that there is also higher diversity along a horizontal plane also as deciduous trees are inter-mixed

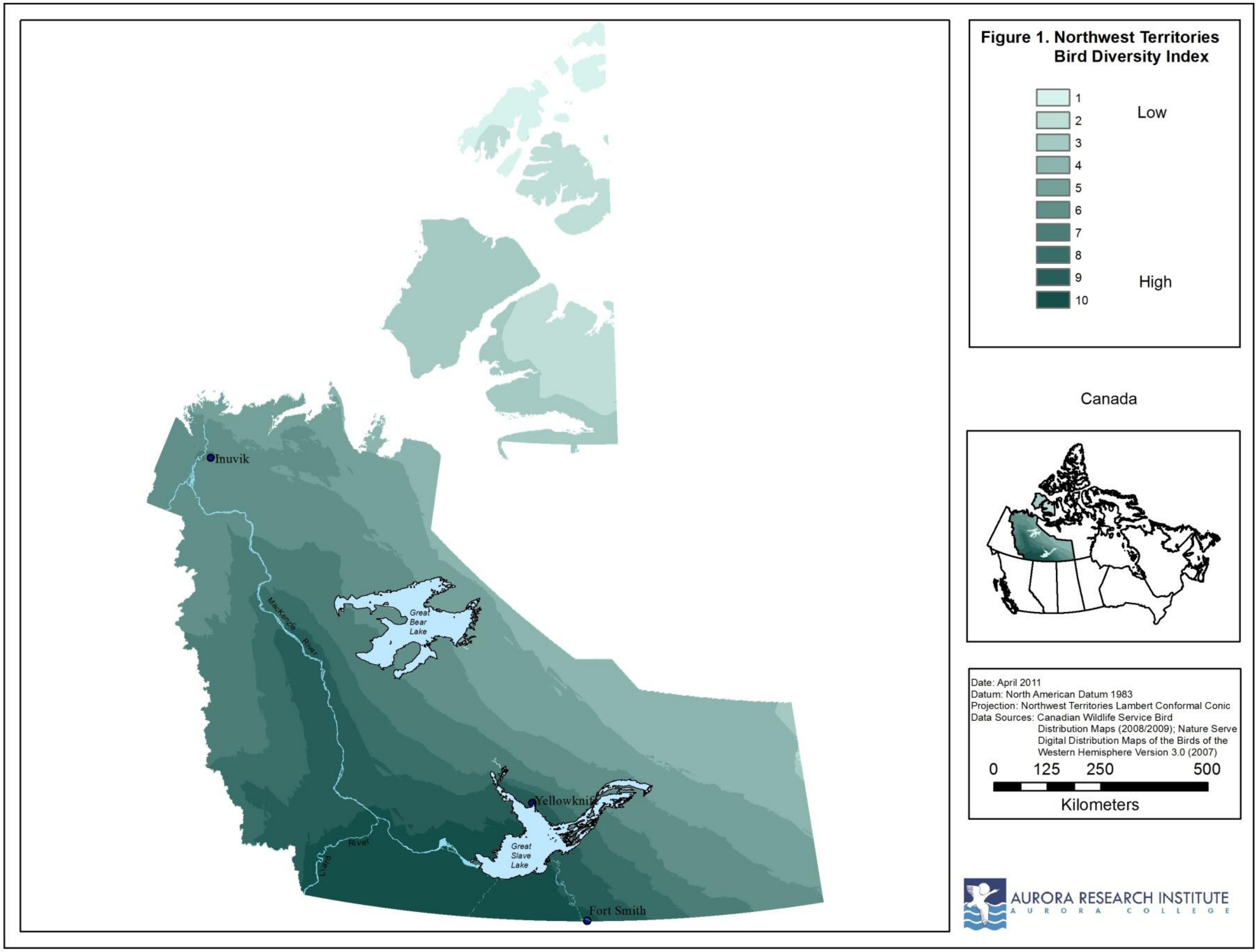
Figure 1. Northwest Territories Bird Diversity Index
1
2
3
4
5
6
7
8
9
10
Low
High
Inuvik
Great Bear Lake
Mackenzie River
Great Slave Lake
Yellowknife
Liard River
Fort Smith
Canada
Date: April 2011
Datum: North American Datum 1983
Projection: Northwest Territories Lambert Conformal Conic
Data Sources: Canadian Wildlife Service Bird Distribution Maps (2008/2009); Nature Serve Digital Distribution Maps of the Birds of the Western Hemisphere Version 3.0 (2007)
0 125 250 500
Kilometers
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AURORA COLLEGE

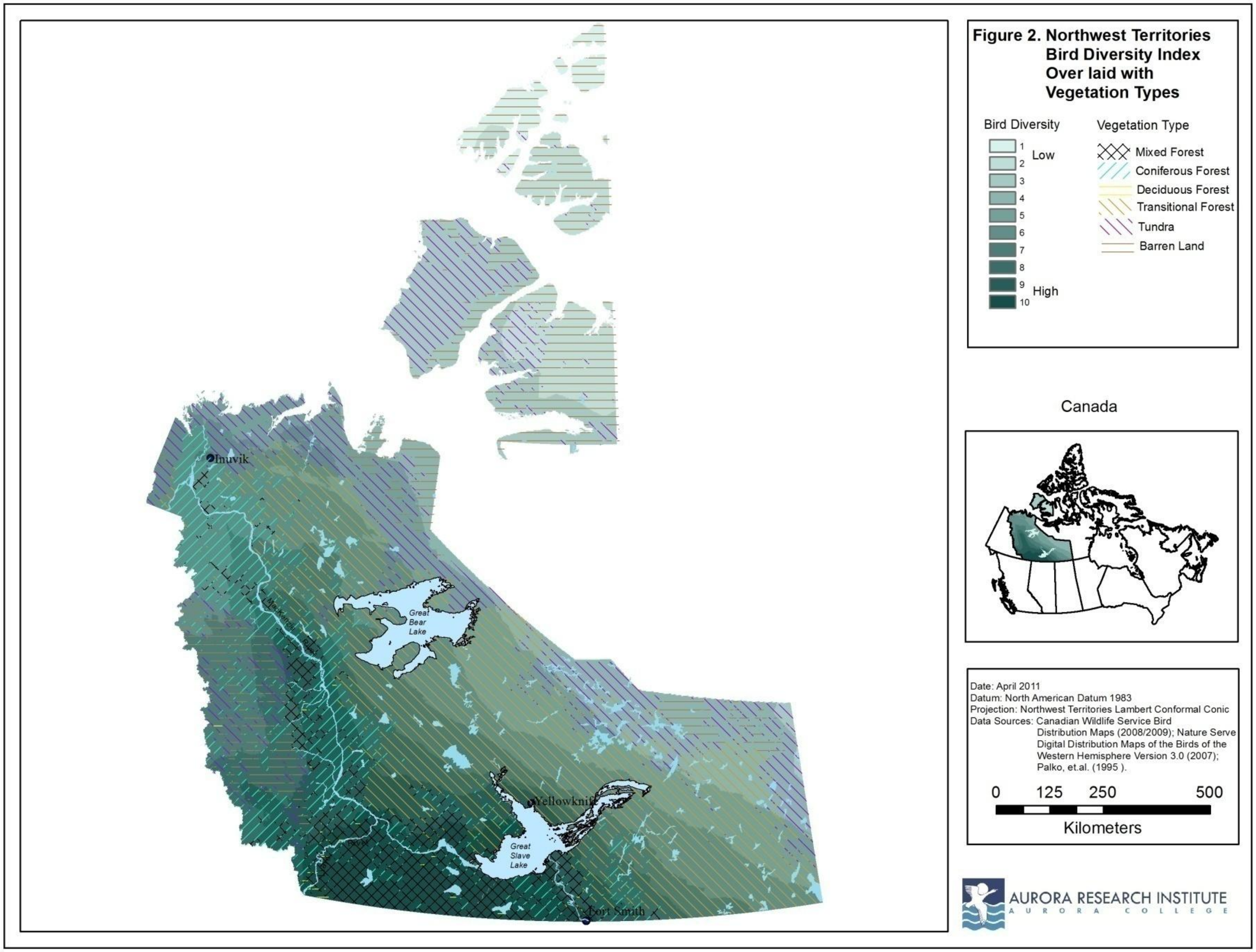
Figure 2. Northwest Territories
Bird Diversity Index
Over laid with
Vegetation Types
Bird Diversity
1 Low
2
3
4
5
6
7
8
9 High
10
Vegetation Type
Mixed Forest
Coniferous Forest
Deciduous Forest
Transitional Forest
Tundra
Barren Land
Canada
Date: April 2011
Datum: North American Datum 1983
Projection: Northwest Territories Lambert Conformal Conic
Data Sources: Canadian Wildlife Service Bird Distribution Maps (2008/2009); Nature Serve Digital Distribution Maps of the Birds of the Western Hemisphere Version 3.0 (2007); Palko, et.al. (1995).
0 125 250 500
Kilometers
AURORA RESEARCH INSTITUTE
AURORA COLLEGE
Inuvik
Great Bear Lake
Yellowknife
Great Slave Lake
Fort Smith

with coniferous trees. Forested areas are also located along the Slave, Liard and Mackenzie River corridors. Throughout the NWT, forested areas have more diverse habitats so more birds occur in these ecosystems.

A second analysis was conducted only for those species identified as **may be at risk**, **sensitive** and **at risk** categories as defined in *NWT Species 2011-2015: General Status Ranks of Wild Species in the Northwest Territories* (Working Group on General Status of NWT Species, 2011). Figure 3 shows bird species-at-risk diversity hotspots surrounding Great Slave Lake, in the southwest corner of NWT, an area surrounding the Fort Smith region, and two areas on the northern mainland (Mackenzie Delta and south of Tuktoyaktuk).

The mammal diversity index follows similar patterns as the bird diversity index map (Figure 4). Mammal diversity is highest north and west of Fort Smith, in the area around the western portion of Great Slave Lake, in the southwest portion of the NWT and along the Mackenzie and Liard River valley corridors. In general, these areas correspond with forested habitats. Moderately high diversity occurs in the Mackenzie Delta's riparian areas and in the mountains. Mountainous areas have greater habitat diversity over short distances due to changes in elevation, aspect and the resulting vegetation types. Riparian areas, which exist on the border of lakes and rivers, have higher diversity as they support both aquatic and land-based animals, are complex habitats and form an edge effect where there is higher diversity. The lowest diversity occurs in the barren land and tundra habitats along the eastern edge of the NWT.

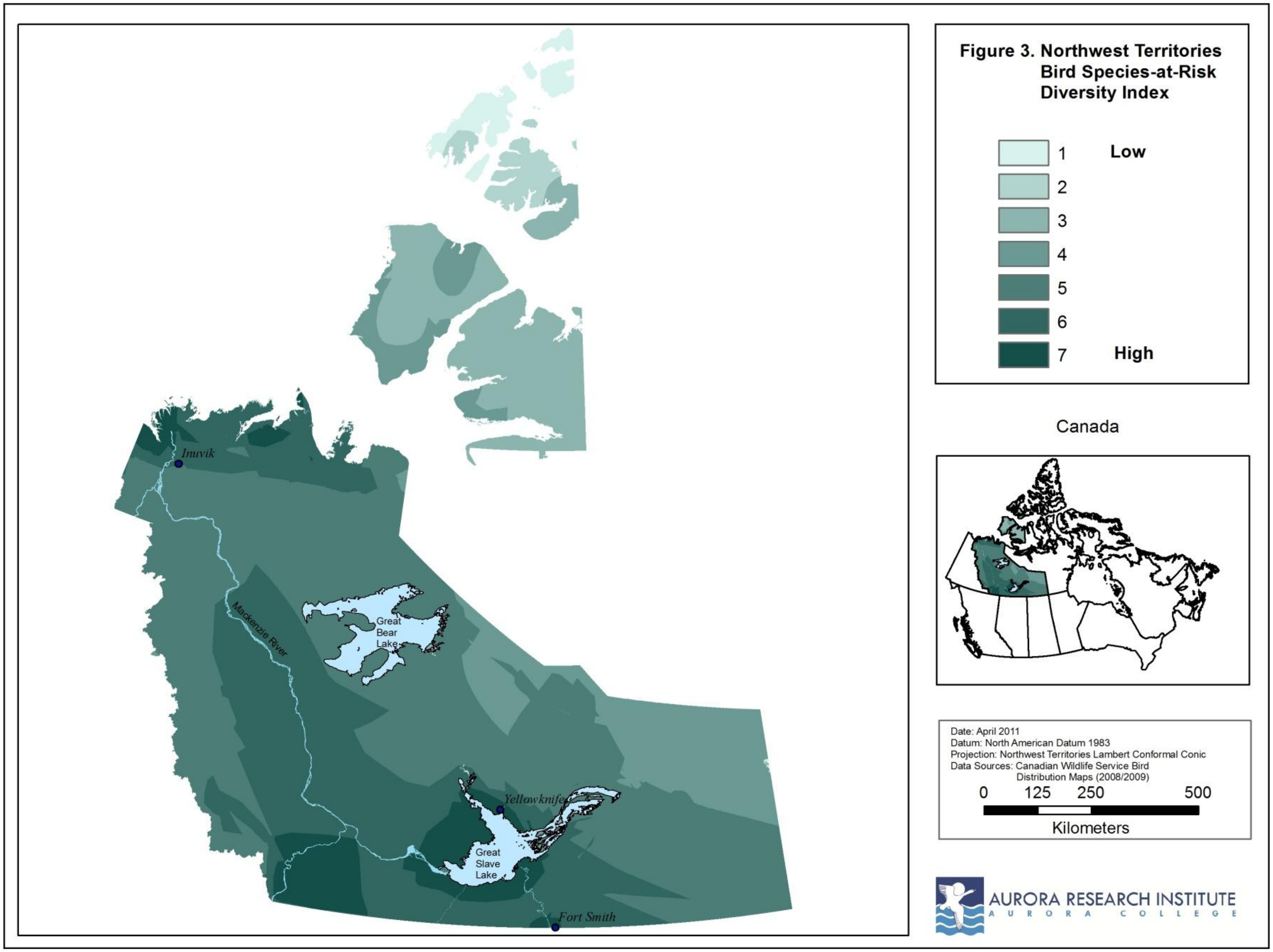

Figure 3. Northwest Territories Bird Species-at-Risk Diversity Index
1 Low
2
3
4
5
6
7 High
Inuvik
Mackenzie River
Great Bear Lake
Yellowknife
Great Slave Lake
Fort Smith
Canada
Date: April 2011
Datum: North American Datum 1983
Projection: Northwest Territories Lambert Conformal Conic
Data Sources: Canadian Wildlife Service Bird Distribution Maps (2008/2009)
0 125 250 500
Kilometers
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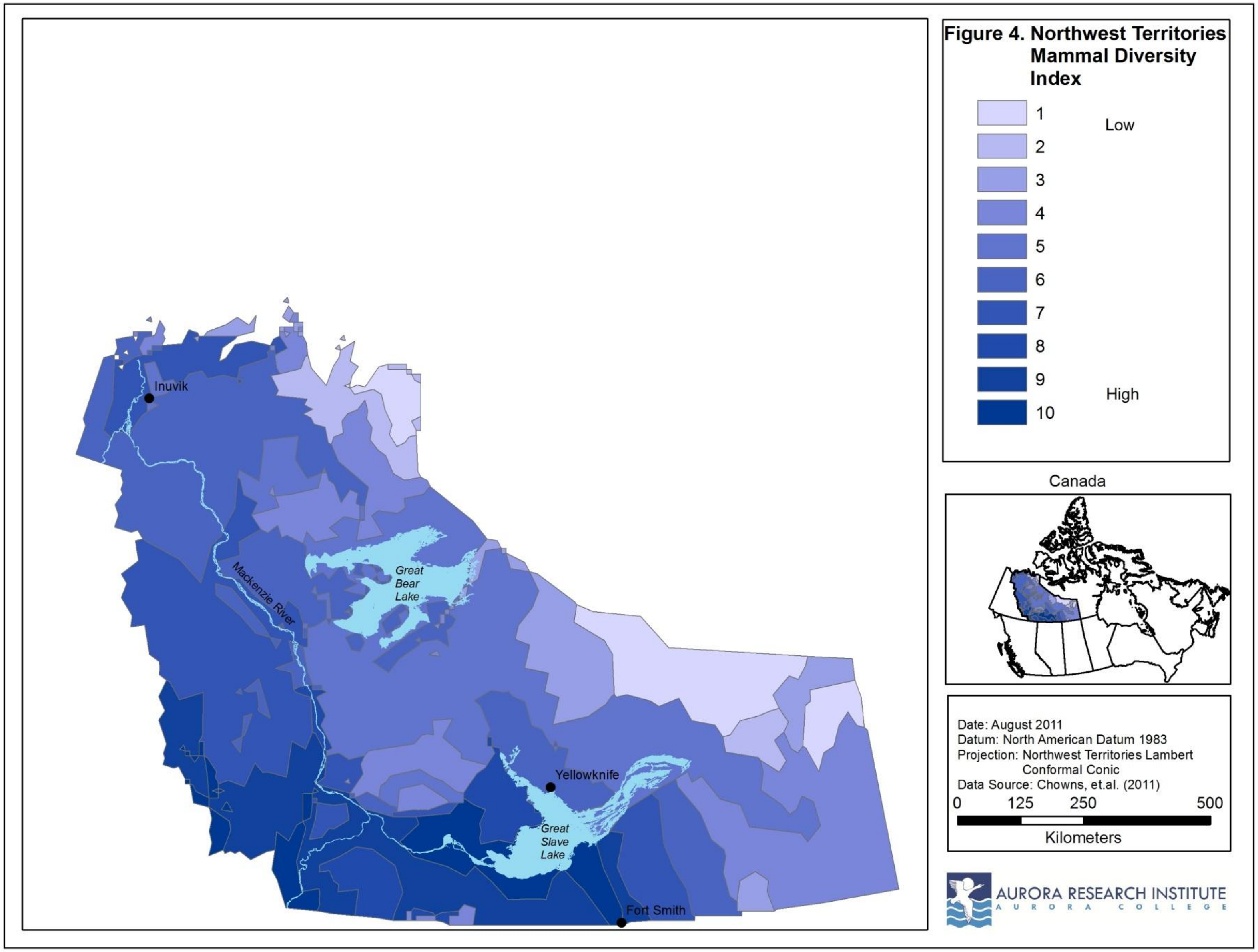

Figure 4. Northwest Territories Mammal Diversity Index

Mammal productivity follows patterns similar to other diversity values (Figure 5). There is highest productivity in the area north and west of Fort Smith along the Slave River valley, around the western edge of Great Slave Lake, in the southwest portion of the territory, and along the Mackenzie and Liard Rivers. There are moderate levels of productivity between Great Slave and Great Bear Lakes, east of Great Slave Lake and in the area around Inuvik.

Additional biodiversity surrogate indicators are shown in Figures 6 and 7. These maps, based on satellite imagery, show land cover diversity in the NWT at different scales. Land cover diversity was measured by assessing the number of different (or similar) pixels in different sized areas. Those areas that have many different land cover types have high diversity while those with the same land cover categories in an area have low diversity. This type of neighbourhood analysis was completed for the NWT to arrive at low, moderate and high land cover diversity index values.

The classified Landsat imagery used for the analysis covers only the NWT mainland with the exception of a few regions in the extreme northeast part of the mainland. To account for differing scales at which diversity operates, land cover diversity was assessed at a variety of scales. The smallest area analyzed used a circular neighbourhood radius of 75 metres around a central pixel for a total area of 150 metres surrounding the central pixel. Other scales included radius analyses of 250, 500, 1250 metres using Landsat satellite imagery re-sampled at a 25 metre spatial resolution.

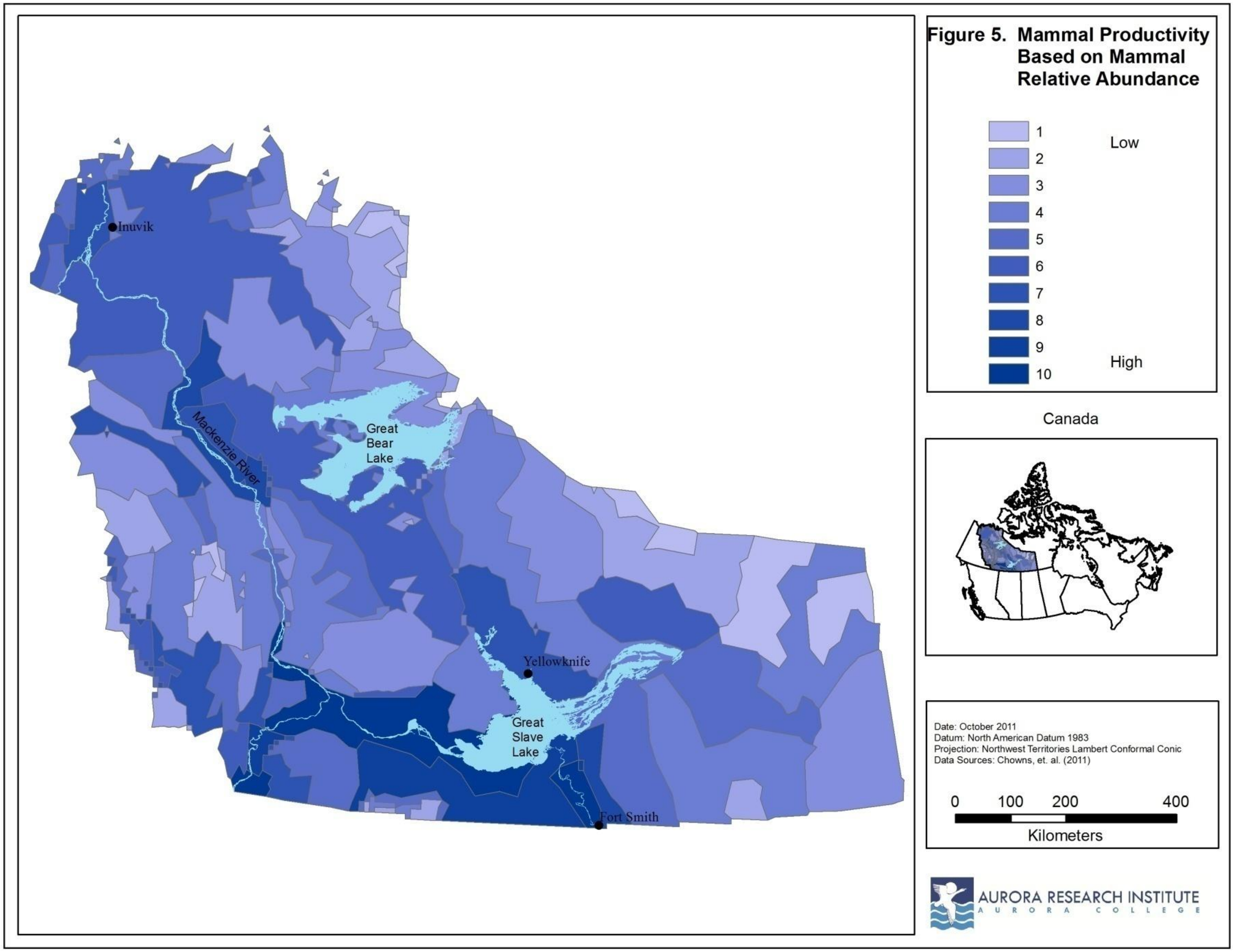

Figure 5. Mammal Productivity Based on Mammal Relative Abundance

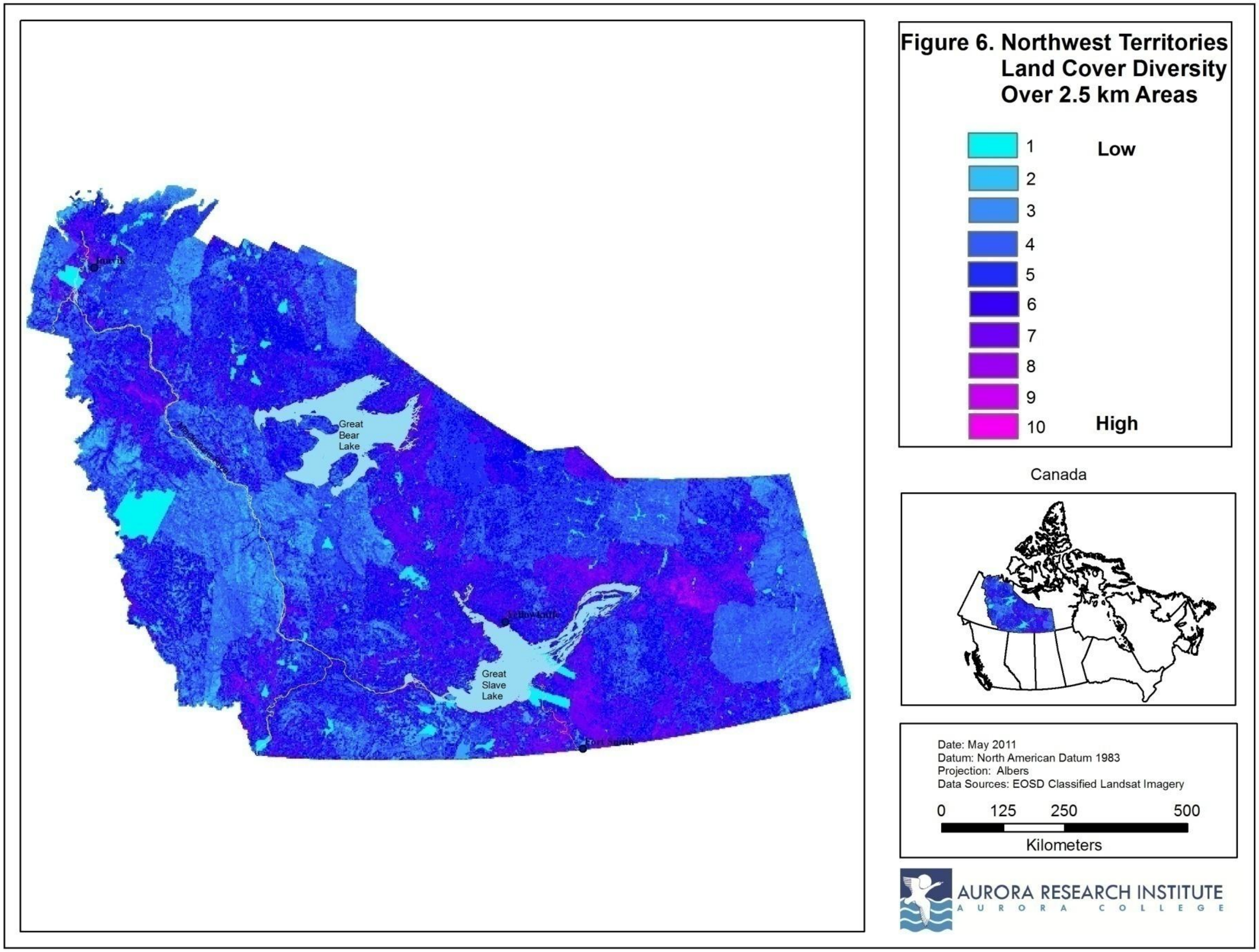

Figure 6. Northwest Territories Land Cover Diversity Over 2.5 km Areas

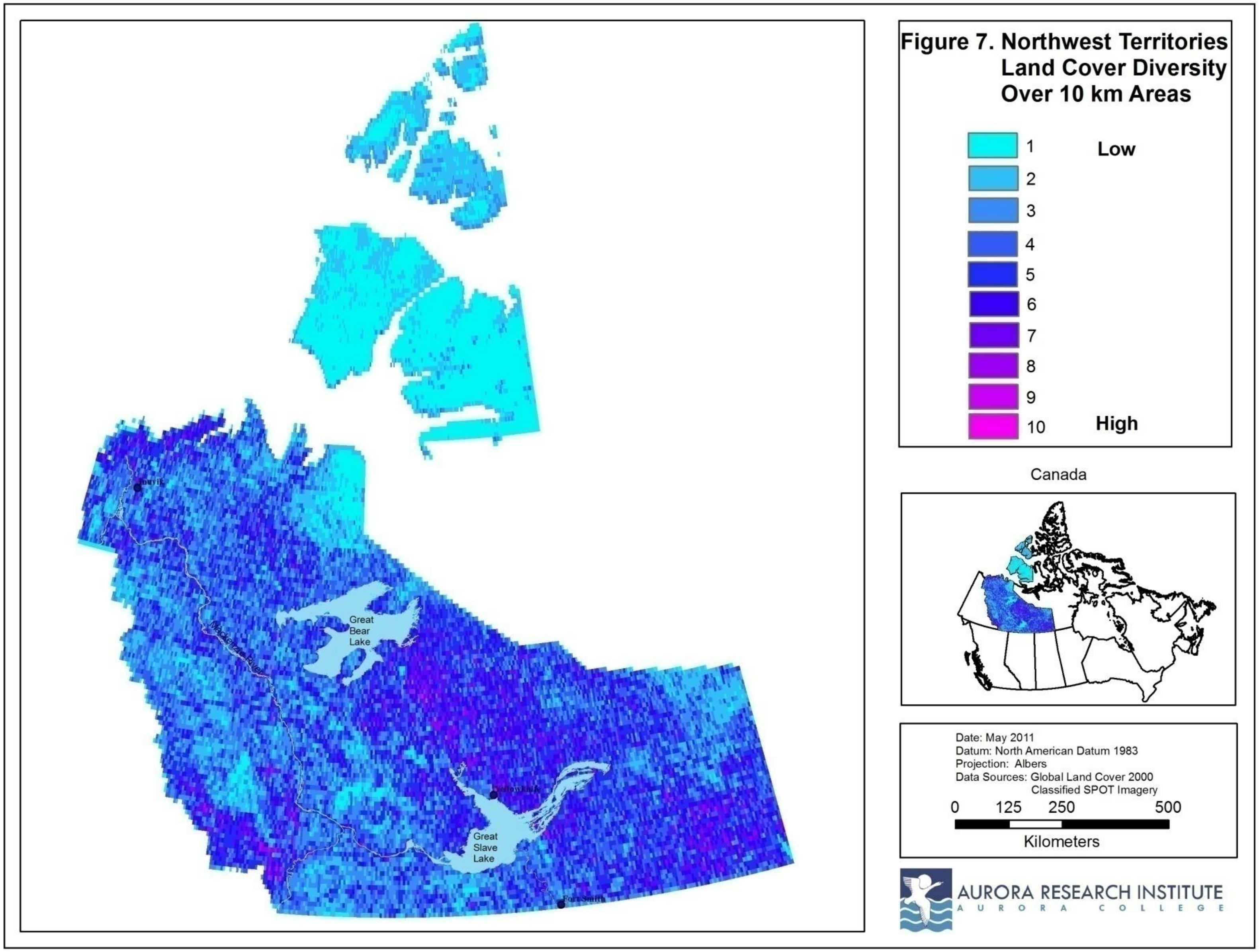

Figure 7. Northwest Territories
Land Cover Diversity
Over 10 km Areas
1
2
3
4
5
6
7
8
9
10
Low
High
Canada
Date: May 2011
Datum: North American Datum 1983
Projection: Albers
Data Sources: Global Land Cover 2000
Classified SPOT Imagery
0
125
250
500
Kilometers
Great
Bear
Lake
Great
Slave
Lake
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Of these analyses only the largest areas showed areas with low to high diversity (Figures 6 and 7). Diversity is known to increase with the total area that is examined as there is more variety across the landscape in terms of moisture, nutrient levels, slope and aspect which vegetation types respond to differently (MacArthur and Wilson, 2001). The 2.5 kilometre area assessment shows high diversity (pink areas) at several locations across the territory including north and west of Fort Smith, east of Great Slave Lake, between Great Slave Lake and Great Bear Lake, in the southwest part of the NWT and in the Mackenzie Delta (Figure 6).

A larger area was used to assess land cover diversity factors described above. A map of the Global Land Cover 2000 satellite imagery is shown in Figure 8 depicting vegetation/land cover in the territory. Using SPOT satellite imagery with a 1 kilometre spatial resolution, neighbourhood analyses were completed using this data with 1, 3 and 5 kilometre radii and the only one that showed high to low diversity was the 10 kilometre area (Figure 7). At the 10 kilometre areas scale diversity appears highest near the Mackenzie Delta, in the southeast and southwest sections of the territory and between Great Slave and Great Bear Lakes.

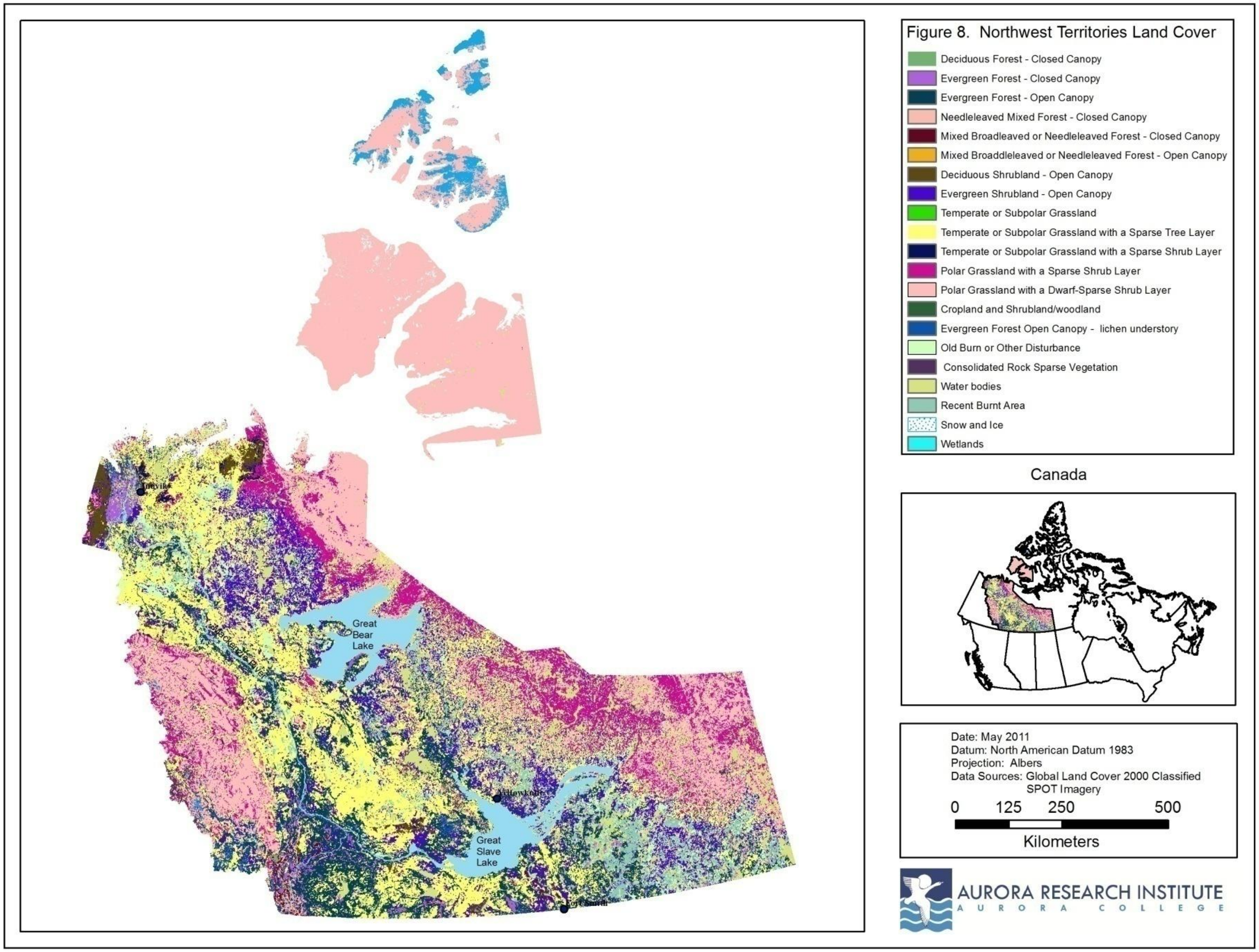

Figure 8. Northwest Territories Land Cover

6.0 Discussion and Conclusion

The southwest corner of the NWT has the highest diversity for bird species-at-risk diversity, bird diversity, and mammal diversity and productivity. The southwest area of the NWT also contains the largest patch of deciduous forest in the NWT.

Another area with high diversity is located north and west of Fort Smith, along the Slave River valley. Land cover, mammal, bird, bird species-at-risk diversity and mammal productivity are all high in this location, probably due to the mixed forest present in this area. As mentioned previously, mixed forests result in greater habitat diversity due to higher vertical and horizontal plant diversity and structure. Land cover diversity maps also show higher diversity east of Great Slave Lake, and between Great Slave Lake and Great Bear Lake.

Last, riparian areas along the Mackenzie, Liard and Slave Rivers, the Mackenzie Delta and the area around Great Slave Lake are diversity hotspots. As the British Columbia Ministry of Forests Research Program (1998) points out " . . . the ecological processes of riparian habitats must be sustained to maintain landscape-level biodiversity . . .". Riparian areas support higher diversity including higher plant diversity which results in higher wildlife diversity; provide nutrient inputs into aquatic ecosystems; moderate water temperatures; provide coarse woody debris (i.e. logs); and provide soil stabilization (British Columbia Ministry of Forests Research Program, 1998).

7.0 Recommendations

1. Areas with highest diversity should be compared with data from the NWT Protected Areas Strategy analyses to determine if the sites selected for park establishment and existing parks coincide with diversity hotspots.
2. Areas with the highest diversity should be considered in environmental planning processes for development or conservation initiatives; these locations in the NWT include:
   a. the Mackenzie, Slave and Liard River valley corridors.
   b. the southwest and south-central portion of the territory that consists of mixed wood forests.
   c. the Mackenzie Delta.

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