Some important points to be aware of when measuring and monitoring connectivity:

Landscape versus habitat connectivity, within-patch and between-patch connectivity, and the influence of changes in habitat amount

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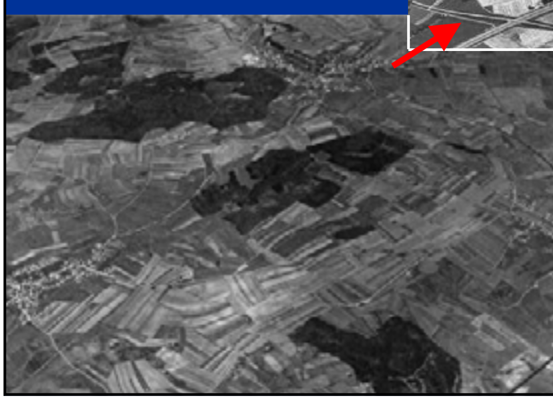
Canadian Maritimes Ecological Connectivity Forum, Dalhousie University

Halifax (NS), 24-25 April 2019

Landscape fragmentation…

1969



1988

…is a major threat to the sustainability of human land use, to biodiversity, and to many ecosystem services.

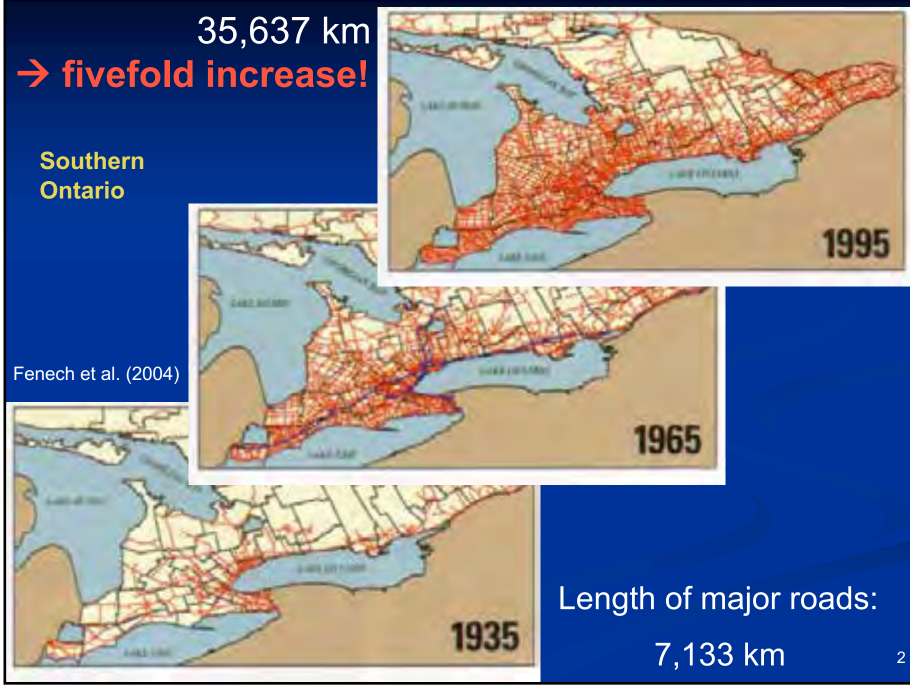
-> reduction in connectivity

Brugger (1992)

35,637 km

→ **fivefold increase!**

Southern Ontario



Fenech et al. (2004)

Length of major roads:

7,133 km

Why monitor ecological connectivity?

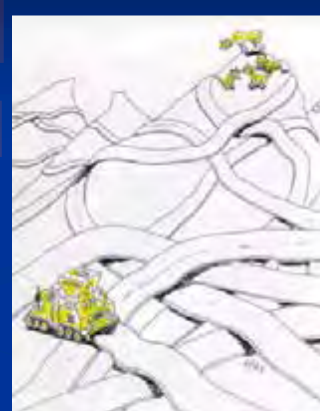
- to document the changes
  - pace of landscape change, changes in trends
    - → e.g., as an indicator of environmental quality
- to assist in the planing of new roads and railways
- to reveal relationships with the presence and abundance of species
  - and discover thresholds
- to compare and balance new construction projects and mitigation measures
  - and compare scenarios
- to introduce quantitative environmental quality standards
  - objectives and limits

Need for indicators for environmental reporting on the state of ecosystems

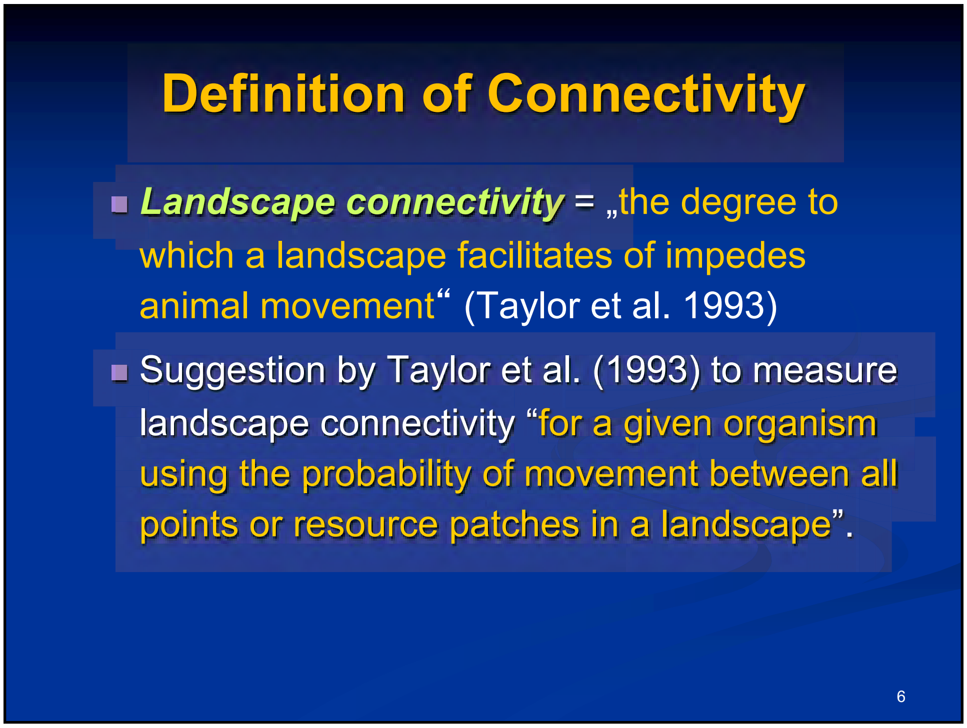
4

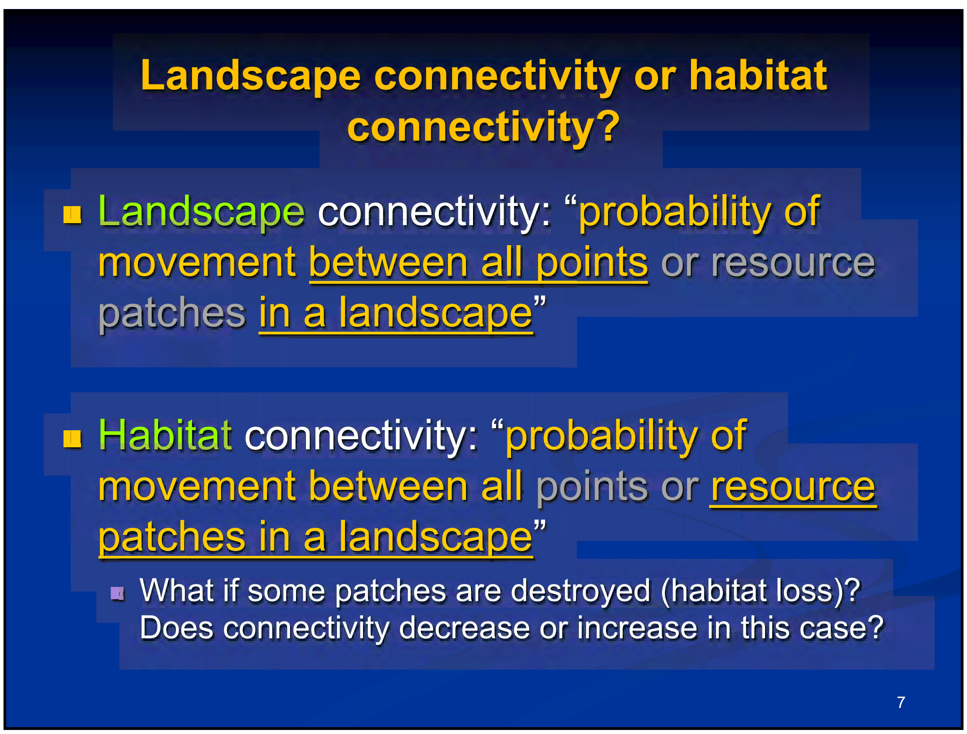
Outline

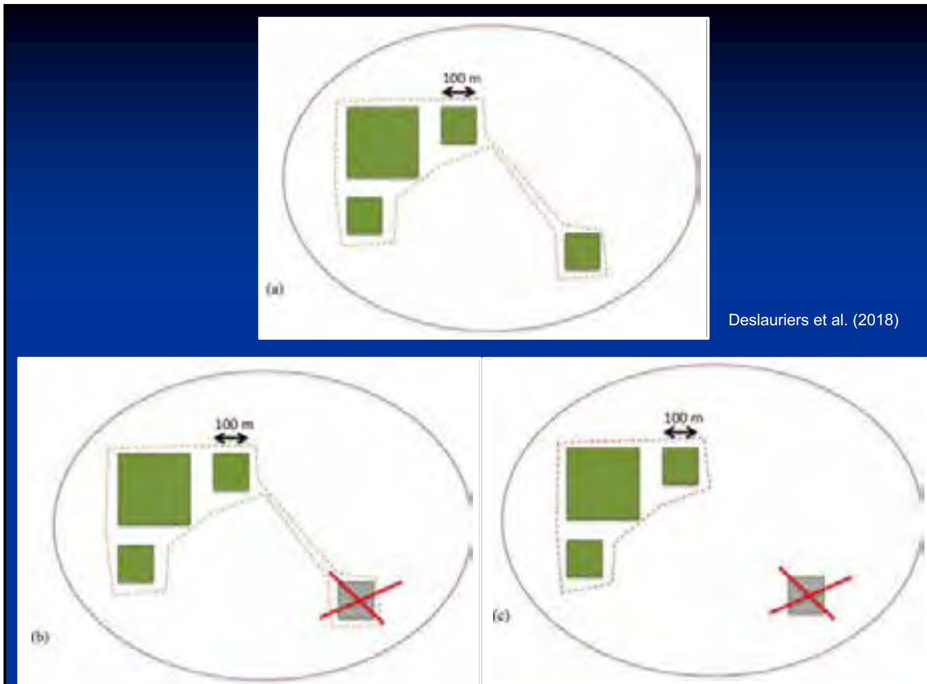
- Important points to take into account
  - Landscape connectivity or habitat connectivity?
  - Within-patch and between-patch connectivity
  - Influence of changes in habitat amount
- Example: Effective mesh size
  - Applications
    - Switzerland
    - Europe
    - Ontario
    - Canadian prairies
    - California
    - City Biodiversity Index
- Conclusions



5

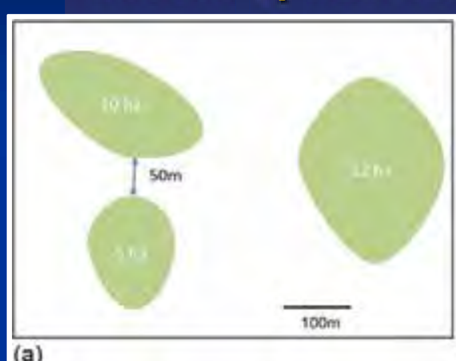

Definition of Connectivity
Landscape connectivity = „the degree to which a landscape facilitates of impedes animal movement“ (Taylor et al. 1993)
Suggestion by Taylor et al. (1993) to measure landscape connectivity “for a given organism using the probability of movement between all points or resource patches in a landscape”.
6


Landscape connectivity or habitat connectivity?
Landscape connectivity: “probability of movement between all points or resource patches in a landscape”
Habitat connectivity: “probability of movement between all points or resource patches in a landscape”
What if some patches are destroyed (habitat loss)? Does connectivity decrease or increase in this case?
7



Deslauriers et al. (2018)

Within-patch connectivity or between-patch connectivity or both?



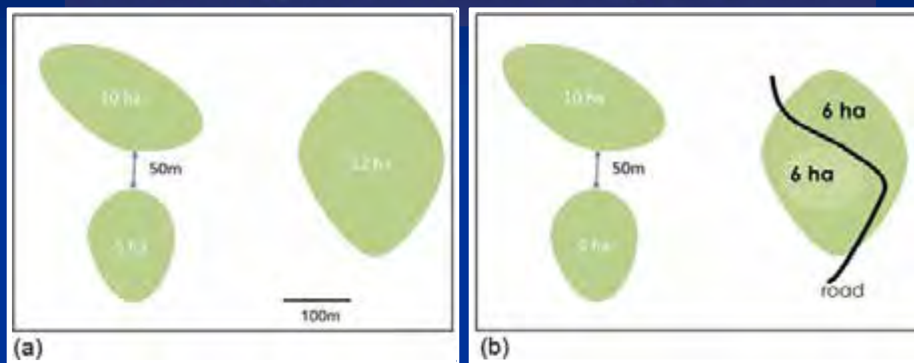
55 %

10ha +5ha) / (12ha+10ha+5ha)= 15ha / 27ha = 0.55 or 55%

Simple idea:

$$C = \frac{\text{Total area of natural areas that are connected } (\leq 100 \text{ m apart})}{\text{Total area of natural areas}}$$

Within-patch connectivity or between-patch connectivity or both?



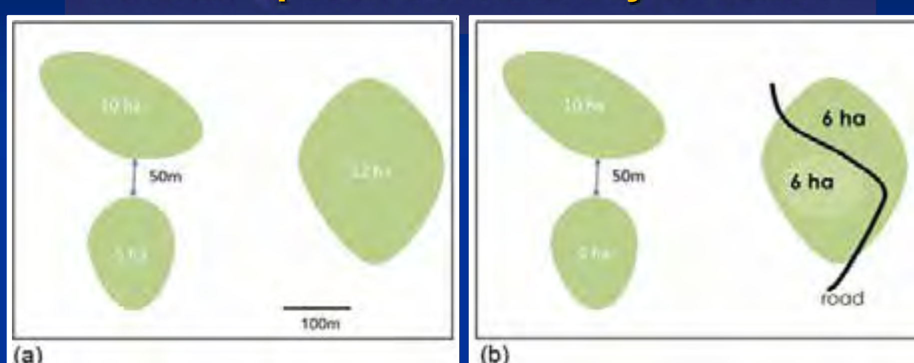
55 % 100 %

Simple idea:

$$C = \frac{\text{Total area of natural areas that are connected } (\leq 100 \text{ m apart})}{\text{Total area of natural areas}}$$

10

Within-patch connectivity or between-patch connectivity or both?



~~55 % 100 %~~

~~Simple idea:~~

~~$$C = \frac{\text{Total area of natural areas that are connected } (\leq 100 \text{ m apart})}{\text{Total area of natural areas}}$$~~

Within-patch connectivity needs to be included!

11

New method

- Based on Effective mesh size (Jaeger 2000)
  - => the probability that two points randomly chosen in a landscape are in the same patch or are considered connected (< 100 m between patches, no major barrier)
- Includes barriers and «intra-patch connectivity»

Original formula of m_{eff}

$$m_{eff} = \left(\left(\frac{A_1}{A_t}\right)^2 + \left(\frac{A_2}{A_t}\right)^2 + \left(\frac{A_3}{A_t}\right)^2 + \ldots + \left(\frac{A_n}{A_t}\right)^2 \right) \cdot A_t = \frac{1}{A_t} \cdot \sum_{i=1}^{n} A_i^2 ,$$

(Jaeger 2000)

where n is the number of patches,
A_i is the size of the i-th patch with $i = 1, \ldots, n$
and A_{total} is the total area of the landscape

Formula of m_{eff} for the CBI

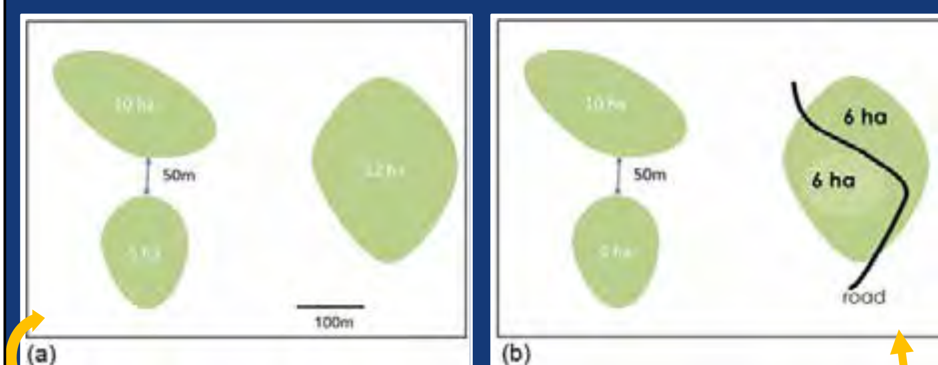
$$m_{eff} = \left(\left(\frac{A_1}{A_t}\right)^2 + \left(\frac{A_2}{A_t}\right)^2 + \left(\frac{A_3}{A_t}\right)^2 + \ldots + \left(\frac{A_n}{A_t}\right)^2\right) \cdot A_t = \frac{1}{A_t} \cdot \sum_{i=1}^{n} A_i^2 ,$$

(Jaeger 2000, Deslauriers et al. 2018)

where n is the number of groups of linked patches (< 100 m), A_i is the size of the i-th group of linked patches with $i = 1, \ldots, n$ and A_{total} is their total area

-> This is the connectivity of the natural areas rather than the connectivity of the landscape (given by the original formula)

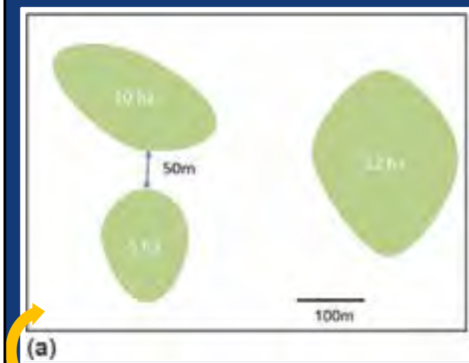
Example



$$IND2 = \frac{1}{A_{total}}\left(A_1^2 + A_2^2\right) = \frac{1}{27\text{ ha}}\left(15*15\text{ ha}^2 + 12*12\text{ ha}^2\right) = \frac{369}{27}\text{ ha} = 13.67\text{ ha}$$

$$IND2 = \frac{1}{27\text{ ha}}(15*15\text{ ha}^2 + 6*6\text{ ha}^2 + 6*6\text{ ha}^2) = \frac{297}{27}\text{ ha} = 11\text{ ha}$$

Example



within-patch connectivity:

$$\frac{125\ \text{ha}^2}{27\ \text{ha}} = 4.63\ \text{ha}$$

$$\frac{144\ \text{ha}^2}{27\ \text{ha}} = 5.33\ \text{ha}$$

between-patch connectivity:

$$\frac{100\ \text{ha}^2}{27\ \text{ha}} = 3.7\ \text{ha}$$

$$IND2 = \frac{1}{A_{total}}\left(A_1^2 + A_2^2\right) = \frac{1}{27\ \text{ha}}\left(15*15\ \text{ha}^2 + 12*12\ \text{ha}^2\right) = \frac{369}{27}\ \text{ha} = 13.67\ \text{ha}$$

$$\begin{aligned} 15*15\ \text{ha}^2 &= (10+5)*(10+5)\ \text{ha}^2 \\ &= (10*10 + 5*5)\ \text{ha}^2 + (10*5 + 5*10)\ \text{ha}^2 \\ &= 125\ \text{ha}^2 + 100\ \text{ha}^2 \end{aligned}$$

within-patch connectivity (125 ha²) — between-patch connectivity (100 ha²)

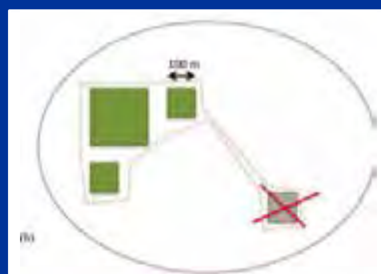
Influence of changes in habitat amount?

17

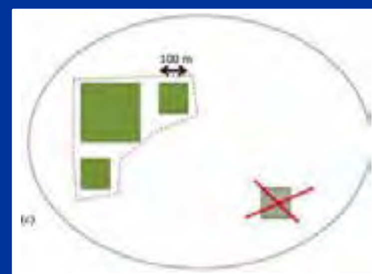
Deslauriers et al. (2018)

4 ha, 1 ha, 1 ha, 1ha

IND2 = 37 ha^2 / (7 ha) = 5.29 ha



IND2 = 36 ha^2 / (7 ha) = 5.14 ha



IND2 = 36 ha^2 / (6 ha) = 6 ha

18

PART II - Indicators

Core Components	Indicators	Maximum Score
Native Biodiversity in the City	1. Proportion of Natural Areas in the City	4 points
	2. Connectivity Measures	4 points
	3. Native Biodiversity in Built Up Areas (Bird Species)	4 points
	4. Change in Number of Vascular Plant Species	4 points
	5. Change in Number of Bird Species	4 points
	6. Change in Number of Butterfly Species	4 points
	7. Change in Number of Species (any other taxonomic group selected by the city)	4 points
	8. Change in Number of Species (any other taxonomic group selected by the city)	4 points
	9. Proportion of Protected Natural Areas	4 points
	10. Proportion of Invasive Alien Species	4 points
Ecosystem Services provided by Biodiversity	11. Regulation of Quantity of Water	4 points
	12. Climate Regulation: Carbon Storage and Cooling Effect of Vegetation	4 points
	13. Recreation and Education: Area of Parks with Natural Areas	4 points
	14. Recreation and Education: Number of Formal Education Visits per Child Below 16 Years to Parks with Natural Areas per Year	4 points
Governance and Management of Biodiversity	15. Budget Allocated to Biodiversity	4 points
	16. Number of Biodiversity Projects Implemented by the City Annually	4 points
	17. Existence of Local Biodiversity Strategy and Action Plan	4 points
	18. Institutional Capacity: Number of Biodiversity Related Functions	4 points
	19. Institutional Capacity: Number of City or Local Government Agencies Involved in Inter-agency Co-operation Pertaining to Biodiversity Matters	4 points
	20. Participation and Partnership: Existence of Formal or Informal Public Consultation Process	4 points
	21. Participation and Partnership: Number of Agencies/Private Companies/NGOs/Academic Institutions/International Organisations with which the City is Partnering in Biodiversity Activities, Projects and Programmes	4 points
	22. Education and Awareness: Is Biodiversity or Nature Awareness Included in the School Curriculum	4 points
	23. Education and Awareness: Number of Outreach or Public Awareness Events Held in the City per Year	4 points
	Native Biodiversity in the City (Sub-total for indicators 1-10)	**40 points**
	Ecosystem Services provided by Biodiversity (Sub-total for indicators 11-14)	**16 points**
	Governance and Management of Biodiversity (Sub-total for indicators 15-23)	**36 points**
	Maximum Total:	**92 points**

Ecological Indicators 94 (2018) 99 113

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original article

Implementing the connectivity of natural areas in cities as an indicator in the City Biodiversity Index (CBI)

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ARTICLE INFO

Article history:
Received 13 August 2016
Received in revised form 15 February 2017
Accepted 18 February 2017
Available online 22 March 2017

Keywords:
Connectivity
Connectors
Convention on Biological Diversity
Effective mesh size
Green infrastructure
Landscape fragmentation
Landscape metrics
Planning scenarios
Singapore Index
Urban ecology
Urban biodiversity
Wildlife corridors

ABSTRACT

The City Biodiversity Index (CBI), or Singapore Index on Cities Biodiversity, serves as a tool to monitor biodiversity in cities and was endorsed by the Convention on Biological Diversity in 2009. Indicator 2 of the CBI measures the connectivity of natural areas in cities. We propose an improved and straightfor ward method for measuring connectivity based on the effective mesh size metric to replace the previous method used in the CBI. The previous version did not account for intra patch (within patch) connectiv ity nor for major barriers. Our evaluation of the new version of Indicator 2 through its application to Montr al and Lisbon con rmed its reliability. In Montr al, natural areas have a total connectivity value of 581.7 ha, the majority of which exists between, rather than within, patches of natural area. Smaller patches (<15 ha) contribute signi cantly to overall connectivity, which may have implications for future conservation efforts. In Lisbon, connectivity (342 ha) is concentrated within patches. We also applied the improved Indicator 2 to a case study in southwestern Montr al, where a greenway network (green infrastructure) has been proposed by a local community organization. We assessed the contribution of Meadowbrook Golf Course to connectivity in scenarios of the proposed greenway network and the effect that residential development would have. Not only would this development eliminate the golf course s current contribution to connectivity, but also its much greater potential contribution to connectivity in future scenarios. Restoring and establishing additional natural areas would signi cantly increase con nectivity in the network. Our results demonstrate that the improved version of Indicator 2 is a suitable method in the CBI. It is equally useful for identifying options to increase the connectivity of natural areas within cities in the future and for determining the impacts of urban development on connectivity. More advanced methods for quantifying connectivity exist and may also be included in Part I of the CBI. How ever, they are often challenging to use and this frequently discourages city planners from including any indicator of connectivity in their biodiversity monitoring. The connectivity metric presented here over comes this problem through its practicality in a wide range of planning structures while still generating meaningful results which may then inspire city planners to move towards using more advanced methods of measuring connectivity. We dedicate this paper to the memory of Bernice Goldsmith (1934 2014).

1. Monitoring biodiversity in cities

Urban wildlife populations are negatively affected by habitat fragmentation, which limits access to resources and mating part ners. This may result in the loss of genetic diversity and in higher rates of extinction, in particular among groups of species with highly specialized habitat requirements (Brook et al., 2003; Di Giulio et al., 2009; Taylor et al., 1993; Tischendorf and Fahrig, 2000). The City Biodiversity Index (CBI), or Singapore Index on Cities Bio diversity, was developed as a tool to evaluate and monitor the state of biodiversity in cities and to provide insights for improving conservation efforts. It was proposed by the Minister of National Development in Singapore, Mr. Mah Bow Tan, at the 9th Meeting of the Conference of the Parties (COP 9) to the Convention on Bio logical Diversity (CBD) in May 2008. The CBI was established by the National Parks Board of Singapore and the Secretariat of the CBD in collaboration with the Global Partnership on Cities and Biodiver sity from 2009 to 2011 (Chan et al., 2014). The Index is comprised of 23 indicators (Table 1), characterized as native biodiversity in the city; ecosystem services provided by native biodiversity; and governance and management of native biodiversity (Chan et al., 2014; p. 4). Few studies have analyzed the CBI and its implementa

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https://doi.org/10.1016/j.ecolind.2017.02.028

Deslauriers et al. (2018)

21

Example of a metric that does not consider within-patch connectivity: *CONNECT*

$$CONNECT = C_i = \left[\frac{\sum_{j>k}^{n_i} c_{ijk}}{\frac{n_i(n_i-1)}{2}} \right] * 100\%$$

a.

CONNECT $= \left(\frac{5}{\frac{4(3)}{2}} \right) * 100 = 20.8\%$

$m_{eff} = \frac{1}{100 \text{ ha}} * (5 \text{ ha} + 5 \text{ ha} + 5 \text{ ha} + 25 \text{ ha})^2 = \frac{1600 \text{ ha}^2}{100 \text{ ha}} = 16 \text{ ha}$

b.

CONNECT $= \left(\frac{9}{\frac{5(4)}{2}} \right) * 100 = 22.5\%$

$m_{eff} = \frac{1}{100 \text{ ha}} * (5 \text{ ha} + 5 \text{ ha} + 5 \text{ ha} + 20 \text{ ha} + 3 \text{ ha})^2 = \frac{1444 \text{ ha}^2}{100 \text{ ha}} = 14.4 \text{ ha}$

Spanowicz & Jaeger (submitted)

Measuring landscape connectivity: On the importance of within-patch connectivity

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Spanowicz & Jaeger (submitted)

Comment on “Roadless Space of the Conterminous United States”

Evan H. Girvetz,[1,2]*† Jochen A. G. Jaeger,[1]‡ James H. Thorne[2]

Watts *et al*. (Reports, 6 May 2007, p. 736) introduced a metric of landscape pattern called roadless volume (RV). However, as with most previous metrics, RV does not explicitly address ecological processes. We demonstrate that RV can produce results inconsistent with the notion of landscape connectivity and contend that more ecologically relevant metrics are available.

A major research trend in landscape ecology is to identify relationships between metrics of landscape structure and ecological processes (*1*, *2*). Li and Wu (*3*) state that the proper use of landscape metrics should include addressing relations between observed landscape patterns and ecological processes. Dozens of landscape metrics have been proposed that are commonly used to quantify pattern and permit comparison across landscapes (*4*). However, they often fail to correlate with ecological processes (*5*). We are concerned that Watts *et al*. (*6*) have proposed another landscape metric—roadless volume (RV)—which may be useful for describing pattern but is problematic for use in analyzing landscape ecological processes. We recognize that the questions posed by the authors are “(i) how much space is there between the roads, and (ii) how much is lost as new roads are added to the network, penetrating roadless space?” (*6*). However, the authors explicitly set their questions in the context of using the metric to assess the effects of roads on ecological conditions, including the fragmentation of habitats. Although RV can be a quantification of remoteness or inaccessibility of areas in a landscape, it does not explicitly relate to any ecological process. In particular, we demonstrate that this metric can produce misleading results if applied to assess habitat fragmentation and landscape connectivity as related to ecological processes associated with species movement. We contend that better metrics are available.

Several landscape metrics have been proposed that explicitly incorporate ecological processes. These include the ecologically scaled landscape index average patch connectivity (*1*), which is the probability that a patch is colonized based on species-specific movement distances and the spatial configuration of habitat patches. This metric addresses a key ecological process impacted by roads, namely, the movement of individuals between habitat patches in the landscape. Another metric that explicitly incorporates this process is effective mesh size (m_{eff}), an expression of the probability that any two locations in the landscape are connected (i.e., not separated by barriers such as roads) (*7*, *8*). This metric can also be interpreted as the average size of the area that an animal placed randomly in the landscape would be able to access without crossing barriers.

Our main concern is that RV may produce misleading results if it is used to quantify habitat fragmentation and landscape connectivity as related to ecological processes associated with species movements. To illustrate this issue, we present two theoretical landscapes (Fig. 1) that have exactly the same length of roads but different fragmentation patterns. The landscape with one small and one large patch (left) is less fragmented and more connected than the landscape with four small patches (right) because there is a higher probability that two animals randomly located in that landscape can encounter each other without having to cross a barrier. However, the RV gives results counter to this, with the less connected four-patch landscape having an RV 12% higher than the more connected two-patch landscape (Fig. 1). This assessment is inconsistent with the notion of landscape connectivity. In contrast, the effective mesh size is 60% lower for the less connected landscape, which agrees with the intuitive understanding of landscape connectivity (*8*). This example shows that although RV may quantify remoteness from roads, its use in analyzing landscape ecological processes should be treated with caution and explicitly examined for its utility in quantifying the process of interest.

The ecological utility of the RV metric could be improved by more accurately modeling the “road-effect zone.” RV assumes that the ecological “value” of every point location increases linearly ad infinitum away from roads. However, recent reviews suggest that most road effects occur within 1000 m of roads and that the slope of the road effect levels off with increasing distance from a road (*9*). Thus, rather than using a linear model, the road-effect zone should be modeled with a diminishing curve (e.g., negative exponential), which can be thought of graphically as shaving off the tops of the pyramids in Fig. 1 at some distance.

Including this distance decay in the calculation of ecologically relevant landscape metrics is straightforward. For example, this can be accomplished for the effective mesh size by subtracting the area of road-effect zone from the size of the patches. In addition, a function specific to a particular species or ecological process can be applied to this calculation to model the diminishing effect of roads at further distances, as well as to incorporate the influence of traffic volume on the width of the road-effect zone, as has been done by Jaeger *et al*. (*10*). The positive effect of wildlife crossing structures on landscape connectivity can also be included in metrics of connectivity, whereas RV cannot address this issue.

The goal of using landscape metrics to assess landscape fragmentation is to gain insight into

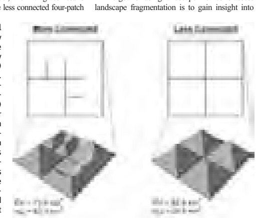

Fig. 1. Two theoretical landscapes fragmented by roads. The left landscape has higher connectivity (lower fragmentation) than the right landscape. However, the RV calculated for the less connected landscape (right) is higher than the RV for the other landscape, which is counterintuitive. In contrast, the effective mesh size (m_{eff}) gives results consistent with the notion of connectivity. RV is calculated as the volume beneath the pseudotopographic surface defined by distance to the nearest road following Watts *et al*. (*6*). Size of each landscape is 10 km × 10 km; width of the roads is 10 m.

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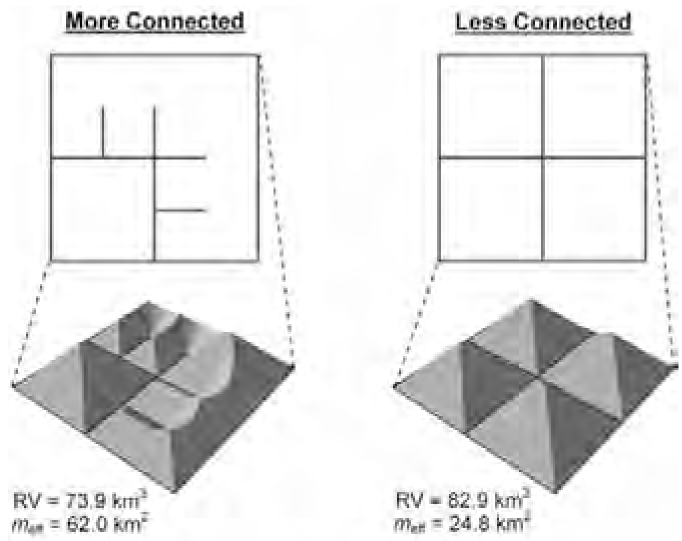
Girvetz et al. (2007)



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Girvetz et al. (2007)

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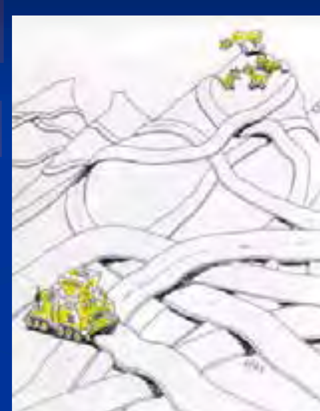
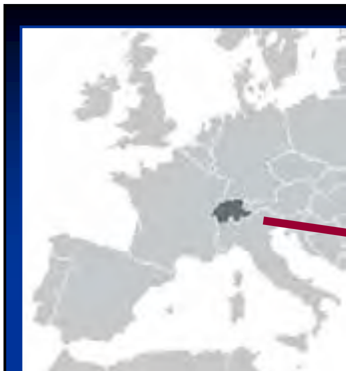
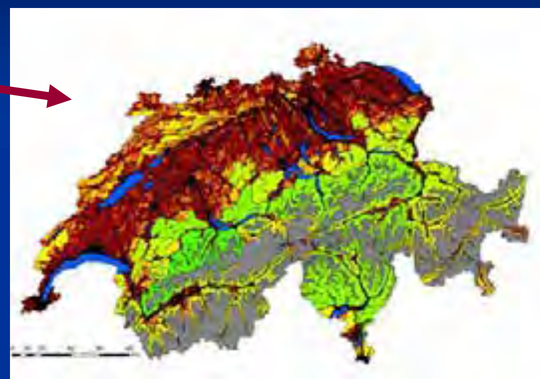




Switzerland

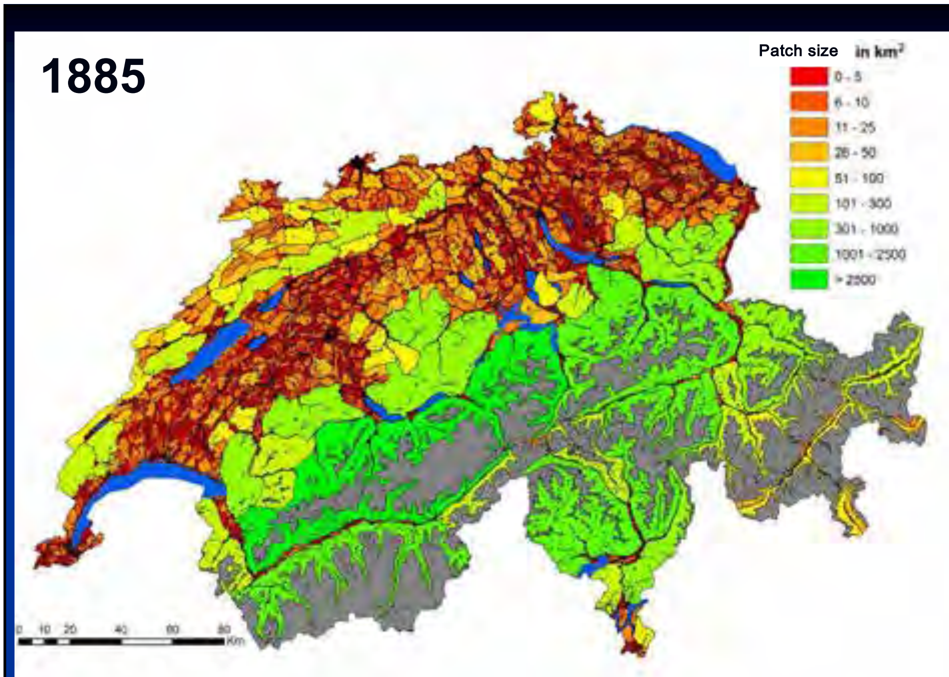


Landscape fragmentation in Switzerland
(Jaeger et al. 2007, etc.)

↓

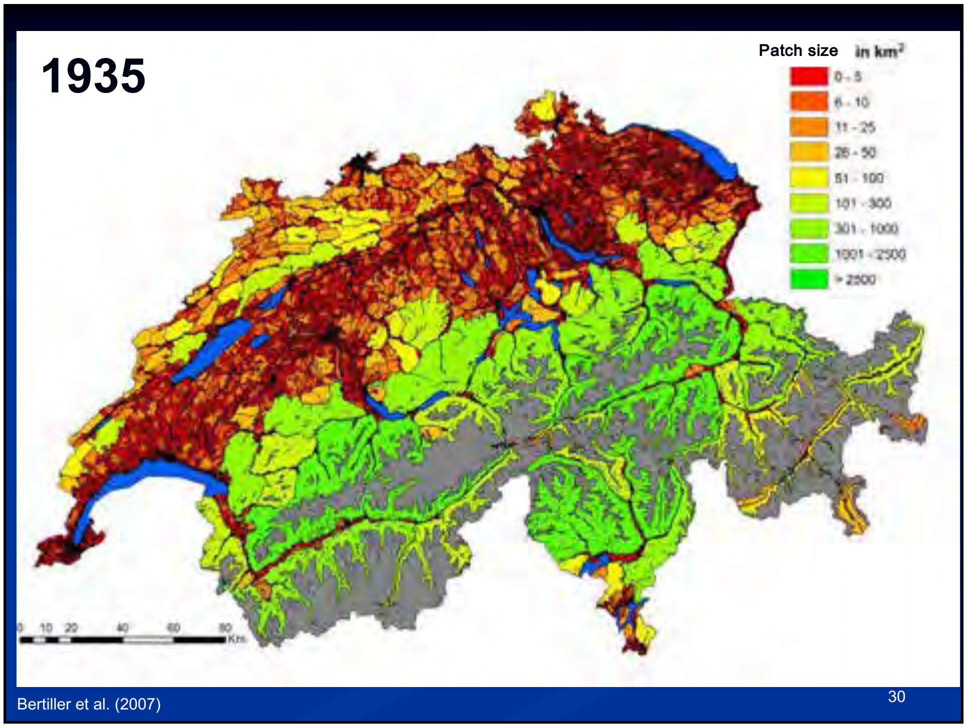
Landscape fragmentation in Europe
(EEA & FOEN 2011)

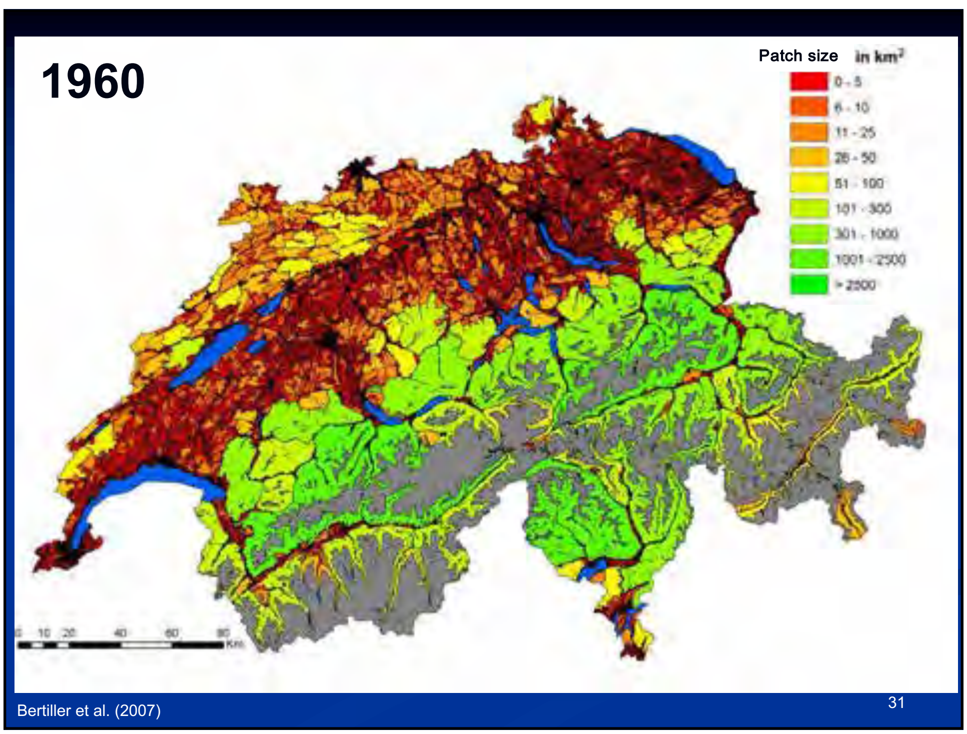
28



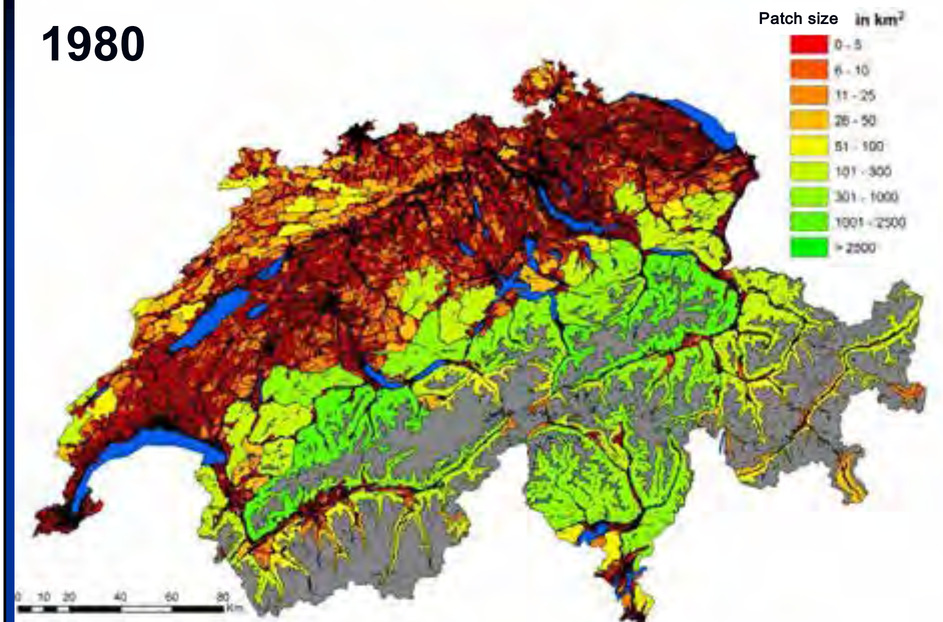
Bertiller et al. (2007)

29


1935
Patch size in km²
0 - 5
6 - 10
11 - 25
26 - 50
51 - 100
101 - 300
301 - 1000
1001 - 2500
> 2500
Km
Bertiller et al. (2007)
30


1960
Patch size in km²
0 - 5
6 - 10
11 - 25
26 - 50
51 - 100
101 - 300
301 - 1000
1001 - 2500
> 2500
Km
Bertiller et al. (2007)
31

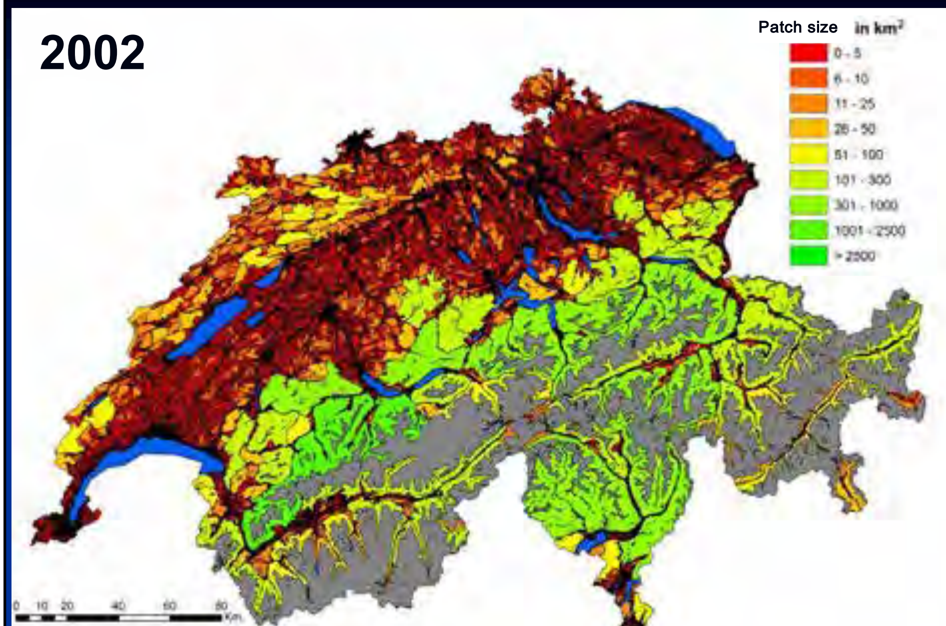
1980



Bertiller et al. (2007)

32

2002

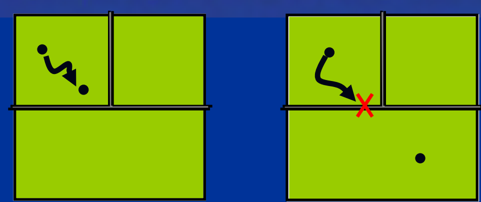


Bertiller et al. (2007)

33

How to measure the degree of landscape fragmentation?

- Serious problems with earlier methods
- New method: effective mesh size, m_{eff}
- Probability that two randomly chosen points in the landscape will be in the same patch:



Jaeger (2000), *Landscape Ecology*

- m_{eff} is included in the programm FRAGSTATS (available online)

34

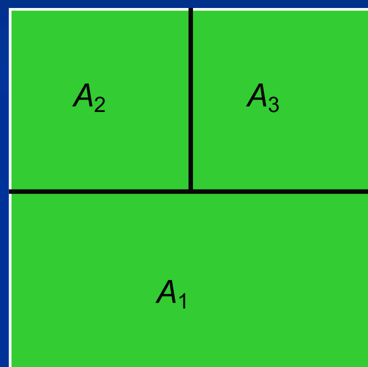
Effective Mesh Size (m_{eff})

- Interpretation: possibility that two individuals can encounter each other (e.g., gene flow)
- Multiplication with A_{total} to convert this probability into an area (= *effective mesh size*)

$$m_{eff} = A_{total} \cdot p$$

35

An example



A_{total} = 4 km^2

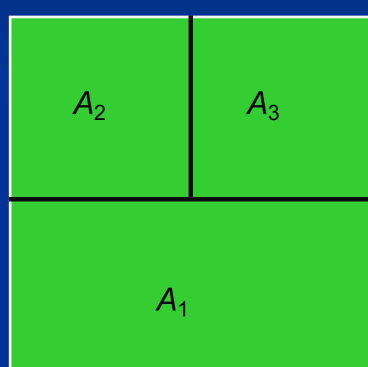
Landscape with two roads (three patches)

A_1 = 2 km^2,

A_2 and A_3 are 1 km^2.

36

An example



A_{total} = 4 km^2

$$p_1 = \frac{1}{2}\cdot\frac{1}{2} = \left(\frac{A_1}{A_{\text{total}}}\right)^2$$

$$p_2 = \frac{1}{4}\cdot\frac{1}{4} = \frac{1}{16} = p_3$$

$$p = p_1 + p_2 + p_3 = \frac{3}{8} = 0.375$$

$$m_{\text{eff}} = A_{\text{total}} * p = \frac{\sum_{i=1}^{n} A_i^2}{A_{\text{total}}} = 1.5\ \text{km}^2$$

37

The formula of the effective mesh size:

$$m_{\text{eff}} = \frac{1}{A_{\text{total}}}\left(A_1^2 + A_2^2 + \ldots + A_i^2 + \ldots + A_n^2\right)$$

$$= \frac{1}{A_{\text{total}}}\sum_{i=1}^{n} A_i^2$$

Jaeger (2000)

38

Implications

- If the landscape becomes more fragmented → encountering probability *p* is lower & effective mesh size is lower
- Fragmenting large patches has a big effect on the effective mesh size
  - Fragmenting small patches also has an effect on the effective mesh size, but the effect is less strong

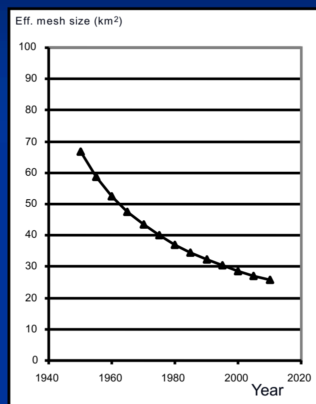
39

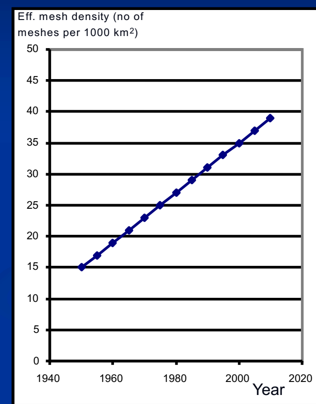
- m_{eff} corresponds to
  - the definition of ***landscape connectivity*** as „the degree to which a landscape facilitates of impedes animal movement“ (Taylor et al. 1993)
  - and to the suggestion by Taylor et al. (1993) to measure landscape connectivity “for a given organism using the probability of movement between all points or resource patches in a landscape”.

40

Jaeger et al. (2007)

Effective mesh density: $s_{eff} = 1/m_{eff}$



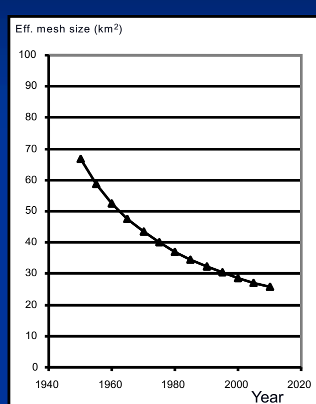


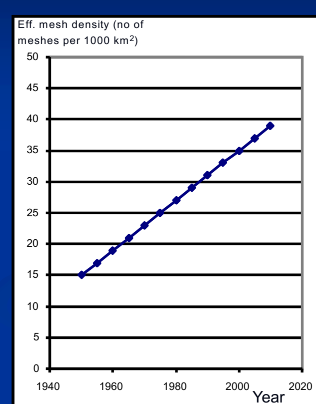
Jaeger et al. (2007)

Hypothetical example where the trend is constant.
Linear increase in the eff. mesh density corresponds to a $^1/_x$-curve in eff. mesh size.

42

Effective mesh density: $s_{eff} = 1/m_{eff}$





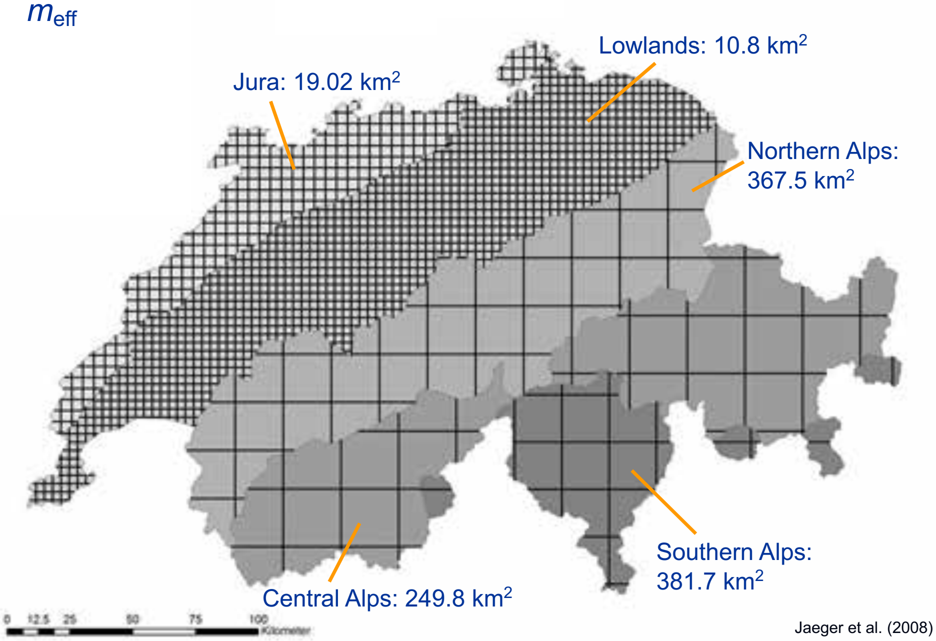
Jaeger et al. (2007)

Landscape connectivity = „the degree to which a landscape facilitates of impedes animal movement“ (Taylor et al. 1993)

Landscape fragmentation

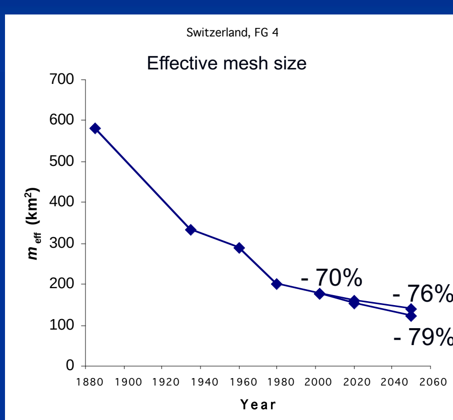
43

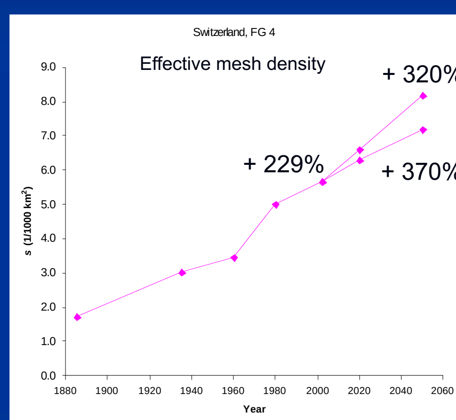
m_{eff}



Jaeger et al. (2008)

Switzerland 1885 to 2002 and trends





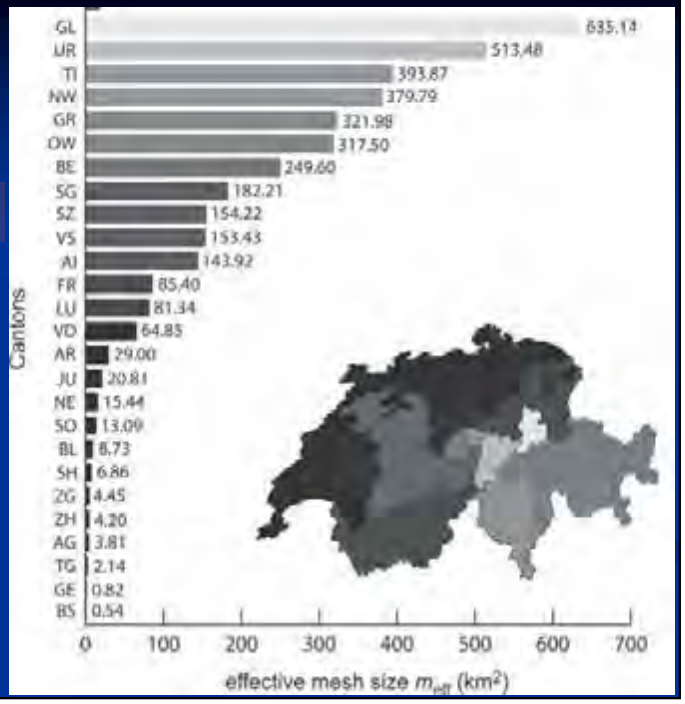
Jaeger et al. (2007)

FG 4: Land areas below 2100 m

45

The 26 cantons in 2002

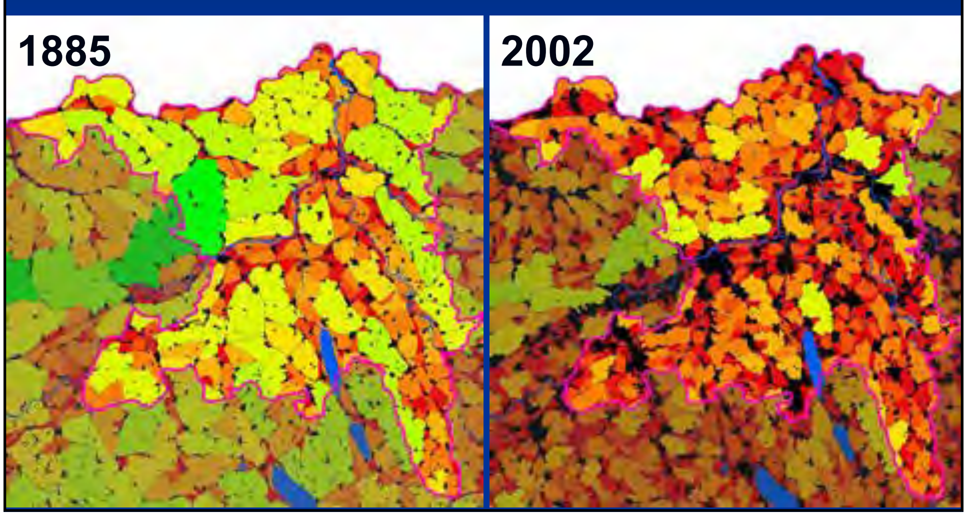
(FG 4)



Jaeger et al. (2008)

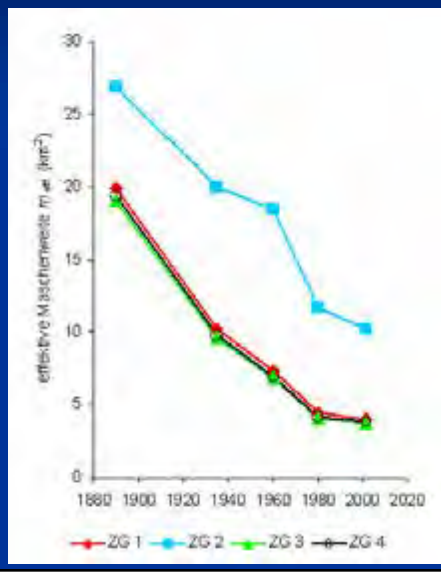
Canton Aargau 1885 and 2002

(FG 4)

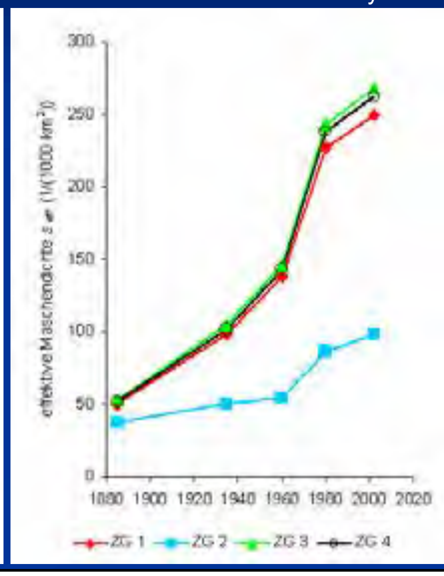


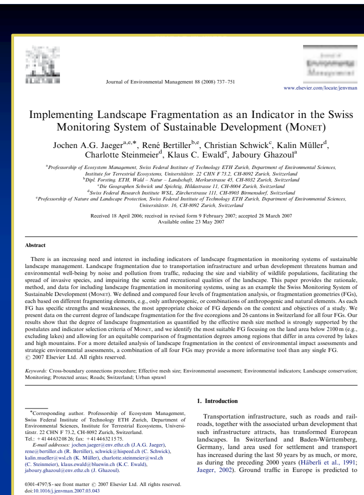
Canton Aargau

Effective mesh size



Effective mesh density





Journal of Environmental Management 88 (2008) 737–751

www.elsevier.com/locate/jenvman

Implementing Landscape Fragmentation as an Indicator in the Swiss Monitoring System of Sustainable Development (MONET)

Jochen A.G. Jaeger[a,e,*], René Bertiller[b,e], Christian Schwick[c], Kalin Müller[d], Charlotte Steinmeier[d], Klaus C. Ewald[e], Jaboury Ghazoul[a]

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[c] *Die Geographen Schwick und Spichtig, Hildastrasse 11, CH-8004 Zurich, Switzerland*
[d] *Swiss Federal Research Institute WSL, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland*
[e] *Professorship of Nature and Landscape Protection, Swiss Federal Institute of Technology ETH Zurich, Department of Environmental Sciences, Universitätstr. 16, CH-8092 Zurich, Switzerland*

Received 18 April 2006; received in revised form 9 February 2007; accepted 28 March 2007
Available online 23 May 2007

Abstract

There is an increasing need and interest in including indicators of landscape fragmentation in monitoring systems of sustainable landscape management. Landscape fragmentation due to transportation infrastructure and urban development threatens human and environmental well-being by noise and pollution from traffic, reducing the size and viability of wildlife populations, facilitating the spread of invasive species, and impairing the scenic and recreational qualities of the landscape. This paper provides the rationale, method, and data for including landscape fragmentation in monitoring systems, using as an example the Swiss Monitoring System of Sustainable Development (MONET). We defined and compared four levels of fragmentation analysis, or fragmentation geometries (FGs), each based on different fragmenting elements, e.g., only anthropogenic, or combinations of anthropogenic and natural elements. As each FG has specific strengths and weaknesses, the most appropriate choice of FG depends on the context and objectives of a study. We present data on the current degree of landscape fragmentation for the five ecoregions and 26 cantons in Switzerland for all four FGs. Our results show that the degree of landscape fragmentation as quantified by the effective mesh size method is strongly supported by the postulates and indicator selection criteria of MONET, and we identify the most suitable FG focusing on the land area below 2100 m (e.g., excluding lakes) and allowing for an equitable comparison of fragmentation degrees among regions that differ in area covered by lakes and high mountains. For a more detailed analysis of landscape fragmentation in the context of environmental impact assessments and strategic environmental assessments, a combination of all four FGs may provide a more informative tool than any single FG.

Keywords: Cross-boundary connections procedure; Effective mesh size; Environmental assessment; Environmental indicators; Landscape conservation; Monitoring; Protected areas; Roads; Switzerland; Urban sprawl

1. Introduction

Transportation infrastructure, such as roads and railroads, together with the associated urban development that such infrastructure attracts, has transformed European landscapes. In Switzerland and Baden-Württemberg, Germany, land area used for settlement and transport has increased during the last 50 years by as much, or more, as during the preceding 2000 years (Häberli et al., 1991; Jaeger, 2002). Ground traffic in Europe is predicted to

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E-mail addresses: jochen.jaeger@env.ethz.ch (J.A.G. Jaeger), rene@bertiller.ch (R. Bertiller), schwick@hispeed.ch (C. Schwick), kalin.mueller@wsl.ch (K. Müller), charlotte.steinmeier@wsl.ch (C. Steinmeier), klaus.ewald@bluewin.ch (K.C. Ewald), jaboury.ghazoul@env.ethz.ch (J. Ghazoul).

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doi:10.1016/j.jenvman.2007.03.043

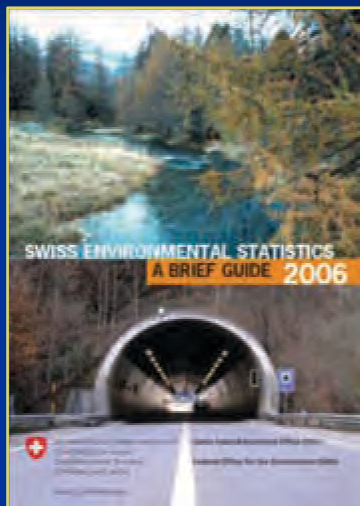
Jaeger et al. (2008)

Jaeger et al. (2007)

also in French and German

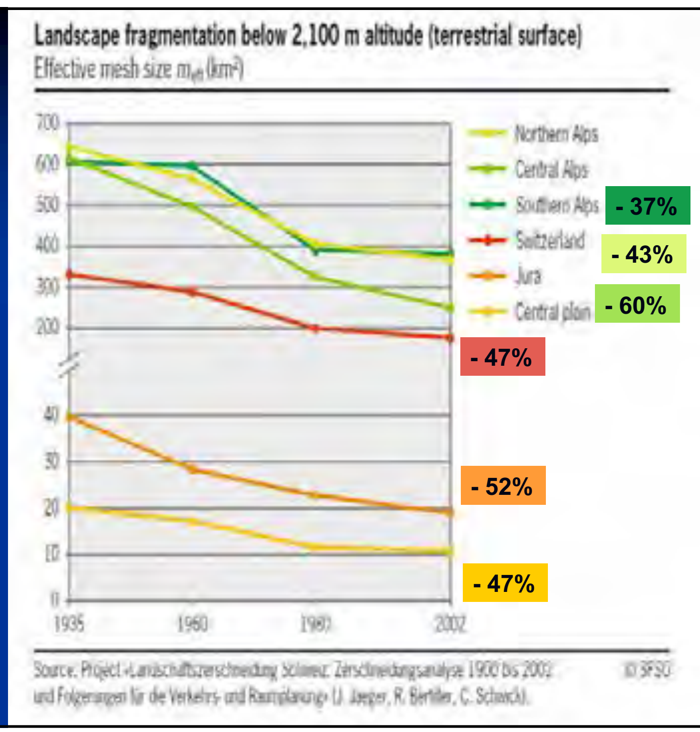
Online:
www.gpe.concordia.ca/jaeger

Results 1935-2002 are used in „*Swiss Environmental Statistics – Brief Guide 2006*“



Landscape fragmentation

Landscape fragmentation by barriers (e.g. roads and urban settlements) has greatly intensified over the past 70 years. Effective mesh size (m_{eff}) reflects the likelihood that two random points in a given landscape will coincide without being separated by barriers. Landscape fragmentation reduces effective mesh size and the likelihood that two random points will coincide. It also reduces the possibility of animals and humans to move around freely without encountering such barriers. This has serious implications for animal life as the ability to survive and reproduce depends on the frequency of encounters between animals of the same species.



Swiss Federal Statistical Office (2007)

10 Landscape and spatial development

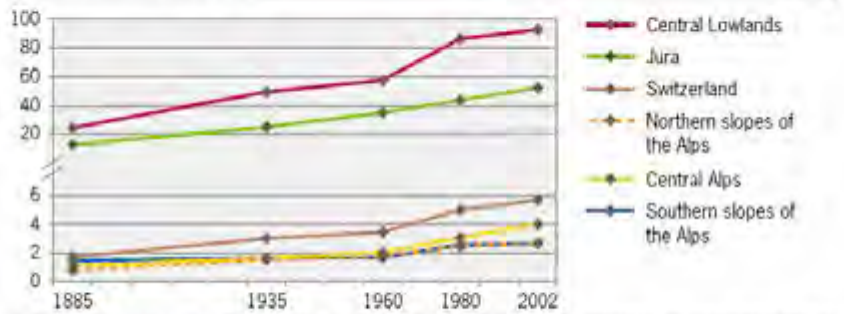
	Trend
Each second the total built-up area in Switzerland is increased by 0.9 m², mainly at the expense of agricultural land.	...
The extent to which the landscape is being fragmented has risen by 88% over the past 70 years.	↗
In 2005 nearly 23% of the total surface area of Switzerland was protected.	→

Switzerland is a country rich in natural and rural landscapes, which play an important role in maintaining the standard of living and are a major resource for tourism.
The intensive use of the land exerts considerable pressure on the landscape, however. It is often rural areas that pay the price of the increasing expansion of built-up areas and of transport infrastructure. At the same time, the tendency to fragment the landscape more and more prevents wild animals from moving freely in their natural habitats. Such freedom of movement is an important prerequisite for reproduction and thus for maintaining the species, however (cf. Section 15).
It is therefore crucial that the landscape be developed with care and that, where necessary, it is protected.

Swiss Federal Statistical Office (2007, p. 17)

Landscape fragmentation below 2100 m altitude (terrestrial surface)

Effective mesh density s_{eff}



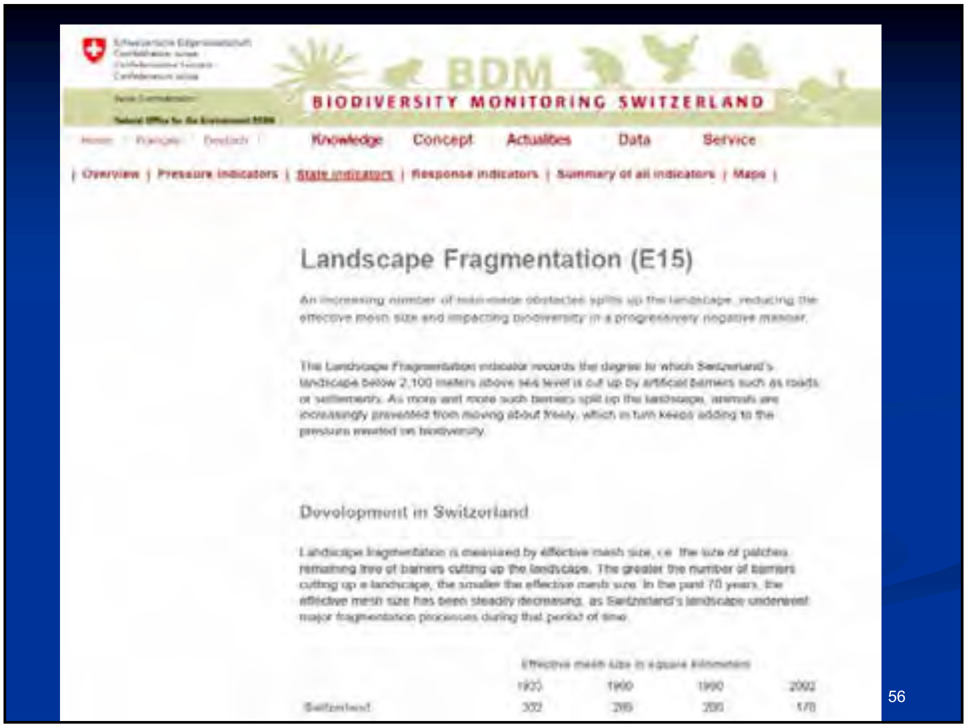
Aid to understanding: The effective mesh density s_{eff} (i.e. the effective number of meshes per 1000 km²) indicates the probability of two randomly chosen points within an area being divided by barriers (e.g. a road or a built-up area). The higher the s_{eff}, the greater the degree of landscape fragmentation.

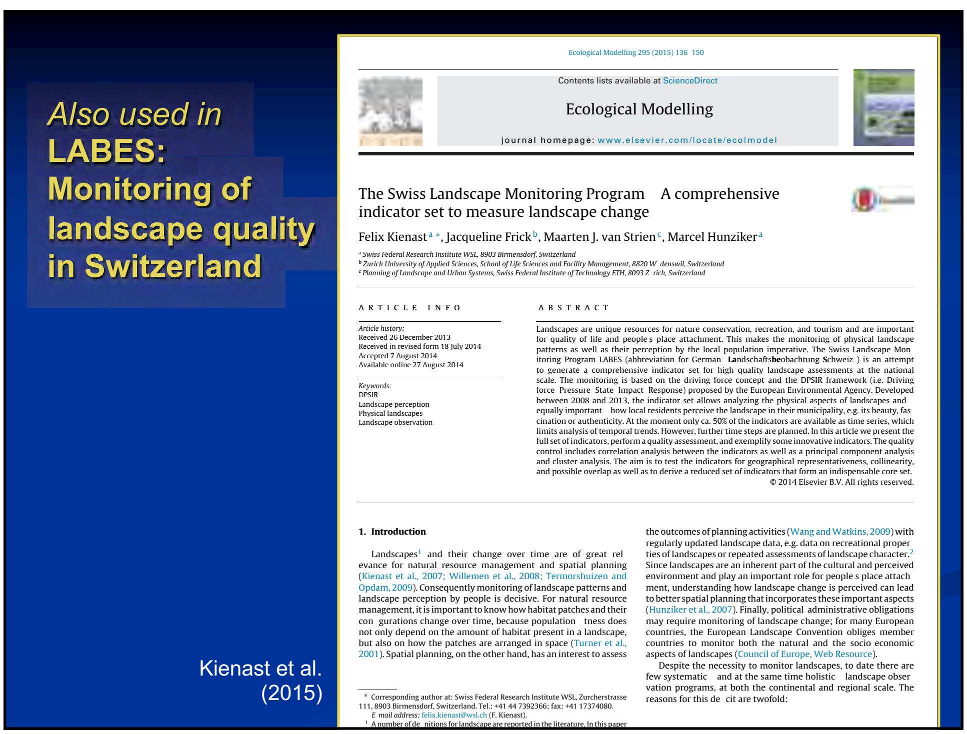
Source: Jaeger, J., Bertiller, R., Schwick, C. (2007): Degree of Landscape Fragmentation in Switzerland – Quantitative analysis 1885–2002 and implications for traffic planning and regional planning, condensed version, Federal Statistical Office © FSO

Swiss Federal Statistical Office (2007, p. 18)

54

http://www.biodiversitymonitoring.ch/





Ecological Modelling 295 (2015) 136 150

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

The Swiss Landscape Monitoring Program A comprehensive indicator set to measure landscape change

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ARTICLE INFO

Article history:
Received 26 December 2013
Received in revised form 18 July 2014
Accepted 7 August 2014
Available online 27 August 2014

Keywords:
DPSIR
Landscape perception
Physical landscapes
Landscape observation

ABSTRACT

Landscapes are unique resources for nature conservation, recreation, and tourism and are important for quality of life and people s place attachment. This makes the monitoring of physical landscape patterns as well as their perception by the local population imperative. The Swiss Landscape Mon itoring Program LABES (abbreviation for German **La**ndschafts**be**obachtung **S**chweiz) is an attempt to generate a comprehensive indicator set for high quality landscape assessments at the national scale. The monitoring is based on the driving force concept and the DPSIR framework (i.e. Driving force Pressure State Impact Response) proposed by the European Environmental Agency. Developed between 2008 and 2013, the indicator set allows analyzing the physical aspects of landscapes and equally important how local residents perceive the landscape in their municipality, e.g. its beauty, fas cination or authenticity. At the moment only ca. 50% of the indicators are available as time series, which limits analysis of temporal trends. However, further time steps are planned. In this article we present the full set of indicators, perform a quality assessment, and exemplify some innovative indicators. The quality control includes correlation analysis between the indicators as well as a principal component analysis and cluster analysis. The aim is to test the indicators for geographical representativeness, collinearity, and possible overlap as well as to derive a reduced set of indicators that form an indispensable core set.

1. Introduction

Landscapes[1] and their change over time are of great rel evance for natural resource management and spatial planning (Kienast et al., 2007; Willemen et al., 2008; Termorshuizen and Opdam, 2009). Consequently monitoring of landscape patterns and landscape perception by people is decisive. For natural resource management, it is important to know how habitat patches and their con gurations change over time, because population tness does not only depend on the amount of habitat present in a landscape, but also on how the patches are arranged in space (Turner et al., 2001). Spatial planning, on the other hand, has an interest to assess the outcomes of planning activities (Wang and Watkins, 2009) with regularly updated landscape data, e.g. data on recreational proper ties of landscapes or repeated assessments of landscape character.[2] Since landscapes are an inherent part of the cultural and perceived environment and play an important role for people s place attach ment, understanding how landscape change is perceived can lead to better spatial planning that incorporates these important aspects (Hunziker et al., 2007). Finally, political administrative obligations may require monitoring of landscape change; for many European countries, the European Landscape Convention obliges member countries to monitor both the natural and the socio economic aspects of landscapes (Council of Europe, Web Resource).

Despite the necessity to monitor landscapes, to date there are few systematic and at the same time holistic landscape obser vation programs, at both the continental and regional scale. The reasons for this de cit are twofold:

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E mail address: felix.kienast@wsl.ch (F. Kienast).

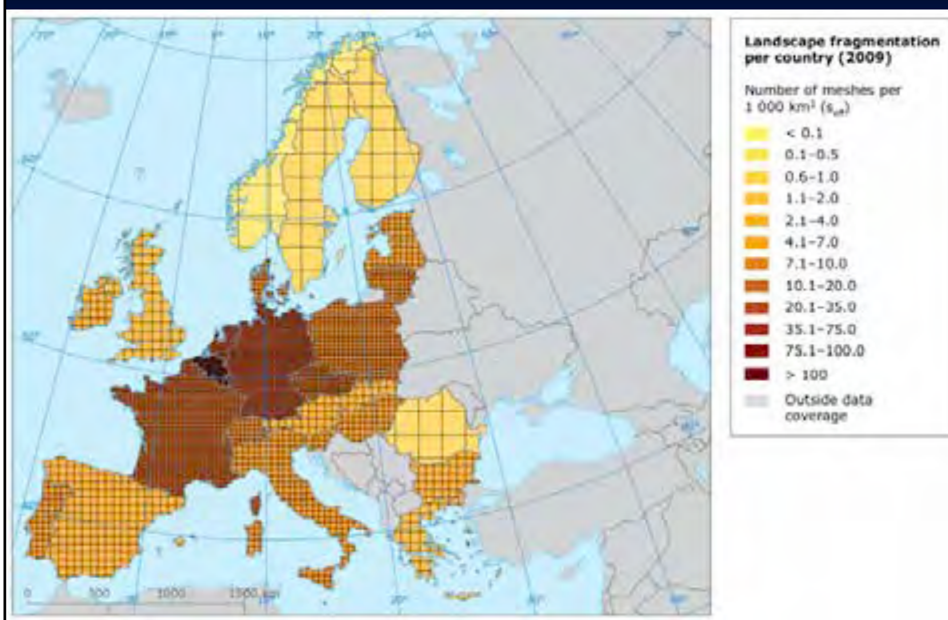
[1] A number of de nitions for landscape are reported in the literature. In this paper

2. Landscape Fragmentation in Europe

- What is the extent of landscape fragmentation in Europe?
- To what degree can the differences between the regions in Europe be explained by socio-economic factors?
  - population density, GDP, volume of freight transportation, etc.

Jaeger et al. (2011)

58



Jaeger et al. (2011)

59

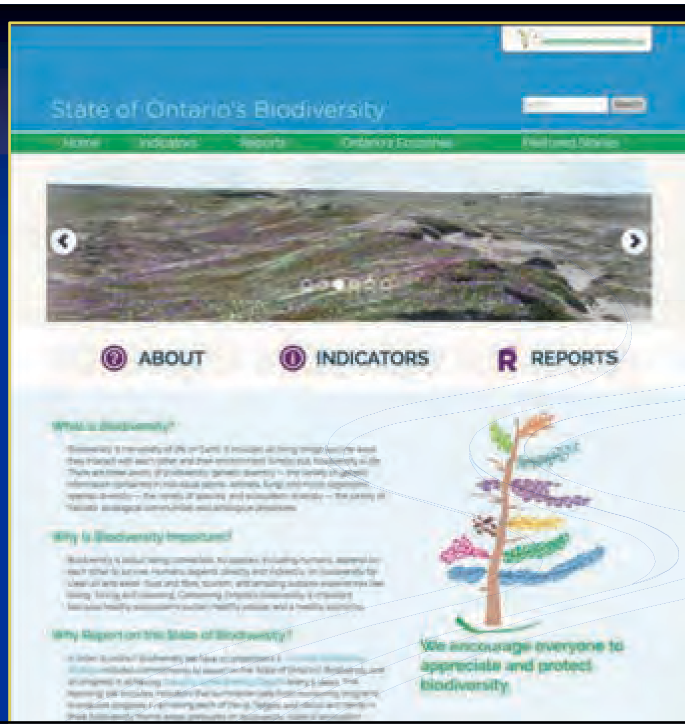
3 immediate priorities:

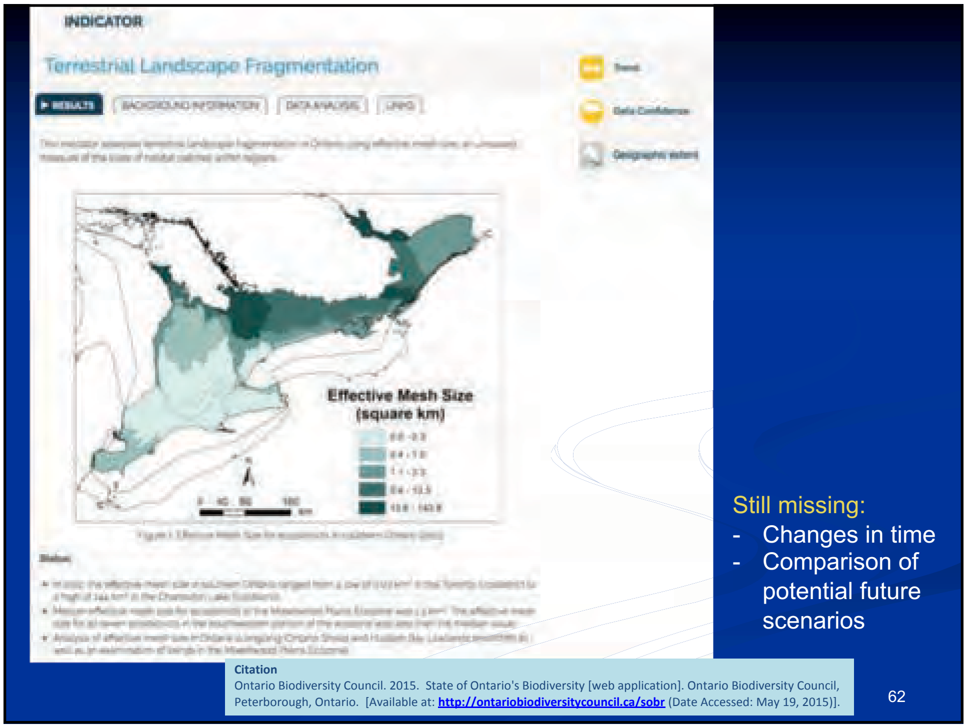
- Immediate protection of large unfragmented areas and wildlife corridors
- Monitoring of landscape fragmentation
- Application of fragmentation analysis as a tool in transportation planning and regional planning

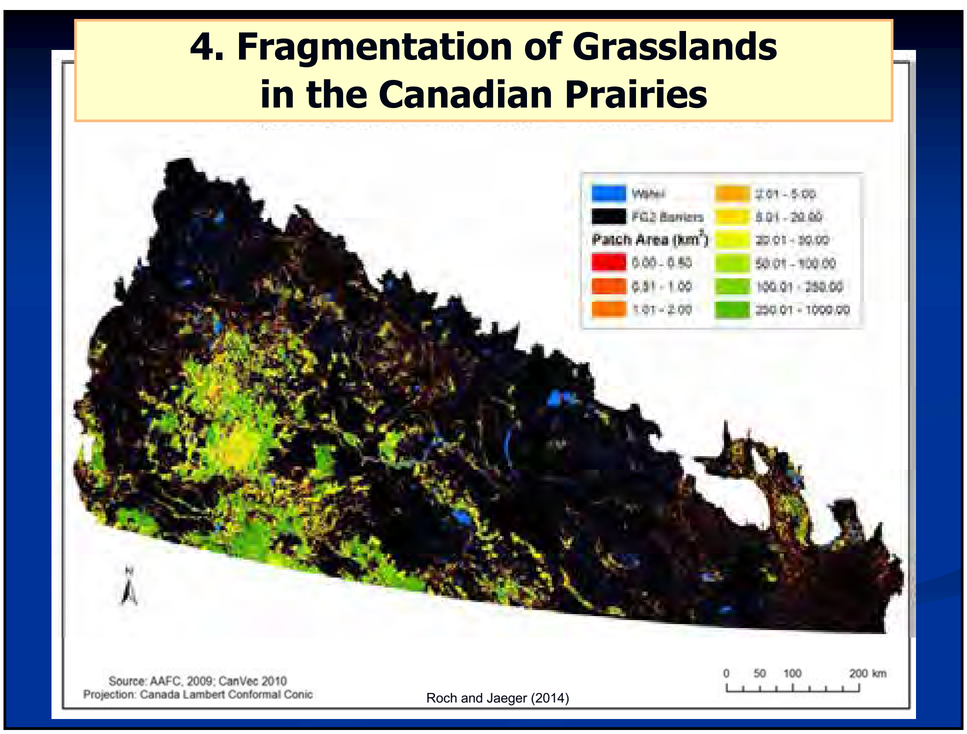
Online: www.eea.europa.eu/publications/landscape-fragmentation-in-europe

60

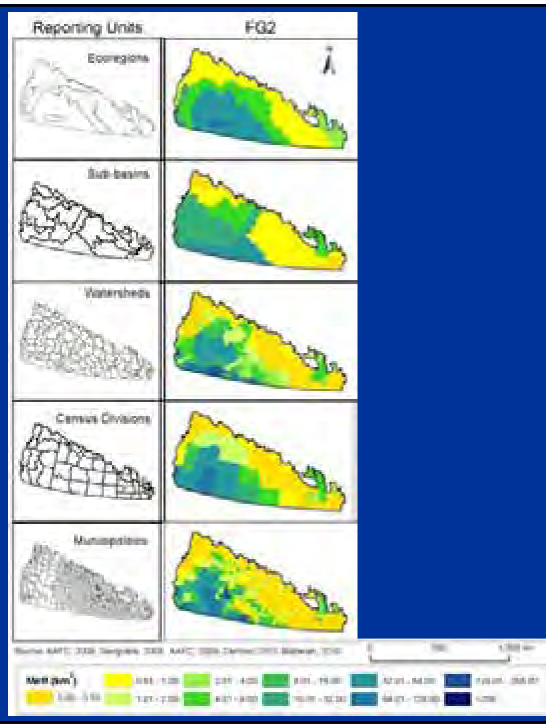
3. Ontario




INDICATOR
Terrestrial Landscape Fragmentation
Effective Mesh Size
(square km)
Still missing:
- Changes in time
- Comparison of potential future scenarios
Citation
Ontario Biodiversity Council. 2015. State of Ontario's Biodiversity [web application]. Ontario Biodiversity Council, Peterborough, Ontario. [Available at: http://ontariobiodiversitycouncil.ca/sobr (Date Accessed: May 19, 2015)].
62

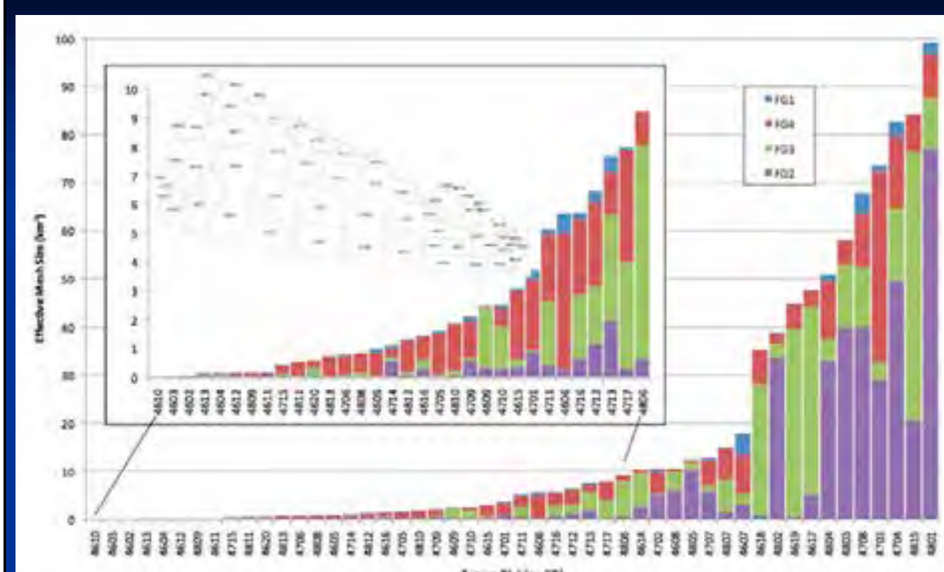

4. Fragmentation of Grasslands in the Canadian Prairies
Water
FG2 Barriers
Patch Area (km²)
0.00 - 0.50
0.51 - 1.00
1.01 - 2.00
2.01 - 5.00
5.01 - 20.00
20.01 - 50.00
50.01 - 100.00
100.01 - 250.00
250.01 - 1000.00
Source: AAFC, 2009; CanVec 2010
Projection: Canada Lambert Conformal Conic
Roch and Jaeger (2014)
0 50 100 200 km

Results



Roch and Jaeger (2014)

64



Roch and Jaeger (2014)

65

Environ Monit Assess (2014) 186:2505 2534
DOI 10.1007/s10661-013-3557-9

Monitoring an ecosystem at risk: What is the degree of grassland fragmentation in the Canadian Prairies?

Laura Roch · Jochen A. G. Jaeger

Received: 18 June 2013 / Accepted: 19 November 2013 / Published online: 4 January 2014

Abstract Increasing fragmentation of grassland habitats by human activities is a major threat to biodiversity and landscape quality. Monitoring their degree of fragmentation has been identified as an urgent need. This study quantifies for the first time the current degree of grassland fragmentation in the Canadian Prairies using four fragmentation geometries (FGs) of increasing specificity (i.e. more restrictive grassland classification) and five types of reporting units (7 ecoregions, 50 census divisions, 1,166 municipalities, 17 sub-basins, and 108 watersheds). We evaluated the suitability of 11 datasets based on 8 suitability criteria and applied the effective mesh size (m_{eff}) method to quantify fragmentation. We recommend the combination of the Crop Inventory Mapping of the Prairies and the CanVec datasets as the most suitable for monitoring grassland fragmentation. The grassland area remaining amounts to 87,570.45 km^2 in FG4 (strict grassland definition) and 183,242.042 km^2 in FG1 (broad grassland definition), out of 461,503.97 km^2 (entire Prairie Ecozone area). The very low values of m_{eff} of 14.23 km^2 in FG4 and 25.44 km^2 in FG1 indicate an extremely high level of grassland fragmentation. The m_{eff} method is supported in this study as highly suitable and recommended for long-term monitoring of grasslands in the Canadian Prairies; it can help set measurable targets and/or limits for regions to guide management efforts and as a tool for performance review of protection efforts, for increasing awareness, and for guiding efforts to minimize grassland fragmentation. This approach can also be applied in other parts of the world and to other ecosystems.

Keywords Effective mesh size · Ecological indicators · Grassland conservation · Landscape fragmentation · Fragmentation *per se* · Protected areas · Prairie ecozone · Roads · Urban sprawl

Abbreviations used

CBI	City Biodiversity Index
FG	Fragmentation geometry
CESI	Canadian Environmental Sustainability Indicators
FSDS	Federal Sustainable Development Strategy
m_{eff}	Effective mesh size
s_{eff}	Effective mesh density
AAFC	Agriculture and Agri-Food Canada

Electronic supplementary material The online version of this article (doi:10.1007/s10661-013-3557-9) contains supplementary

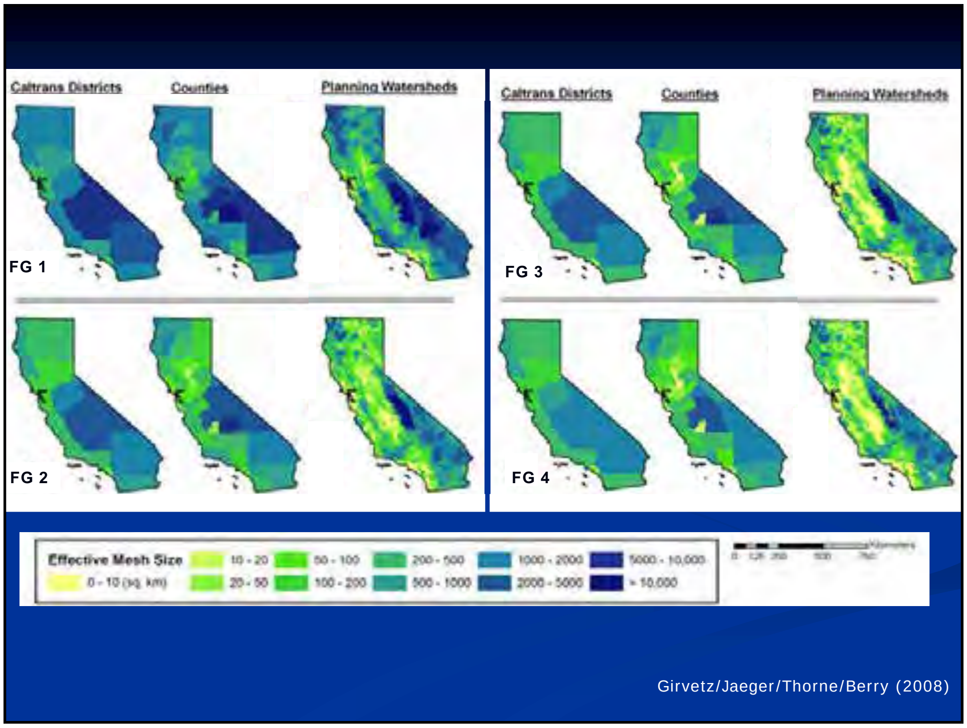
Roch and Jaeger (2014)

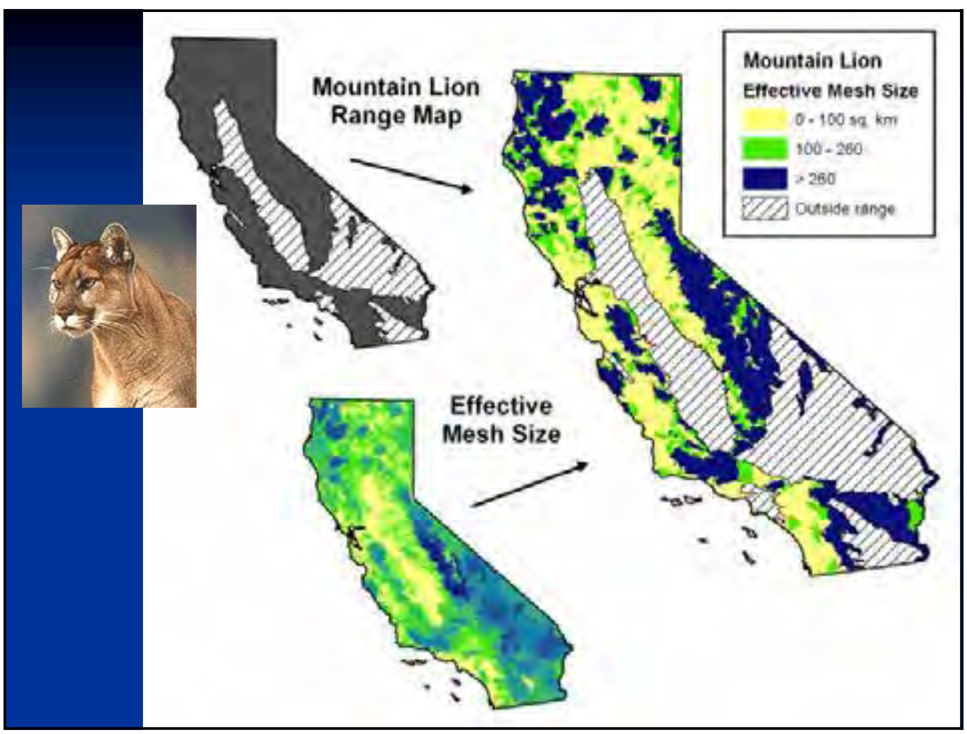
66

5. California

Fragmentation Geometry	Elements Included
1	Highways, major roads, railroads, urbanized areas
2	+ minor roads
3	+ agricultural fields
4	+ lakes, major rivers, high elevations

Girvetz/Thorne/Berry/Jaeger (2008)


Caltrans Districts
Counties
Planning Watersheds
FG 1
FG 2
FG 3
FG 4
Effective Mesh Size
0 - 10 (sq. km)
10 - 20
20 - 50
50 - 100
100 - 200
200 - 500
500 - 1000
1000 - 2000
2000 - 5000
5000 - 10,000
> 10,000
Girvetz/Jaeger/Thorne/Berry (2008)


Mountain Lion Range Map
Effective Mesh Size
Mountain Lion
Effective Mesh Size
0 - 100 sq. km
100 - 260
> 260
Outside range

Landscape and Urban Planning 86 (2008) 205–218

Contents lists available at ScienceDirect

Landscape and Urban Planning

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Integration of landscape fragmentation analysis into regional planning: A statewide multi-scale case study from California, USA

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ARTICLE INFO

Article history:
Received 29 August 2007
Received in revised form 18 December 2007
Accepted 20 February 2008
Available online 2 May 2008

Keywords:
Effective mesh size
Landscape connectivity
Habitat fragmentation
Wildlife movement
Road ecology
Transportation planning

ABSTRACT

Landscape fragmentation due to urban development, transportation infrastructure, and agriculture poses a threat to environmental integrity. There is a need to quantify the level of landscape fragmentation in an ecologically meaningful way for inclusion in planning and decision-making. Effective mesh size (m_{eff}) is an ecologically relevant metric that quantifies landscape fragmentation based on the probability that two randomly chosen points in a region are located in the same non-fragmented patch. We investigated variation in m_{eff} measured by transportation districts, municipal counties, and six spatial levels of watersheds within the state of California. Four fragmentation geometries were developed by overlaying highways, roads, urbanized areas, agricultural areas, and natural fragmenting features. Two m_{eff} calculation methods were compared: one where planning unit boundaries fragment the landscape (CUT), the other allowing for cross-boundary connections (CBC). The CUT procedure always produced lower m_{eff} values than CBC, with greater differences occurring in smaller planning units, confirming the bias introduced using boundaries with landscape metrics. Calculated m_{eff} values varied from 0 to 20 885 km^2 across 6994 units in California. Roads contributed the most to fragmentation, while agriculture contributed little, as California's agricultural areas are already heavily fragmented by roads. This paper provides a systematic, quantitative, and intuitive method for transportation, land use and environmental planners to analyze cumulative impacts of multiple fragmenting features across a range of spatial scales within a variety of planning units. This approach could be used for analyzing the impact of future land development scenarios, and integrated into regional planning processes.

1. Introduction

Landscape fragmentation due to roads, urbanization, and other human development has major impacts on wildlife, including many species of concern (Forman et al., 2003; Trombulak and Frissell, 2000). These impacts include direct mortality (Mazerolle, 2004; Riley et al., 2003), behavioral changes (Mazerolle et al., 2005), reduced dispersal capacity (Forman and Alexander, 1998) ... scape fragmentation for use in environmental and conservation planning.

Analytical approaches are needed that can quantify habitat fragmentation at multiple spatial scales, and can be easily used by planners. Many measures of landscape fragmentation have been proposed (Gustafson, 1998; McGarigal et al., 2002). Such metrics have evolved from those that simply quantify landscape patterns to metrics that also relate to ecological processes (Li and Wu, 2004) ...

Girvetz et al. (2008)

70

6. Use of m_{eff} in the City biodiversity Index (CBI)

THE SINGAPORE INDEX ON CITIES' BIODIVERSITY

Introduction

Cities occupy only 2% of the Earth's surface, yet consume about 75% of its natural resources and has an ecological impact on an exponentially vast area. The projected global human population by 2050 is 9.2 billion, with 6.4 billion residing in urban areas. As such, cities will play an increasingly crucial role in biodiversity conservation.

Tan, then Singapore's Minister for National Development, proposed the development of an index for cities to benchmark conservation efforts and evaluate progress in reducing the rate of biodiversity loss, led by the Secretariat of the Convention on Biological Diversity (SCBD).

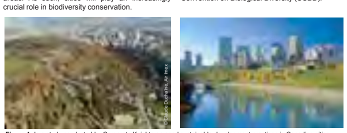


Figure 1: In a study conducted by Corporate Knights on good sustainable development practices in Canadian cities, Montreal (left) and Edmonton (right) both attributed their perfect score for biodiversity monitoring to their application of the Singapore Index.

Cities are increasingly forming alliances to share best practices, notably the Global Partnership on Local and Sub-national Action for Biodiversity. However, there was no single index which meaningfully measured biodiversity conservation efforts at the city level.

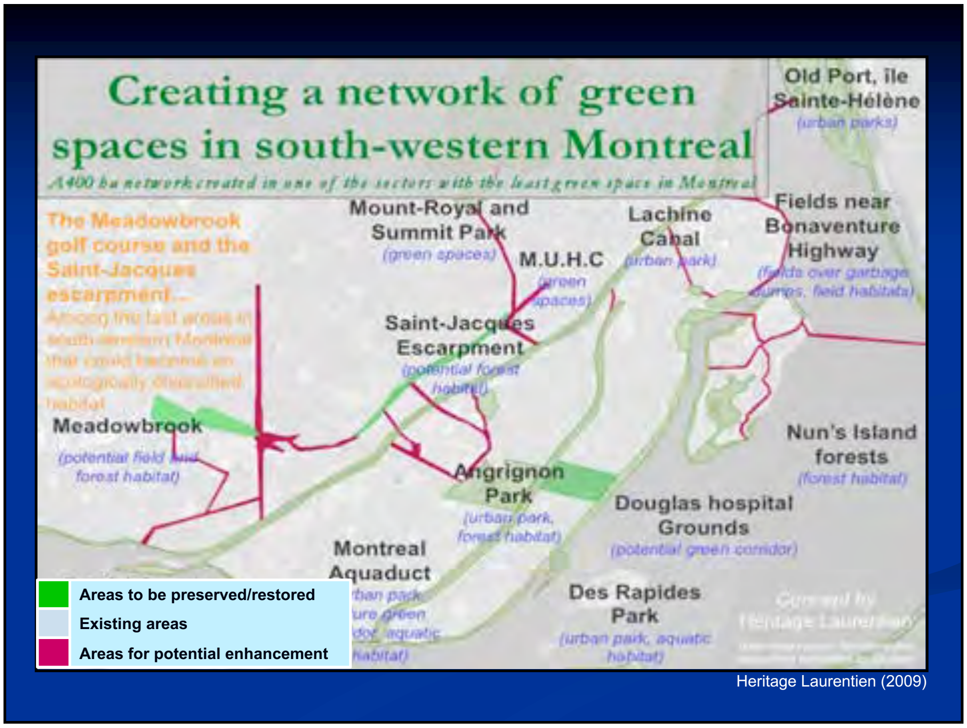
At the High-Level Segment of the 9th Meeting of the Conference of Parties to the Convention on Biological Diversity (COP-9) in 2008, Mr Mah Bow

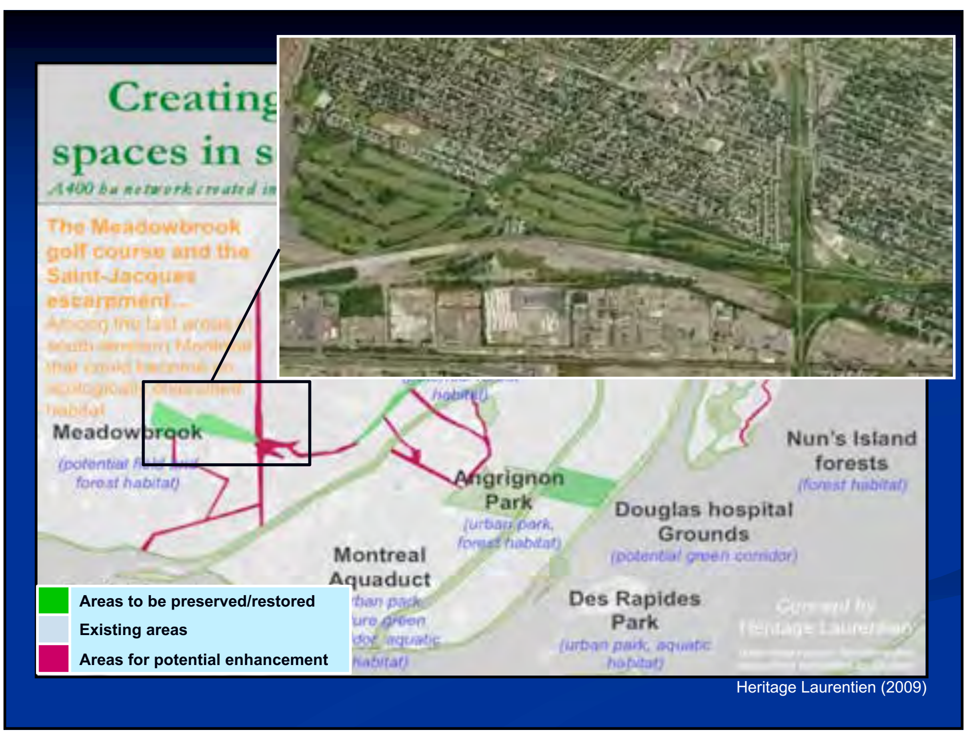
At COP-10 in 2010, Parties endorsed the Plan of Action on Sub-national Governments, Cities and Other Local Authorities for Biodiversity (Decision X/22) which encourages Parties to actively engage cities and local authorities in implementing the CBD. The Plan of Action highlights the City Biodiversity Index (CBI), also known as the Singapore Index on Cities' Biodiversity (Singapore Index), as a monitoring tool to assist local authorities to evaluate their progress in urban biodiversity conservation.

Global Partnership on Local and Sub-national Action for Biodiversity

Development of the Singapore Index

71


Creating a network of green spaces in south-western Montreal
A400 ha network created in one of the sectors with the least green space in Montreal
The Meadowbrook golf course and the Saint-Jacques escarpment...
Mount-Royal and Summit Park
(green spaces)
M.U.H.C
(green spaces)
Lachine Canal
(urban park)
Old Port, île Sainte-Hélène
(urban parks)
Fields near Bonaventure Highway
(fields over garbage dumps, field habitats)
Saint-Jacques Escarpment
(potential forest habitat)
Meadowbrook
(potential field and forest habitat)
Nun's Island forests
(forest habitat)
Angrignon Park
(urban park, forest habitat)
Douglas hospital Grounds
(potential green corridor)
Montreal Aquaduct
Des Rapides Park
(urban park, aquatic habitat)
Areas to be preserved/restored
Existing areas
Areas for potential enhancement
Heritage Laurentien (2009)


Creating
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The Meadowbrook golf course and the Saint-Jacques escarpment...
Meadowbrook
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(potential green corridor)
Montreal Aquaduct
Des Rapides Park
(urban park, aquatic habitat)
Areas to be preserved/restored
Existing areas
Areas for potential enhancement
Heritage Laurentien (2009)

Research Questions

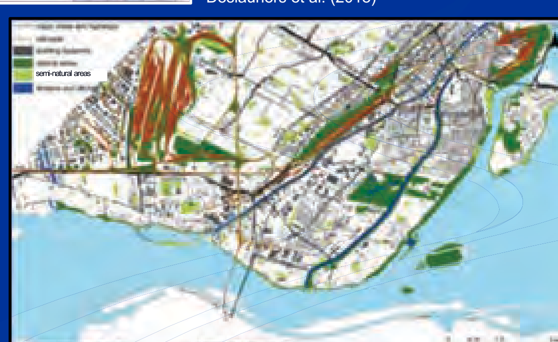
1. What is the current level connectivity in the network?

2. What is the potential future level of connectivity in the network?

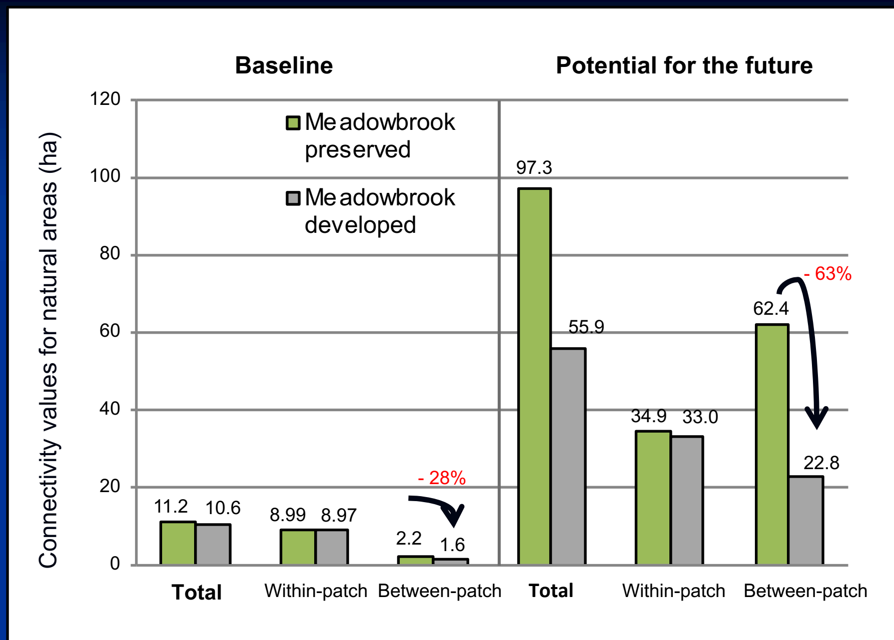
3. What is Meadowbrook's contribution to connectivity?

Baseline Situation

Deslauriers et al. (2018)



Future Scenario



Deslauriers et al. (2018)

Conclusions

- With Meadowbrook developed, we would loose Meadowbrook's significant contribution to connectivity for wildlife (and people)
  - and in particular **it's large potential** for increased connectivity in the area in the future

Ecological Indicators 94 (2018) 99 113

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original article

Implementing the connectivity of natural areas in cities as an indicator in the City Biodiversity Index (CBI)

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A R T I C L E I N F O

Article history:
Received 13 August 2016
Received in revised form 15 February 2017
Accepted 18 February 2017
Available online 22 March 2017

Keywords:
Connectivity
Connectors
Convention on Biological Diversity
Effective mesh size
Green infrastructure
Landscape fragmentation
Landscape metrics
Planning scenarios
Singapore Index
Urban ecology
Urban biodiversity
Wildlife corridors

A B S T R A C T

The City Biodiversity Index (CBI), or Singapore Index on Cities Biodiversity, serves as a tool to monitor biodiversity in cities and was endorsed by the Convention on Biological Diversity in 2009. Indicator 2 of the CBI measures the connectivity of natural areas in cities. We propose an improved and straightforward method for measuring connectivity based on the effective mesh size metric to replace the previous method used in the CBI. The previous version did not account for intra patch (within patch) connectivity nor for major barriers. Our evaluation of the new version of Indicator 2 through its application to Montr al and Lisbon con rmed its reliability. In Montr al, natural areas have a total connectivity value of 581.7 ha, the majority of which exists between, rather than within, patches of natural area. Smaller patches (<15 ha) contribute signi cantly to overall connectivity, which may have implications for future conservation efforts. In Lisbon, connectivity (342 ha) is concentrated within patches. We also applied the improved Indicator 2 to a case study in southwestern Montr al, where a greenway network (green infrastructure) has been proposed by a local community organization. We assessed the contribution of Meadowbrook Golf Course to connectivity in scenarios of the proposed greenway network and the effect that residential development would have. Not only would this development eliminate the golf course s current contribution to connectivity, but also its much greater potential contribution to connectivity in future scenarios. Restoring and establishing additional natural areas would signi cantly increase connectivity in the network. Our results demonstrate that the improved version of Indicator 2 is a suitable method in the CBI. It is equally useful for identifying options to increase the connectivity of natural areas within cities in the future and for determining the impacts of urban development on connectivity. More advanced methods for quantifying connectivity exist and may also be included in Part I of the CBI. However, they are often challenging to use and this frequently discourages city planners from including any indicator of connectivity in their biodiversity monitoring. The connectivity metric presented here overcomes this problem through its practicality in a wide range of planning structures while still generating meaningful results which may then inspire city planners to move towards using more advanced methods of measuring connectivity. We dedicate this paper to the memory of Bernice Goldsmith (1934 2014).

1. Monitoring biodiversity in cities

Urban wildlife populations are negatively affected by habitat fragmentation, which limits access to resources and mating part ...

... diversity, was developed as a tool to evaluate and monitor the state of biodiversity in cities and to provide insights for improving conservation efforts. It was proposed by the Minister of National Development in Singapore, Mr. Mah Bow Tan, at the 9th Meeting ...

Deslauriers et al. (2018)

78

Conclusions

- Some important points need particular attention
  - Landscape connectivity or habitat connectivity, within-patch connectivity and between-patch connectivity, influence of changes in habitat amount, …
- Examples (m_{eff})
  - Switzerland, Europe, Ontario, Canadian prairies, California, City Biodiversity Index
- m_{eff} is easy to use & can be applied in various ways
  - Monitoring
    - environmental, biodiversity, landscape quality, ...
    - compare between-patch connectivity and within-patch connectivity
  - Comparison of scenarios
  - Setting of targets and limits

79

Thank you!

- Christian Schwick, René Bertiller
- Felix Kienast
- Megan Deslauriers, Adrienne Asgary, Naghmeh Nazarnia

Any Questions?

For funding:
German Research Foundation (DFG)
Swiss Federal Office for the Environment (FOEN)
Environment Canada
et al.

Measuring Forest Connectivity in Nova Scotia:

Comparing a variety of methods to gain perspective

Caitlin Cunningham, PhD Student

Dalhousie University

April 25, 2019

DALHOUSIE UNIVERSITY NOVA SCOTIA NSERC CRSNG

Acknowledgements

- Peter Bush
  Nova Scotia Department of Lands and Forestry
- John Brazner
  Nova Scotia Environment
- Karen Beazley
  Dalhousie University

NEG-ECP Resolution 40-3

"Maintaining and restoring ecological connectivity is an important strategy for boosting the resilience of the region's native ecosystems and biodiversity, as well as its economy and human communities. Connected habitats provide the natural pathways necessary for fish, wildlife, and plants to move to meet their life needs and to find suitable habitat as climate conditions change. Intact ecosystems also provide sustainable economic and social benefits on which the region's well-being depends – including renewable forest products, outdoor recreation and tourism, clean air and water, flood attenuation, carbon sequestration, and our sense of place"

Research Goals

- Evaluate forest connectivity across Nova Scotia
- Compare different metrics for connectivity
- Identify places where connectivity is restricted

Measuring Connectivity

- Mesh Size
- Circuitscape
- Fragstats

Mesh Size

- Measure Isolation of Segments of Habitats and Ecosystems
- Probability that 2 points will be in Connected Patches
- $m_{eff} = \frac{1}{A_{total}}(A_1^2 + A_2^2 + \cdots + A_n^2)$

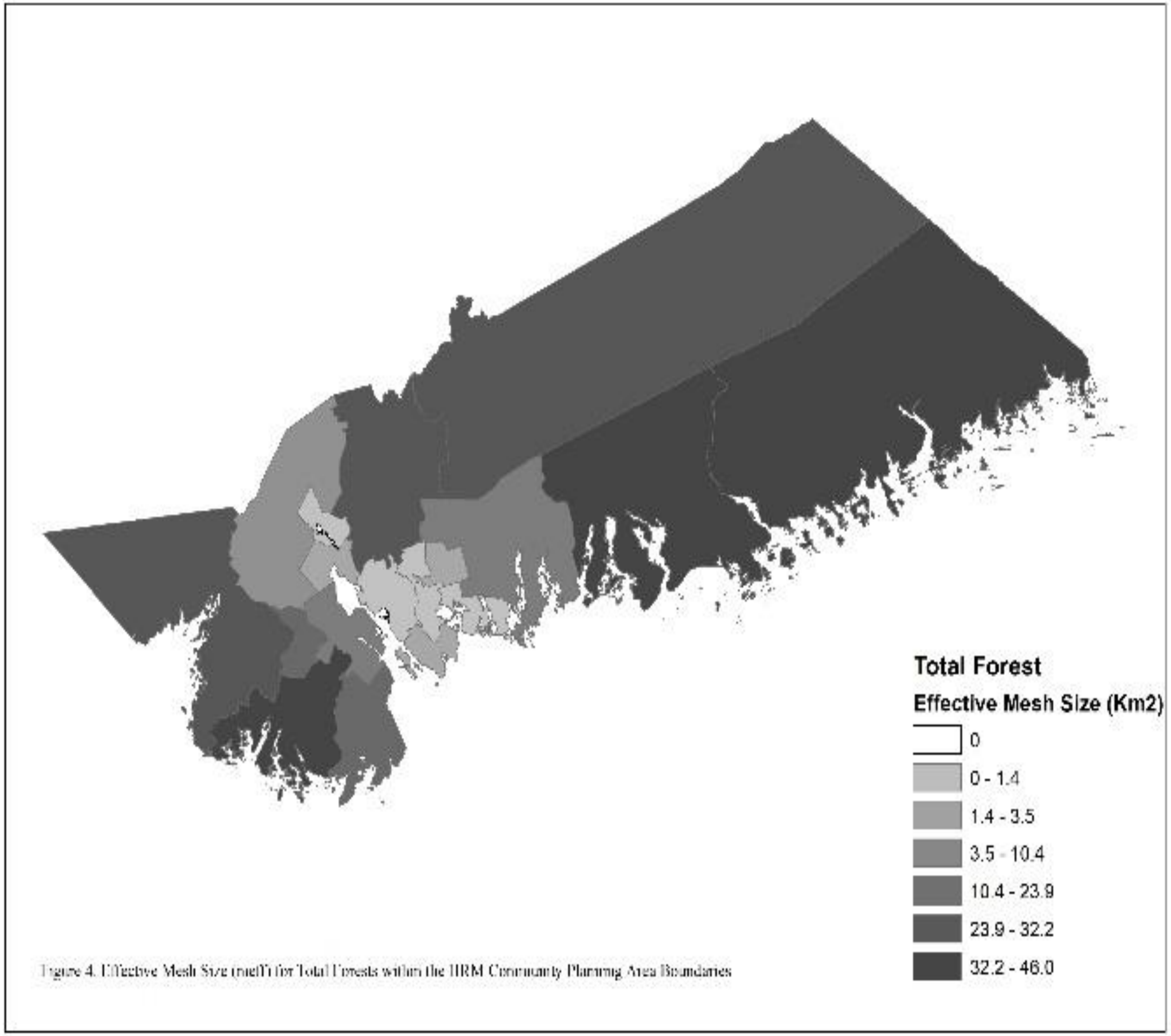
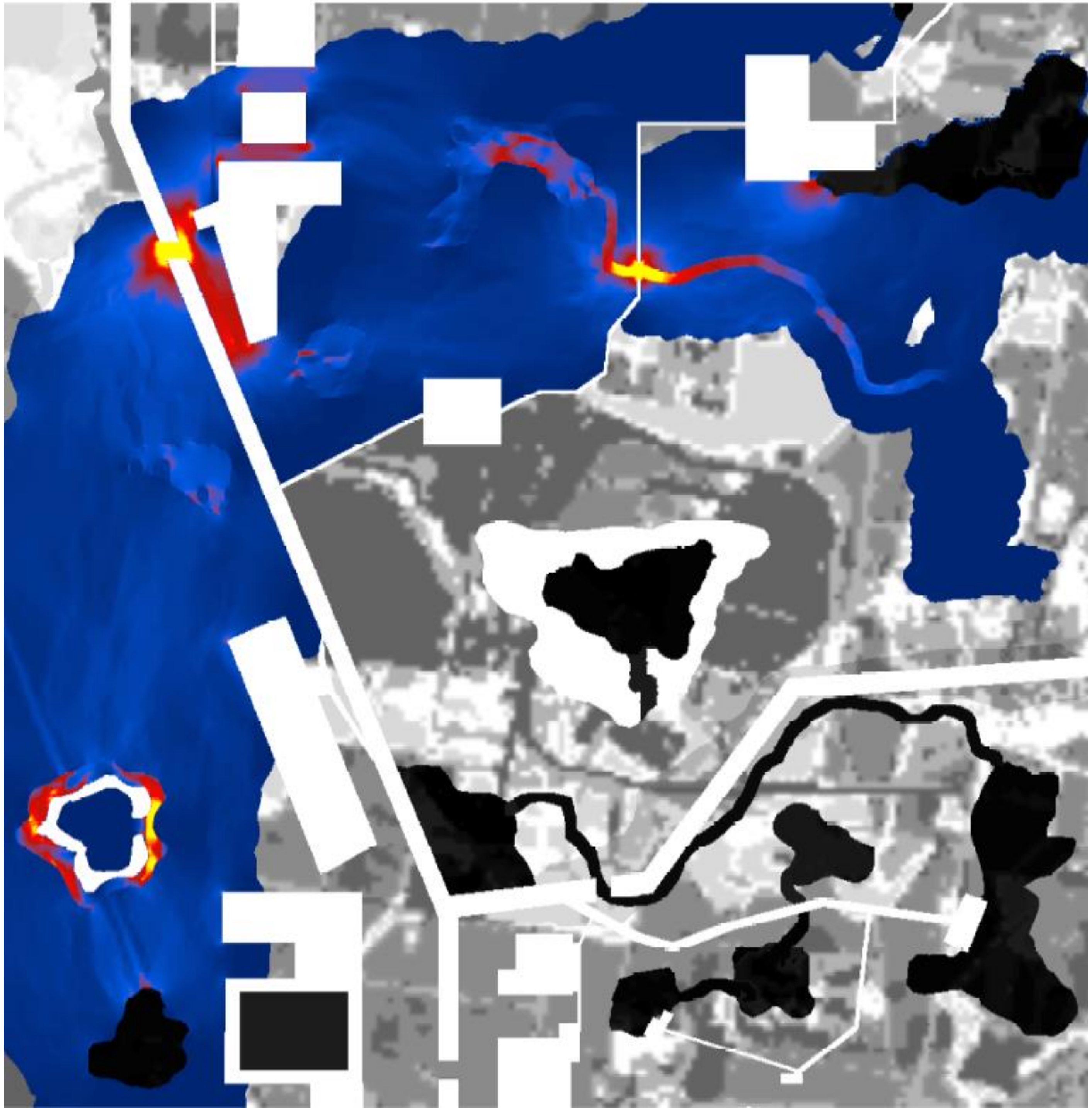


Figure 4. Effective Mesh Size (meff) for Total Forests within the HRM Community Planning Area Boundaries

(Smith, 2018)

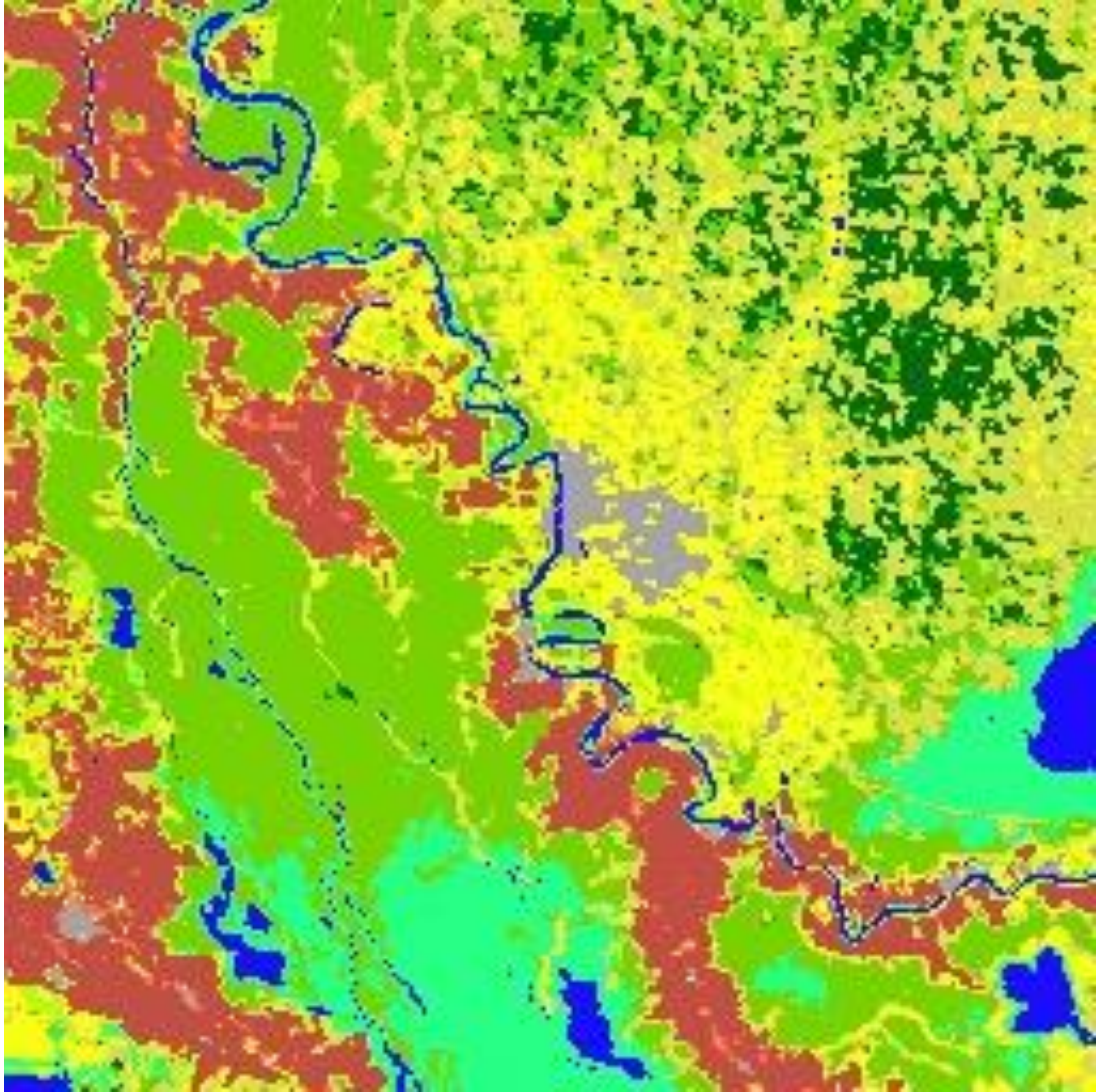
Circuitscape

- Resistance, Voltage, Current
- Identifying Barriers and Probability of Animal Movement



Fragstats

- Calculating Landscape Metrics
- Mean Patch Size, Edge Density, Diversity Indices
- Compare to Home Ranges

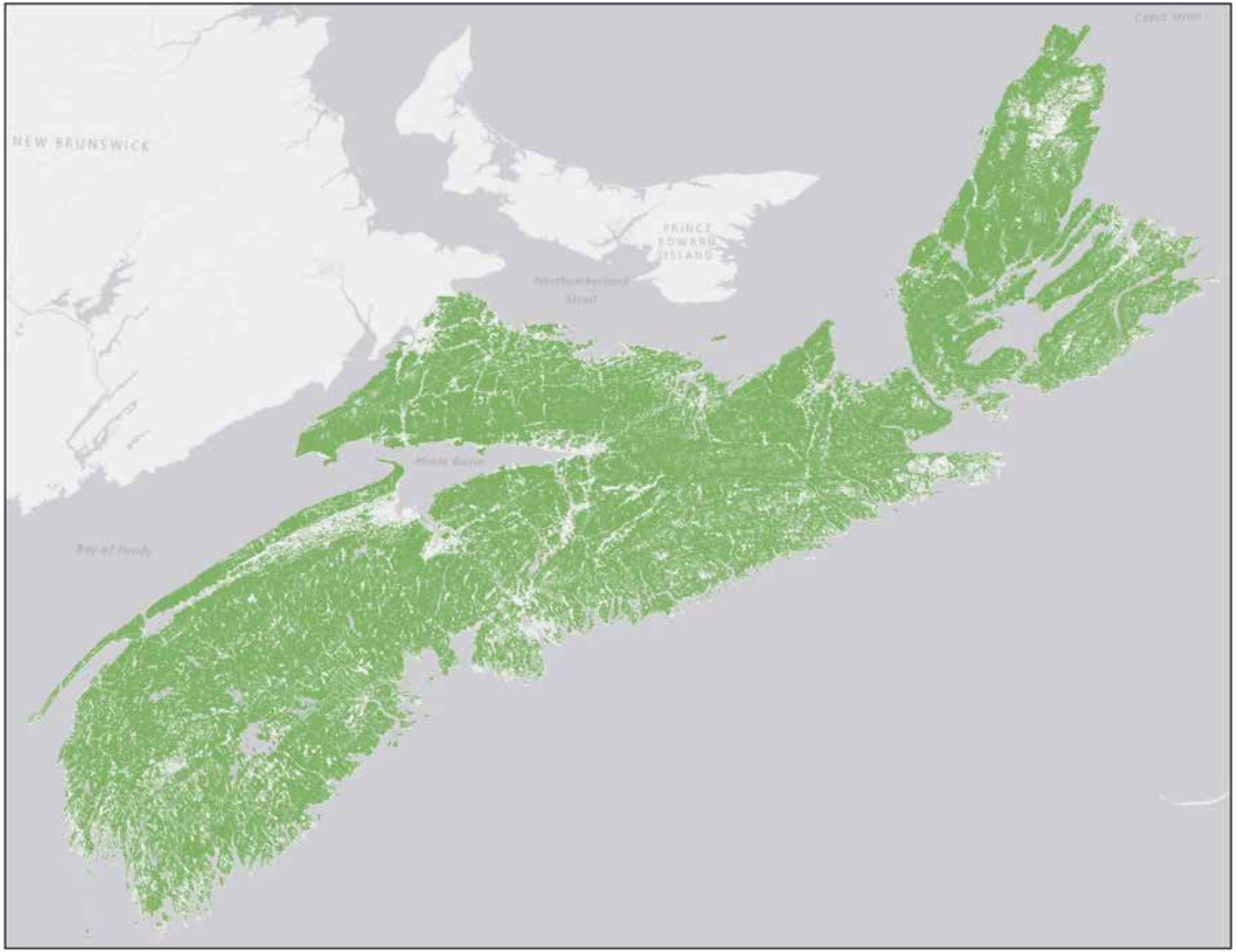


What is a forest?

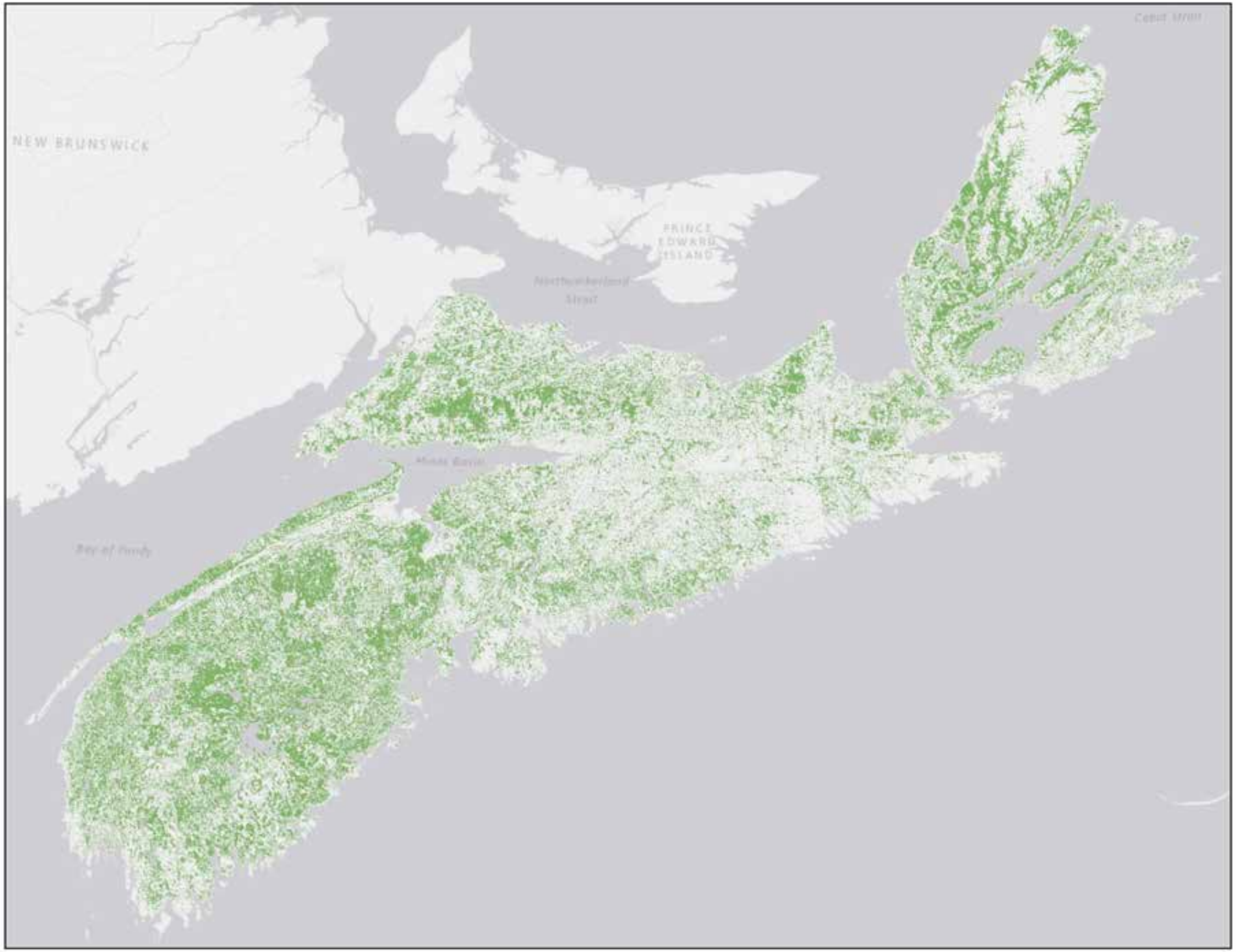

Emera

Multiple Definitions of Forest

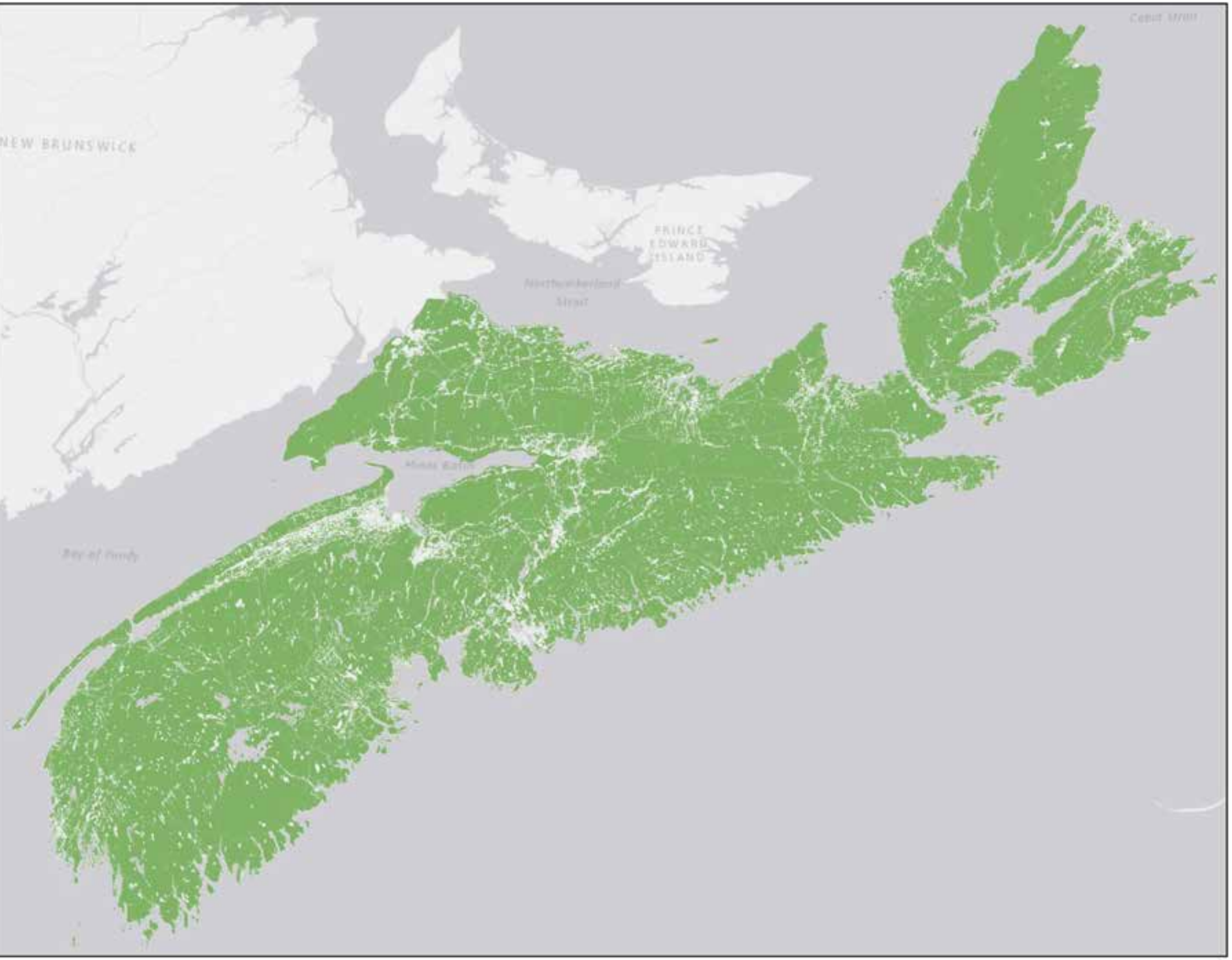
- Forest: Any Treed Ecosystem
- Mature Forest: Natural Stands over 40 years of age
- Natural Landscape: Any non-anthropogenic land class


NEW BRUNSWICK
PRINCE EDWARD ISLAND
Northumberland Strait
Minas Basin
Bay of Fundy

All Forest



Mature Forest



Natural Landscapes

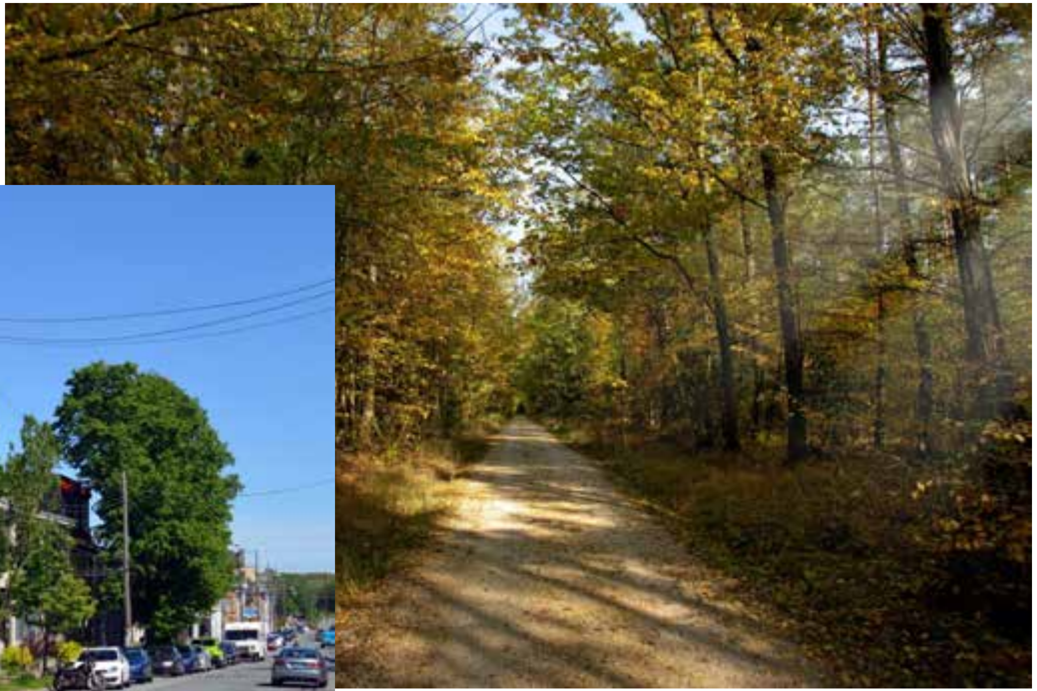
Influence of Roads on Connectivity

- Major source of fragmentation
- Detrimental effects on wildlife movement

Road Effect Zone

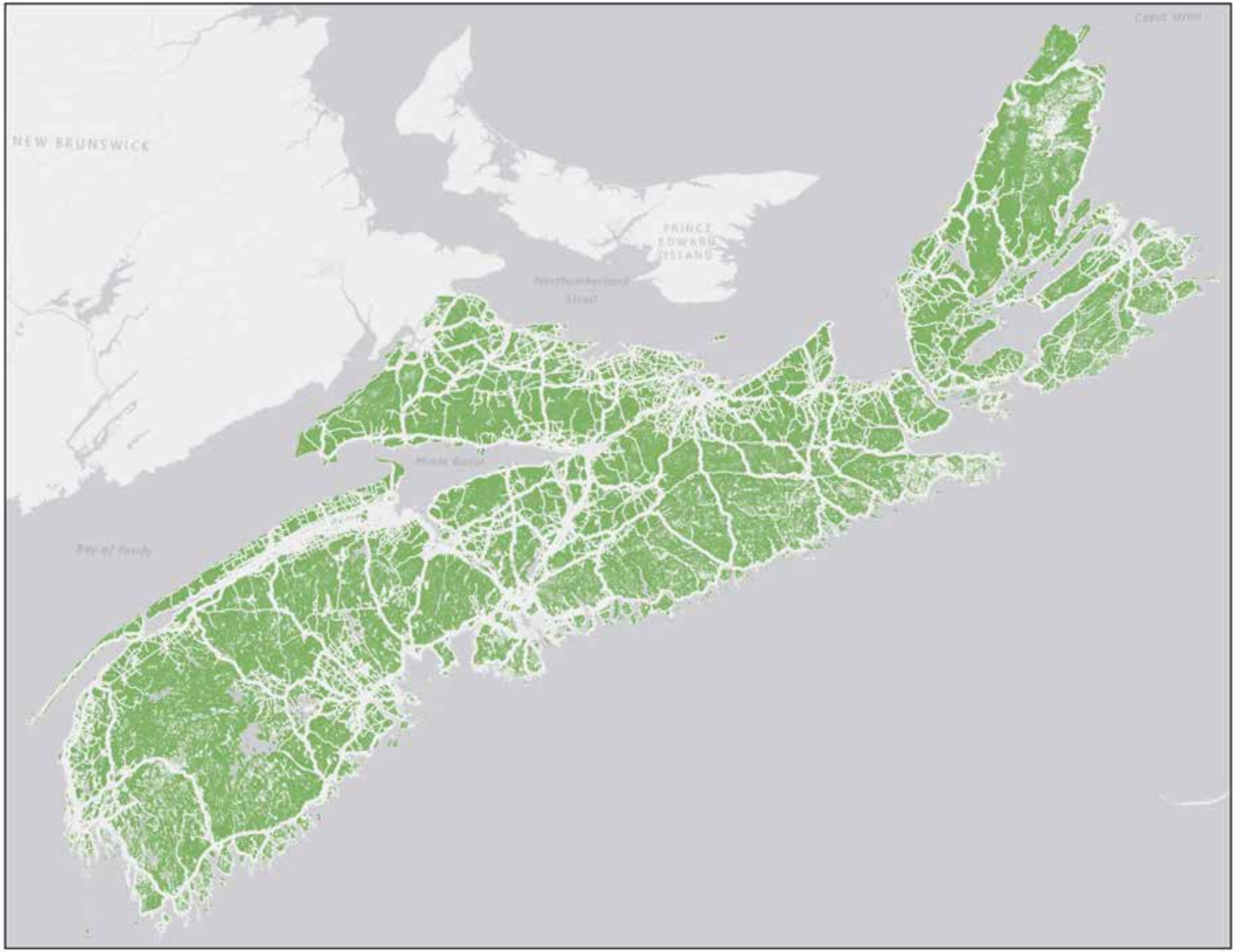
Area affected by roads

Variety of factors considered including roadkill, dust, road salt and wildlife avoidance

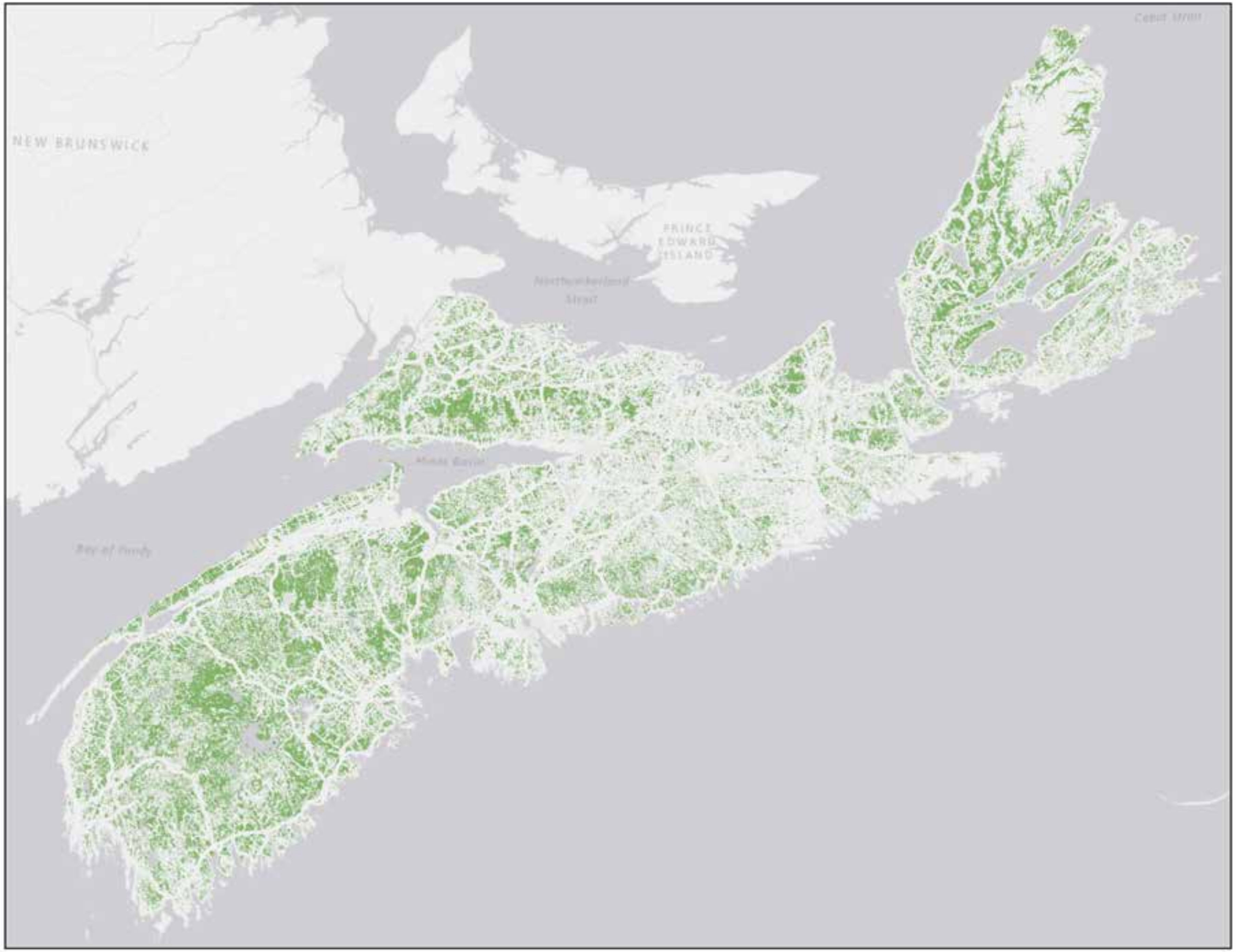


Road Types	Road Effect Zone
Highway/Service Lane; Arterial/Collectors; Local/Street (Urban)	810 m
Local/Street (Rural)	305 m
Resource/Recreation	200 m

(Forman, 2000)

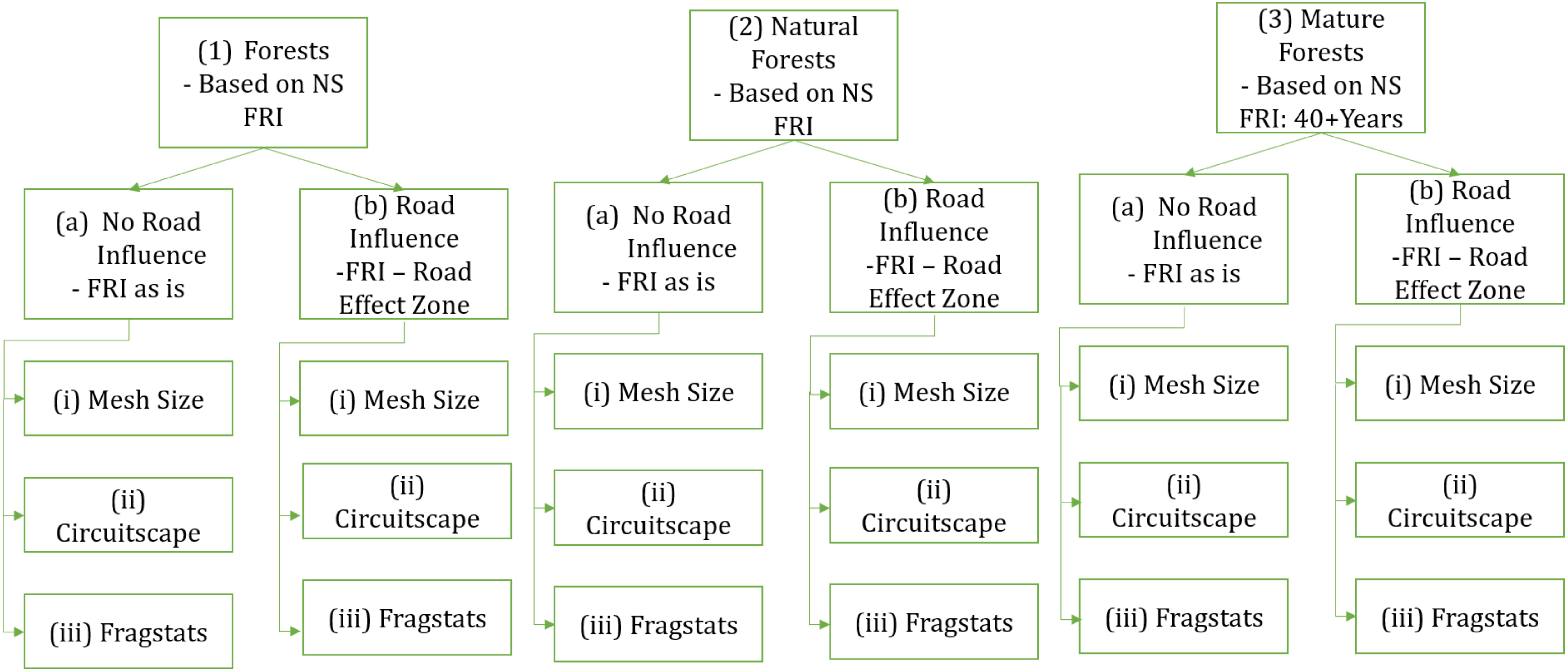

Cabot Strait
NEW BRUNSWICK
PRINCE EDWARD ISLAND
Northumberland Strait
Minas Basin
Bay of Fundy

All Forest



Mature Forest

Natural
andscapes


(1) Forests
- Based on NS FRI
(2) Natural Forests
- Based on NS FRI
(3) Mature Forests
- Based on NS FRI: 40+Years
(a) No Road Influence
- FRI as is
(b) Road Influence
-FRI – Road Effect Zone
(a) No Road Influence
- FRI as is
(b) Road Influence
-FRI – Road Effect Zone
(a) No Road Influence
- FRI as is
(b) Road Influence
-FRI – Road Effect Zone
(i) Mesh Size
(ii) Circuitscape
(iii) Fragstats
(i) Mesh Size
(ii) Circuitscape
(iii) Fragstats
(i) Mesh Size
(ii) Circuitscape
(iii) Fragstats
(i) Mesh Size
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(iii) Fragstats
(i) Mesh Size
(ii) Circuitscape
(iii) Fragstats
(i) Mesh Size
(ii) Circuitscape
(iii) Fragstats

Questions? Feedback?

caitlin.cunningham@dal.ca

HALIFAX GREEN NETWORK PLAN

Photo credit: Vlastimil Koutecky, Flickr Creative Commons

Canadian Maritimes Ecological Connectivity Forum
April 25, 2019

NOVA SCOTIA

- Forestry & Mining
- Crown lands
- 100 series Hwys. & pre ’96 rural roads
- Endangered species
- Environmental regulations

HALIFAX

- Land use planning
- Buildings and structures
- Roads, AT, Transit
- Central Services
- Storm Water Management
- Municipal Parks

HGNP PROCESS

PHASE 1| **FOUNDATIONS**

- Trends & Best Practice Analysis
- Public Engagement
- Landscape Values Mapping
- State of the Landscape Report
- Cultural Landscape Framework Study

PHASE 2| **PLAN DIRECTIONS**

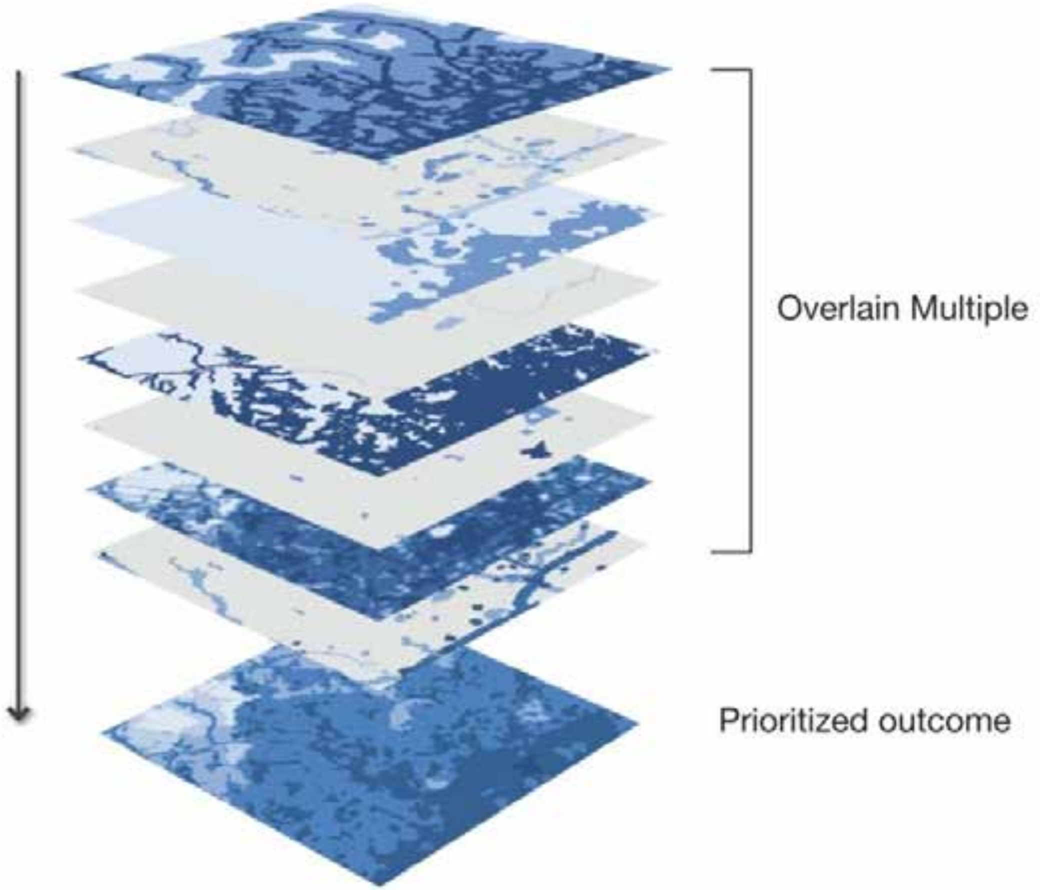
- Public Engagement
- Create Green Network Maps
- Green Network Plan – Primer Document

PHASE 3| **FINAL PLAN**

- Public Engagement
- Develop Final Plan
- Stakeholder Consultation
- Finalize Plan
- CPED/Regional Council

Method & Evidence

- Open space values & issues
- Data collection & analysis
  - 75 + data elements
  - Interacting set of maps
  - High value areas
- Scenarios & Impacts
  - Development impacts
  - Social and cultural impacts
  - Economic impacts
- Geo-Design – creating the
  - preferred network scenario



VALUED ELEMENTS

HALIFAX

ECOSYSTEM + BIODIVERSITY

Areas of Important Biodiversity
Barrens
Endangered Moose Habitat
Essential Connectivity Regions
Forest Mature 100 Years or More
Generalized Connectivity
Important Bird Areas
Large Patches1000 to 5000 Ha
Large Patches 5000 or more Ha
Large Patches 500 to 1000 Ha
Protected Water
Rare Forest
Riparian Buffers
Salmon Habitat (100m Buffer)
Seawater Intrusion Areas
Significant Habitat
Surficial Aquifers
Surficial Geology
Tertiary Watersheds
Watershed Anthropogenic Cover
Water Table Depth upto2meters
Wells Buffered
Wetland Patch Complex Wildlife
Species of Concern Observations

HALIFAX

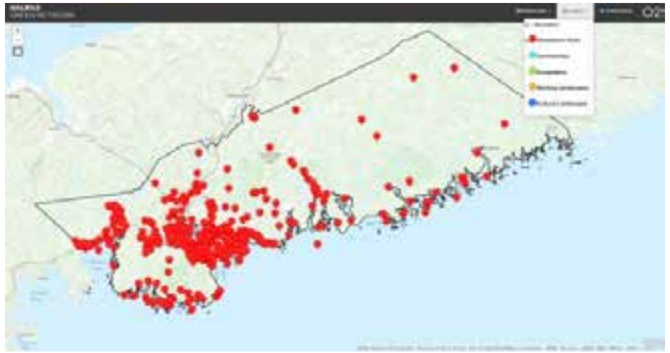
ECOLOGY - SUMMED VALUES

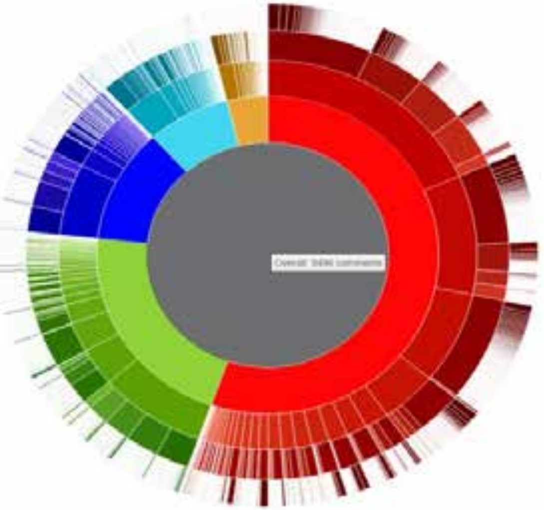
HALIFAX

DRAFT


hfxgov
@hfxgov
Following
Yes, pls take part. 1st event, pop-up at Hfx Central Library, is on May 30, 9am-12pm #openspace
Halifax Cycling @BIKEHFX
Want to see more urban green space? Take part in @hfxgov #greenbelt public engagement events: ow.ly/NuVlZ @SackvilleRivers
RETWEETS 3
FAVORITE 1
11:01 AM - 27 May 2015


PlanHRM
HALIFAX GREEN NETWORK
An Open Space & Greenbelting Priorities Plan for the Region
HALIFAX





RESEARCH & ANALYSIS

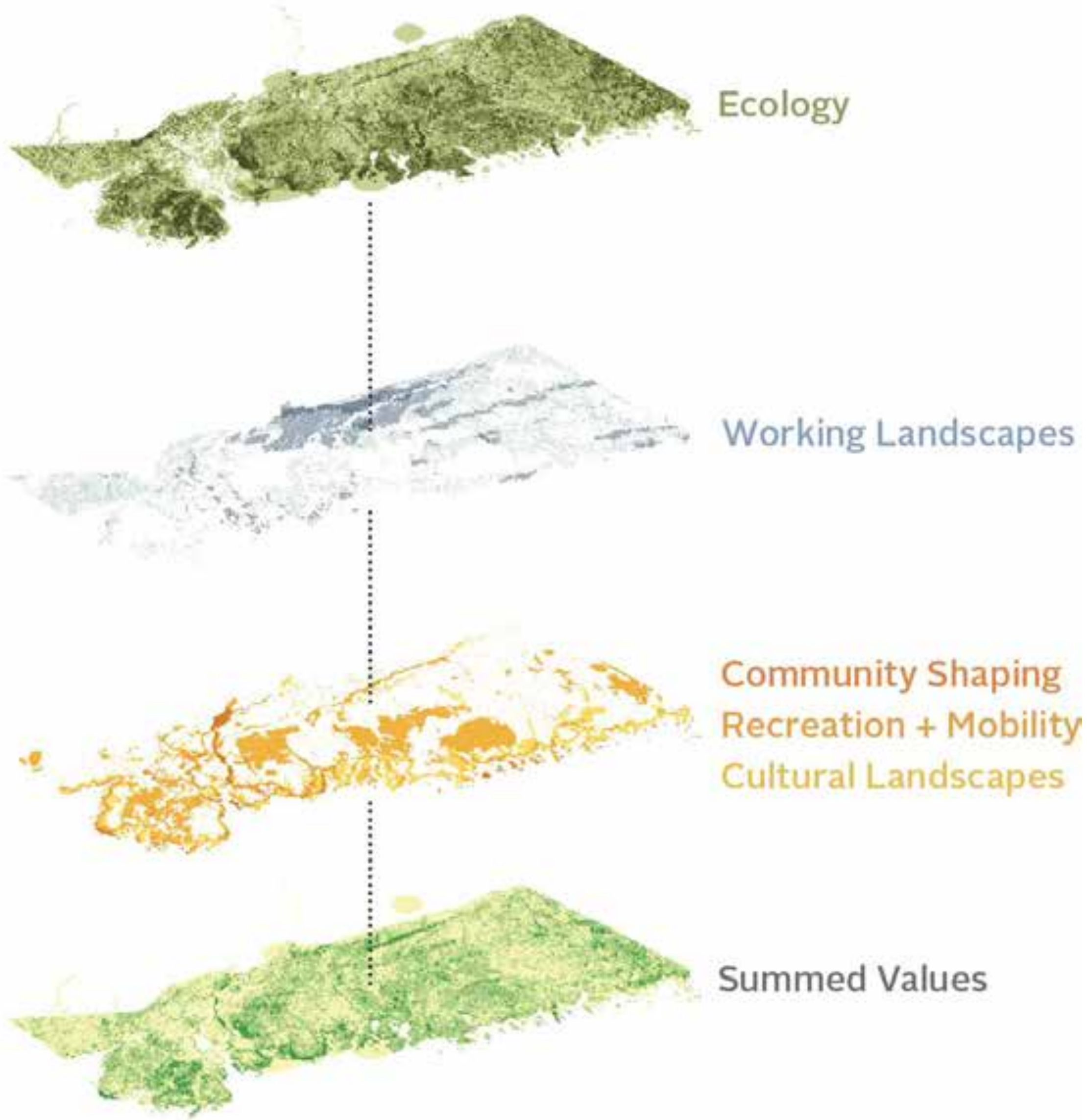


Photo credit: O2 Planning and Design

THEMES


ECOLOGY


WORKING
LANDSCAPES


OUTDOOR
RECREATION

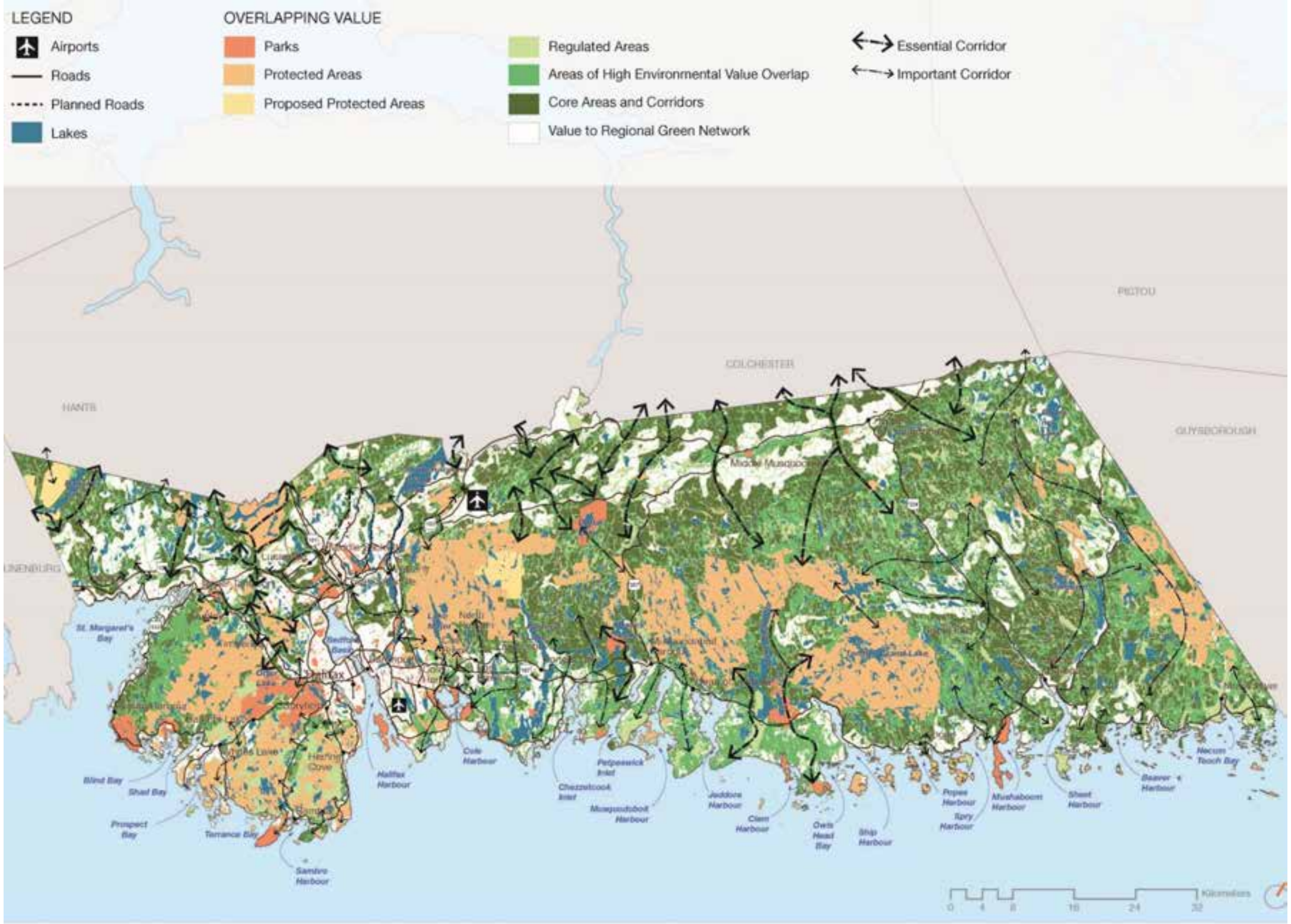

COMMUNITY
SHAPING


CULTURAL
LANDSCAPES

ECOLOGY

Goal: Support a healthy and sustainable natural ecosystem.

Photo credit: Mike Dembeck


LEGEND
Airports
Roads
Planned Roads
Lakes
OVERLAPPING VALUE
Parks
Protected Areas
Proposed Protected Areas
Regulated Areas
Areas of High Environmental Value Overlap
Core Areas and Corridors
Value to Regional Green Network
Essential Corridor
Important Corridor
PICTOU
COLCHESTER
HANTS
GUYSBOROUGH
St. Margaret's Bay
Blind Bay
Shad Bay
Prospect Bay
Terrance Bay
Sambro Harbour
Halifax Harbour
Cole Harbour
Petpeswick Inlet
Chezzetcook Inlet
Musquodoboit Harbour
Jeddore Harbour
Clam Harbour
Owls Head Bay
Ship Harbour
Popes Harbour
Spry Harbour
Mushaboom Harbour
Sheet Harbour
Beaver Harbour
Necum Teuch Bay
Kilometres
0
4
8
16
24
32

KEY HIGHLIGHTS

- adopt the HGNP Ecology Map (Map 5) in the Regional Plan;
- consolidate and apply environmental protection zones to large wetland complexes and vulnerable land forms;
- refine and strengthen existing variable watercourse buffering requirements;
- support naturalized approaches to storm water management; and
- request an amendment to the *HRM Charter* to enable the Municipality to acquire environmental reserves through the subdivision and development process, in addition to parkland dedication requirements.

WORKING LANDSCAPES

Goal: Support the sustainable use and management of the Region’s natural resources.

KEY HIGHLIGHTS

- provide greater as-of-right (streamlined permitting process) opportunities for primary resource industries;
- limit or prohibit conservation design developments (residential development) in the Regional Plan’s Agricultural Designation; and
- relax restrictions on tourism related home-based businesses in rural areas
- consider large scale rural based tourism proposals through discretionary planning process (Council decision, public consultation)

COMMUNITY SHAPING

Goal: Use the Green Network to guide the growth and development of communities.

KEY HIGHLIHGTS

- consider the Green Network when reviewing and considering changes to urban boundaries;
- prioritize the development of brownfield and infill sites over greenfield development areas;
- prioritize the preservation and creation of natural connections to the Chebucto Peninsula; and
- Direct rural development to clearly defined rural centres, while carefully controlling the scale and design of residential development in areas located between these centres.

OUTDOOR RECREATION

Goal: Manage a municipal park network that meets the outdoor recreation needs of residents and visitors, supports ecological and cultural conservation, and shapes community form and identity.

KEY HIGHLIGHTS

- promote the importance of parks for community health and well-being;
- evaluate service delivery gaps and overlap;
- use the land capability tool, included in the HGNP, to evaluate existing and proposed parks;
- establish an Open Space Network in cooperation with provincial and federal governments and conservation groups;
- continue to place emphasis on establishing the Regional Parks identified in the Regional Plan, while recognizing new nature parks and open space areas; and
- request an amendment to the *HRM Charter* to enable the Municipality to establish parkland dedication requirements based on density.

CULTURAL LANDSCAPES

Goal: Identify, preserve and celebrate cultural landscapes and their value in connecting people to the land and telling their stories.

KEY HIGHLIGHTS

- develop a cultural landscape program;
- clarify the scope and role of cultural landscapes studies as part of master planning exercises; and
- proactively engage underrepresented groups to identify valued cultural landscapes.

MONITORING

- Regional Plan Key Performance Indicators

- Develop partnerships with federal and provincial departments, universities and non-profit groups
  - Wildlife movements & biodiversity
  - Water quality & quality
  - Green cover

IMPLEMENTATION

- 79 actions
- Four types of implementation tools
  - Land Use Planning
  - Park Network Management
  - Current and Future Project Work
  - Partnerships
- Immediate and on-going guidance to activities and decisions
- Short (1-2 year), medium (2-4 year) or long (4-7 year) timeframes

HALIFAX GREEN NETWORK PLAN

Questions?

Photo credit: Vlastimil Koutecky, Flickr Creative Commons

Integrating Wildlife Connectivity with Municipal Land Use Planning in Cumberland, NS

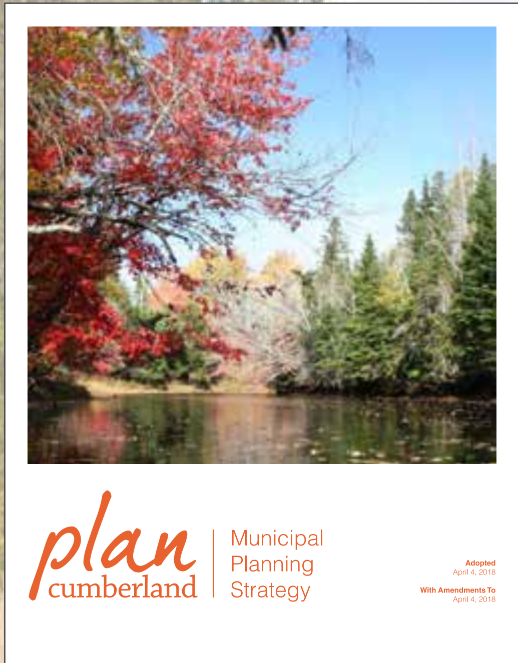
April 25, 2019

Canadian Maritimes Ecological Connectivity Forum


UPLAND

CHAPTER 18 OF THE ACTS OF 1998
An Act Respecting Municipal Government

The Municipal Government Act
(“MGA”)



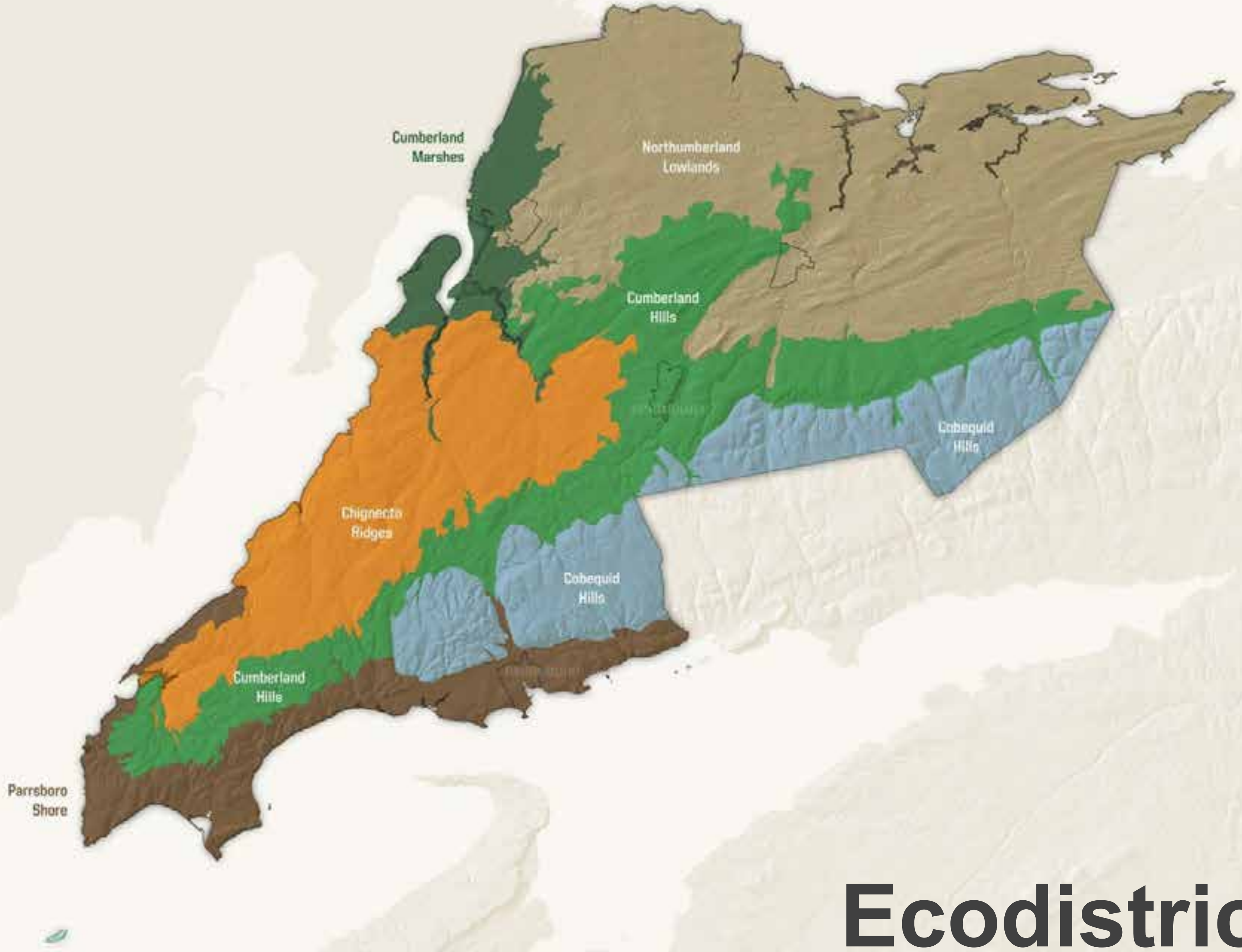
Municipal Planning Strategy ("MPS")

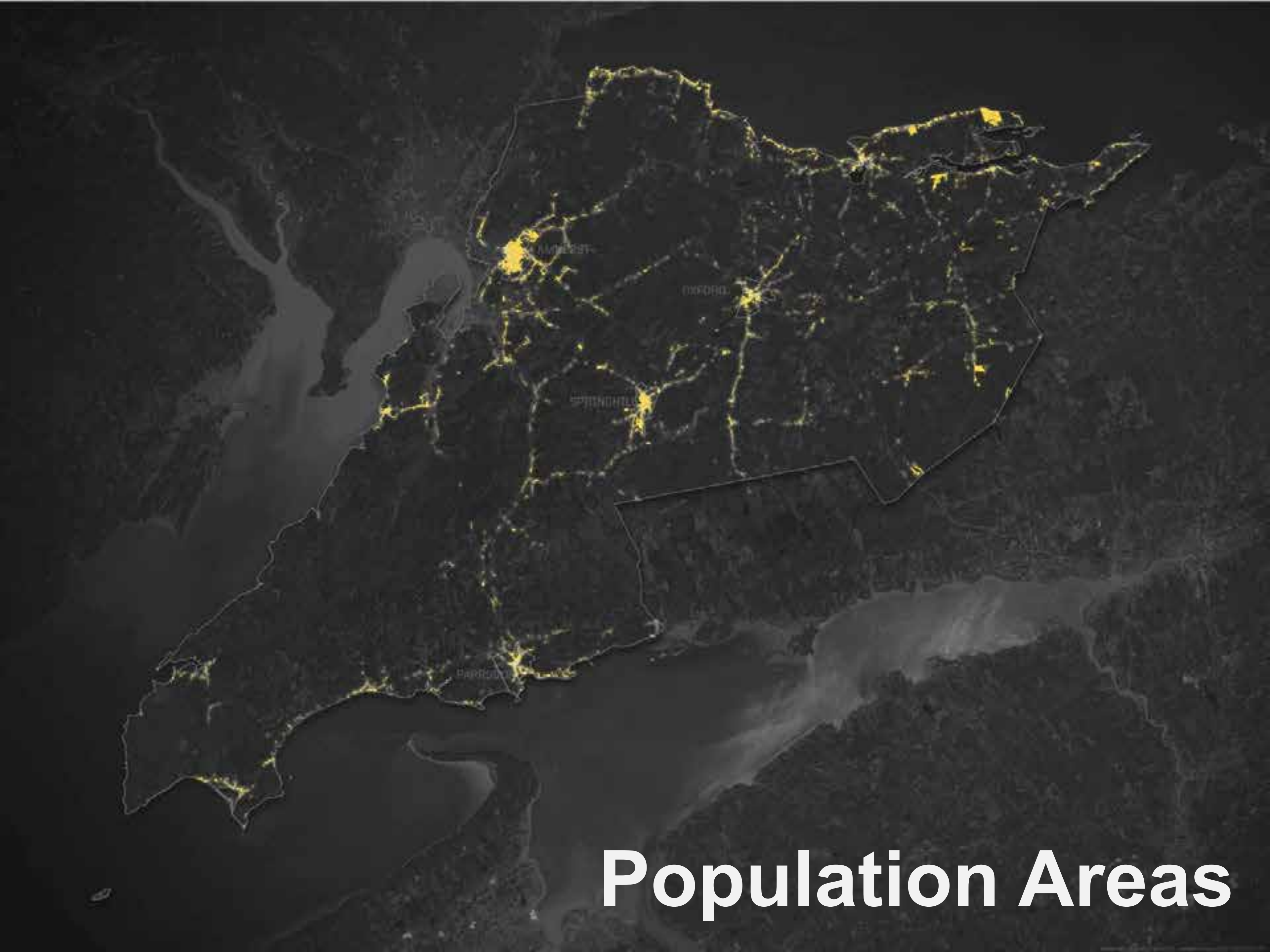
- Overarching vision for the community
- Statement of values
- Policies for land use and development
- Procedures and considerations for changing the plan
- Considerations for discretionary proposals

Land Use By-law ("LUB")

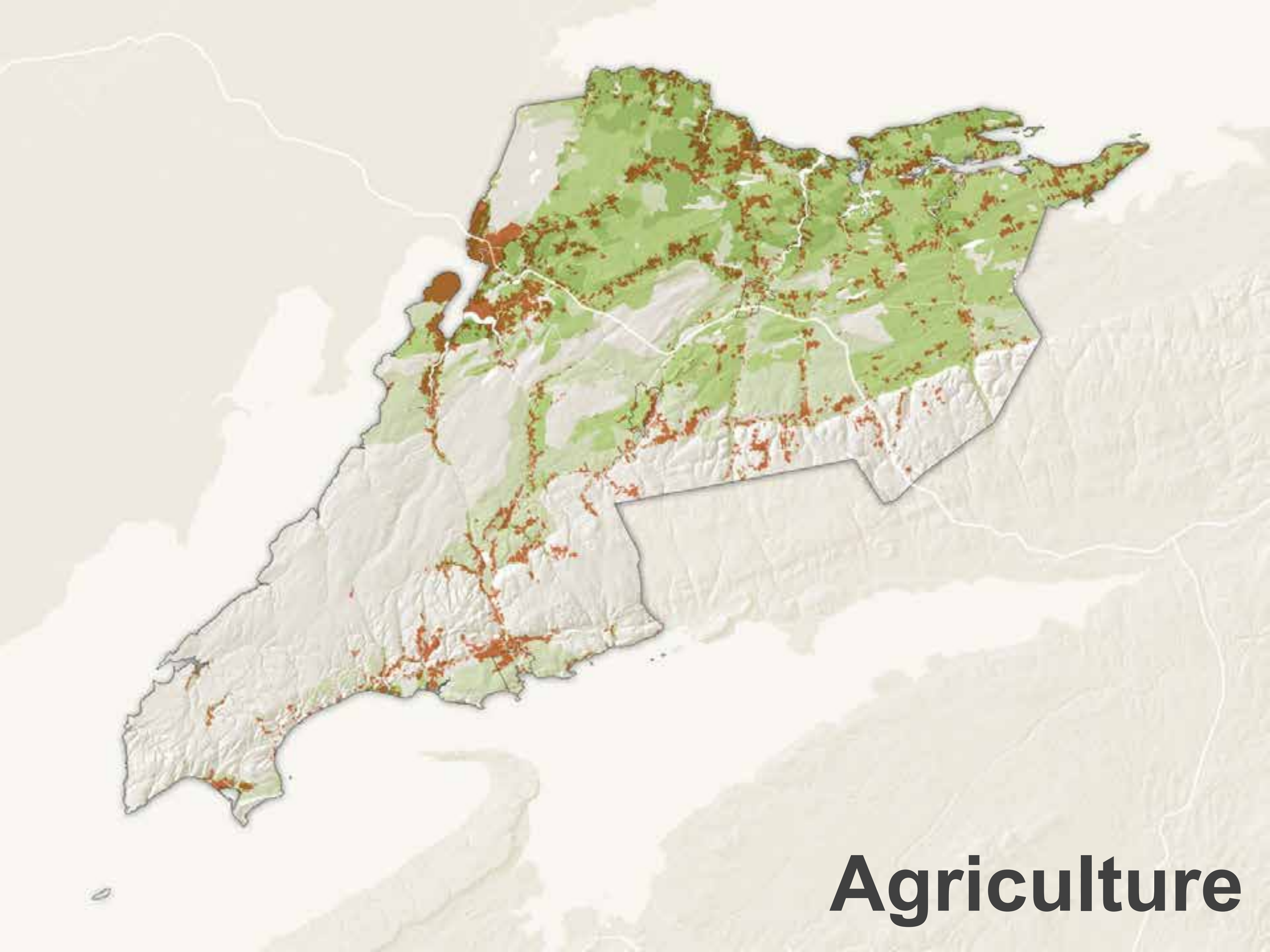
- Regulations for implementing the MPS
- Zoning
- Procedures for issuing permits
- Controls USES and FORM

Ecodistricts

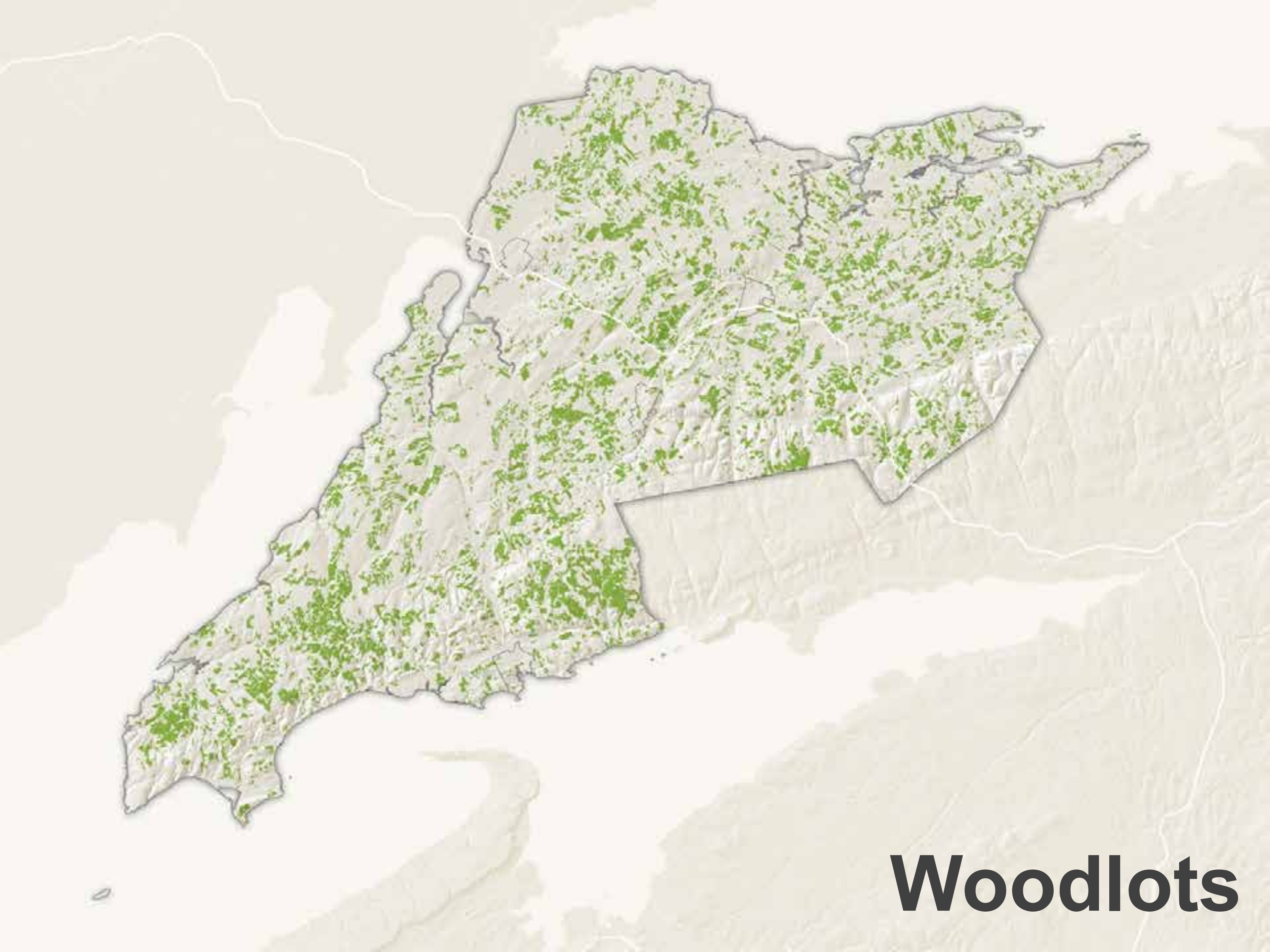




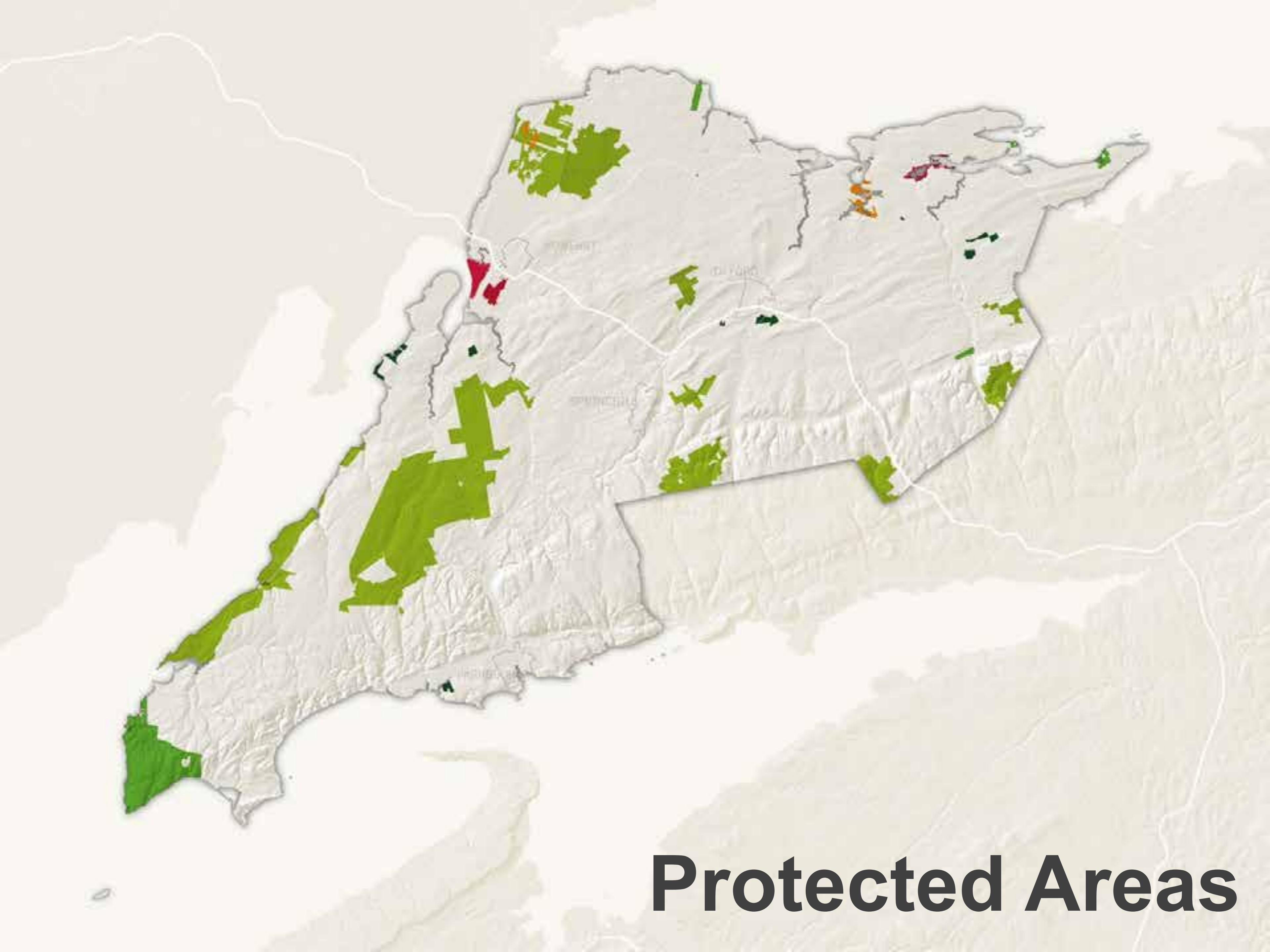
Population Areas



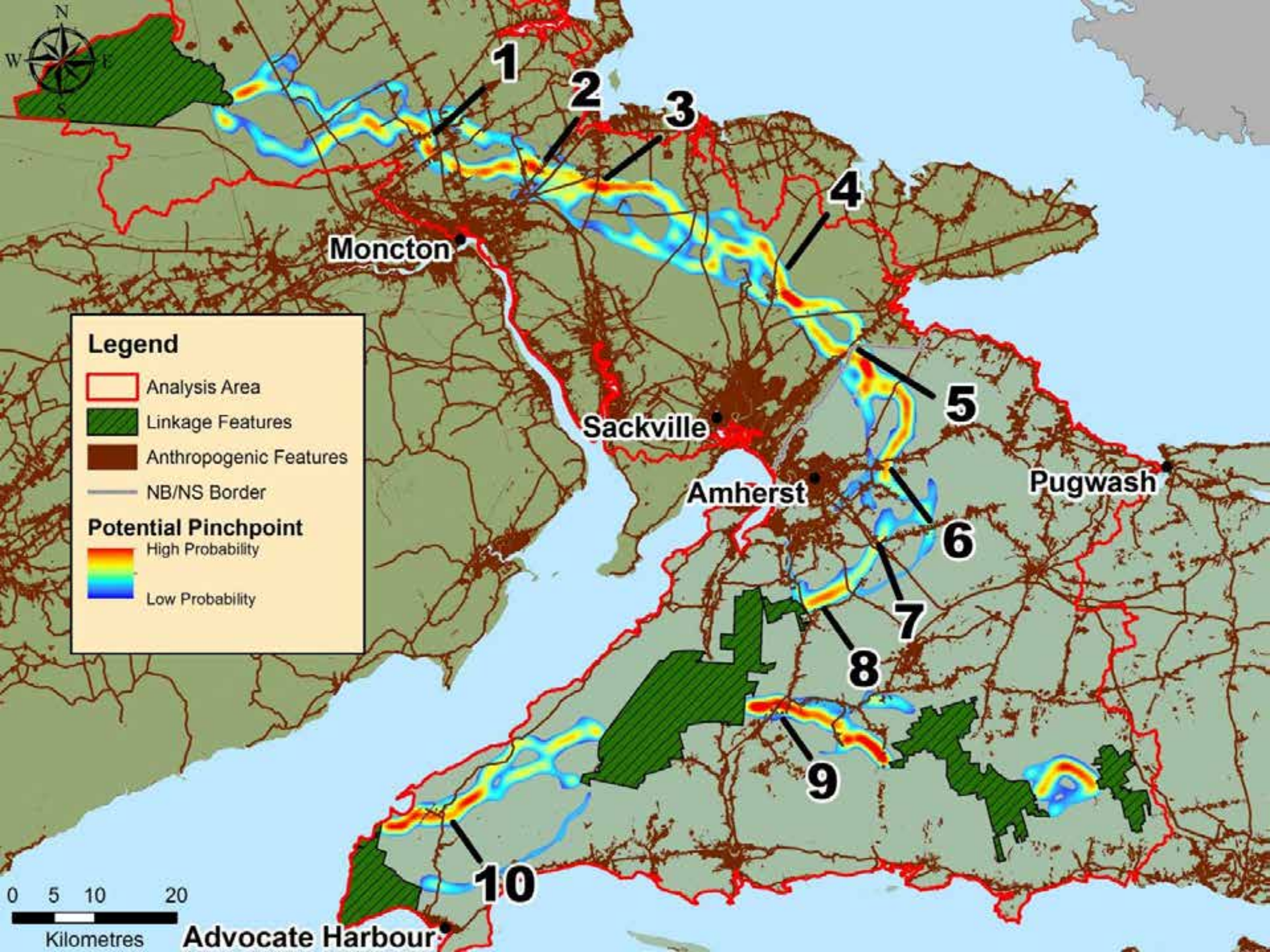
Agriculture



Woodlots



Protected Areas



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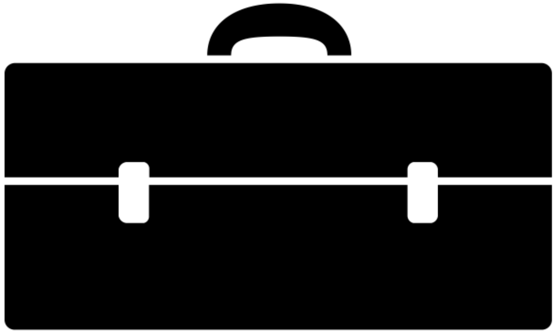
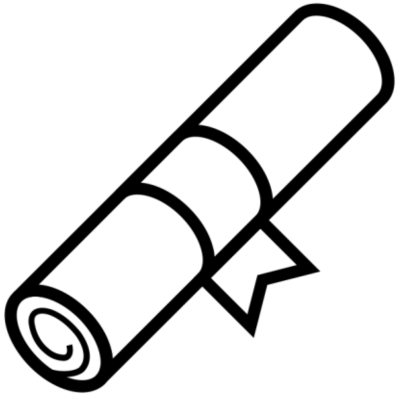
Moncton
Sackville
Amherst
Pugwash
Advocate Harbour
Legend
Analysis Area
Linkage Features
Anthropogenic Features
NB/NS Border
Potential Pinchpoint
High Probability
Low Probability
0 5 10 20
Kilometres

Challenges

1



2



Direct Approach

"[…]

Council ***recognizes the important role*** *that Cumberland's landscapes play in supporting Nova Scotia's wildlife populations, and wishes to support the work of the Nature Conservancy and other organizations working to preserve the lands most valuable to conservation efforts.* ***Council encourages the formal designation of wildlife connectivity corridors****. Council has also elected to—as part of making a decision on planning applications—****consider whether a proposed development would have an inappropriate impact on wildlife connectivity.****"*

Schedule B: **Sensitive Environments**

Cumberland County
Sensitive Environments
Towns + FN Reserves
Core Wilderness

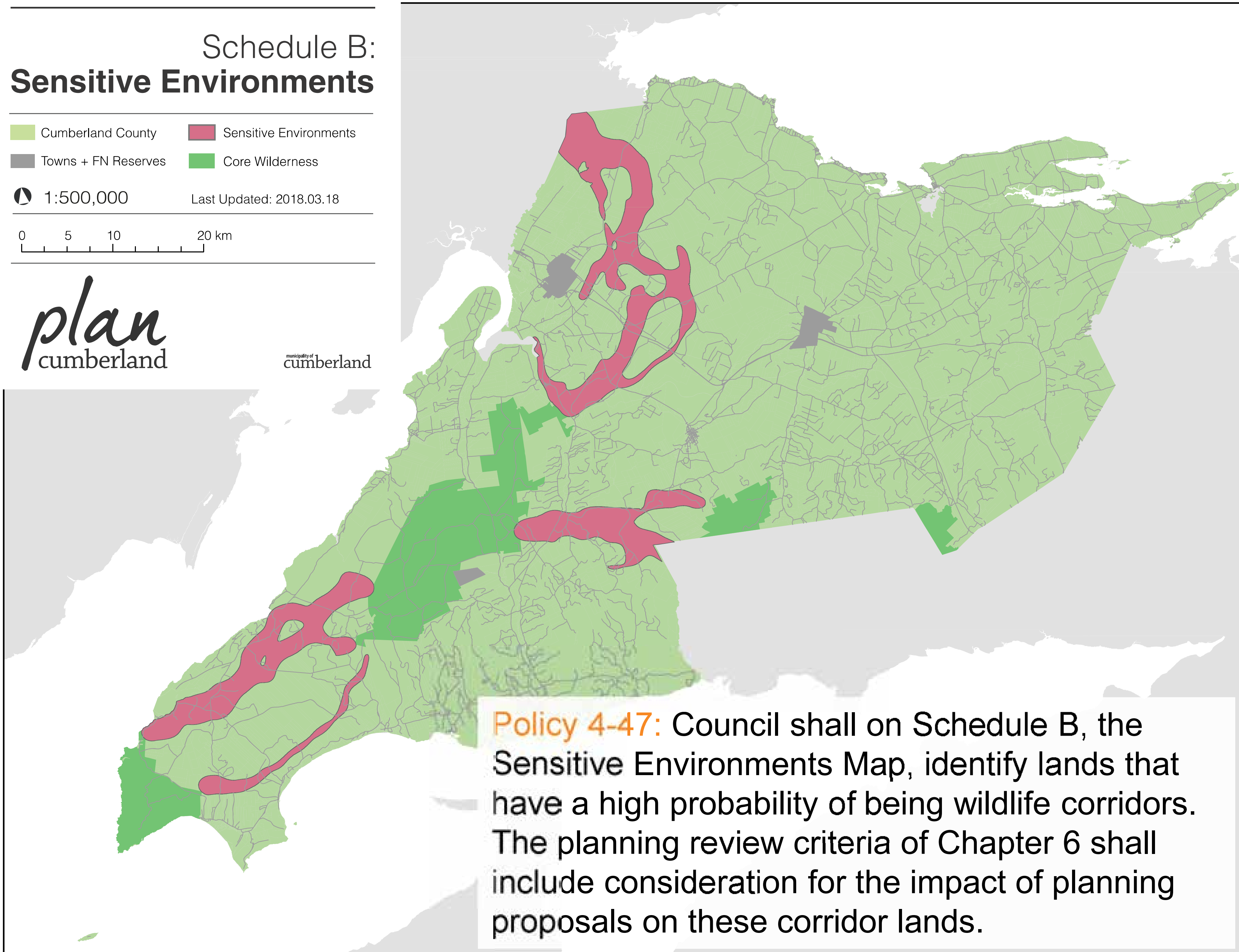
1:500,000

Last Updated: 2018.03.18

0 5 10 20 km

plan cumberland

municipality of cumberland

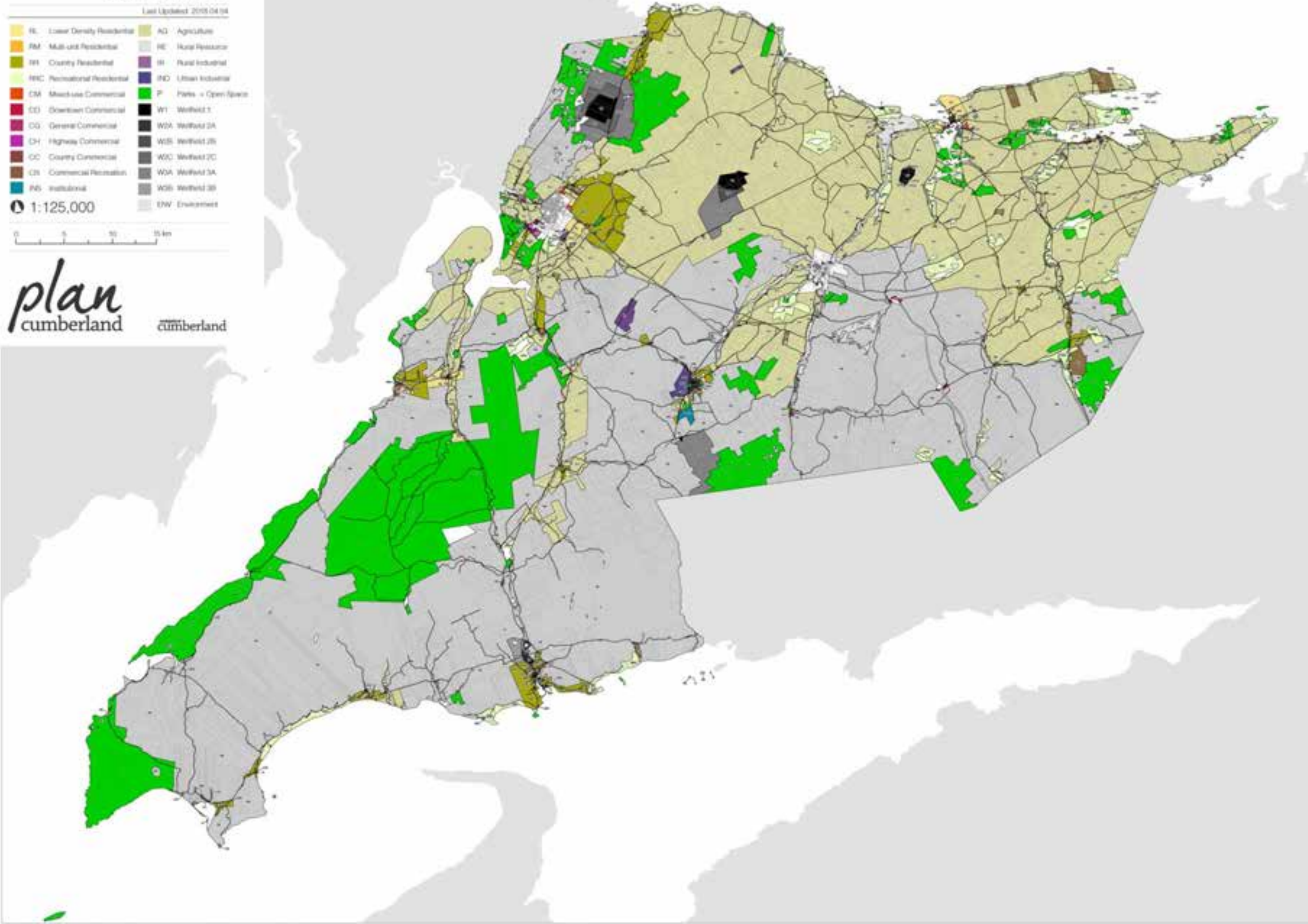


Policy 4-47: Council shall on Schedule B, the Sensitive Environments Map, identify lands that have a high probability of being wildlife corridors. The planning review criteria of Chapter 6 shall include consideration for the impact of planning proposals on these corridor lands.

Indirect Approach

Schedule A:

Land Use Zoning Map Cumberland



Thank You!

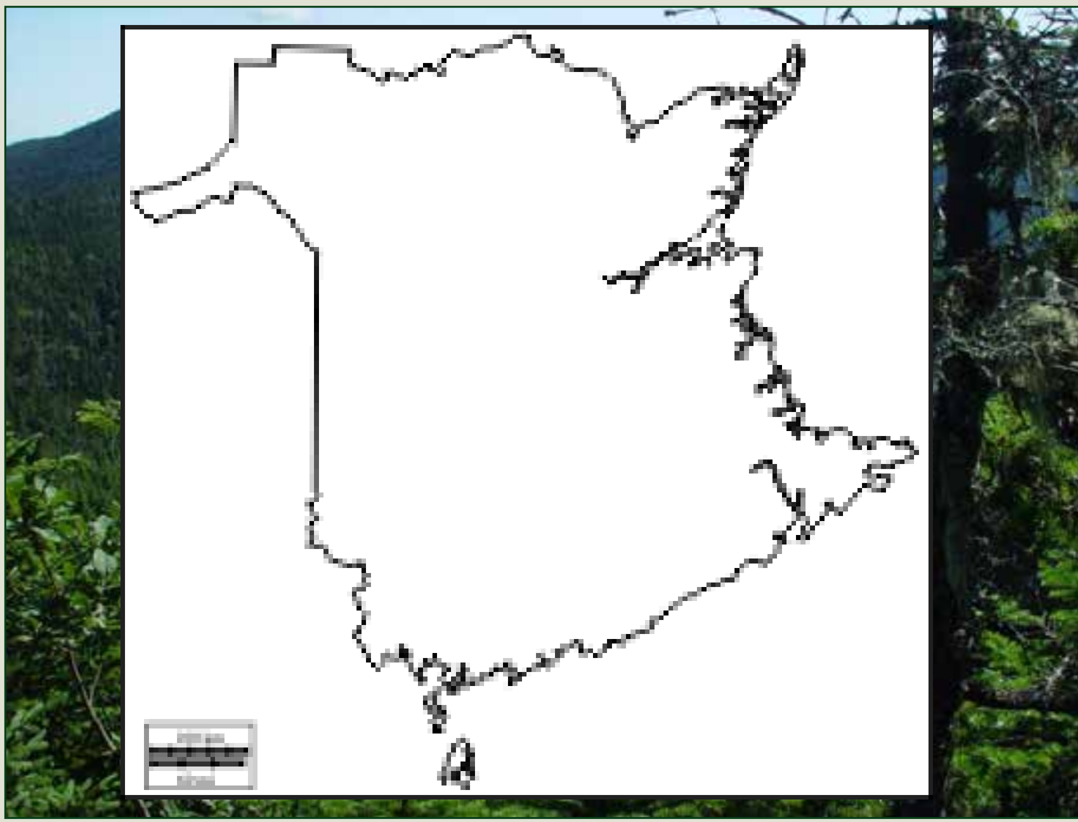
ian@uplandstudio.ca
902.423.0649

Maine’s Habitat Outreach Program: Providing Technical Assistance at Multiple Scales

Amanda Shearin, Habitat Outreach Coordinator/Wildlife Planner
Maine Department of Inland Fisheries and Wildlife



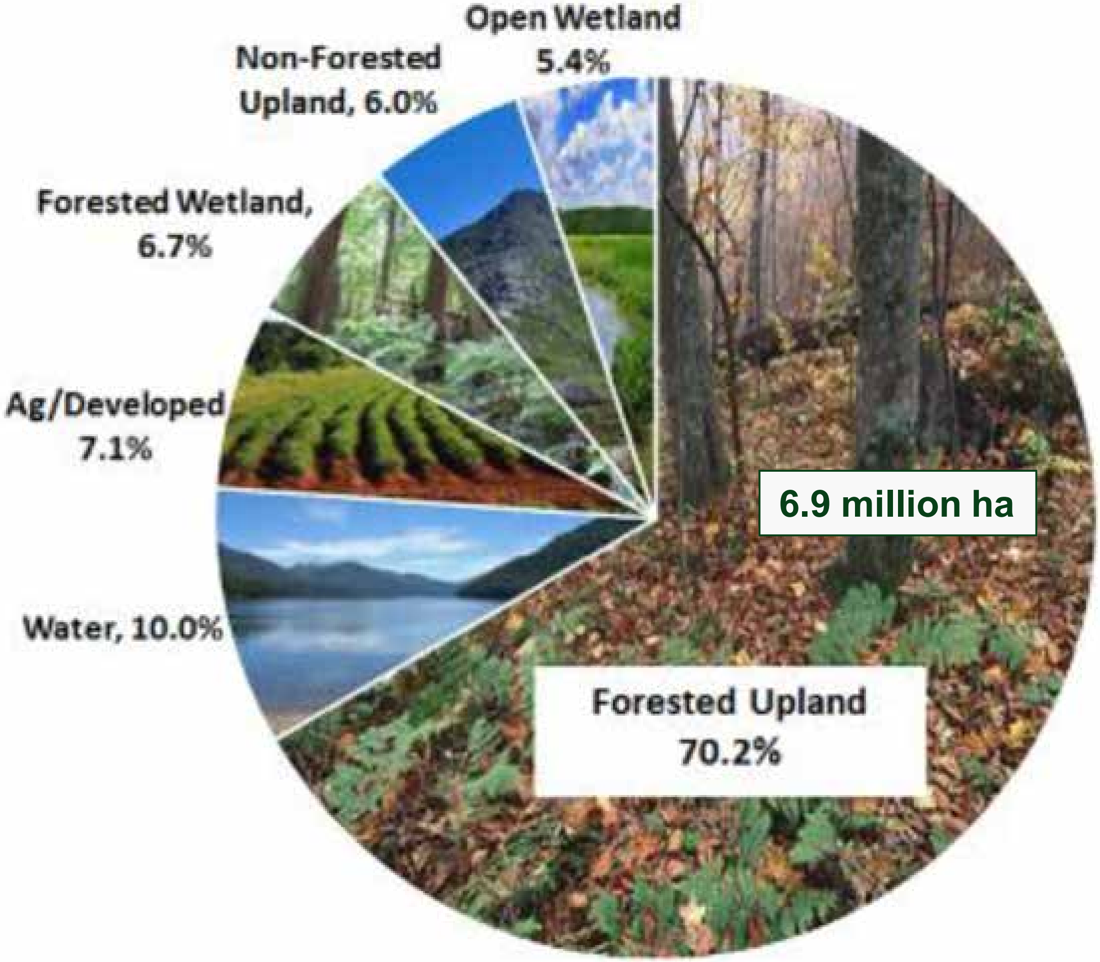

A Maine Crash Course



94% privately owned

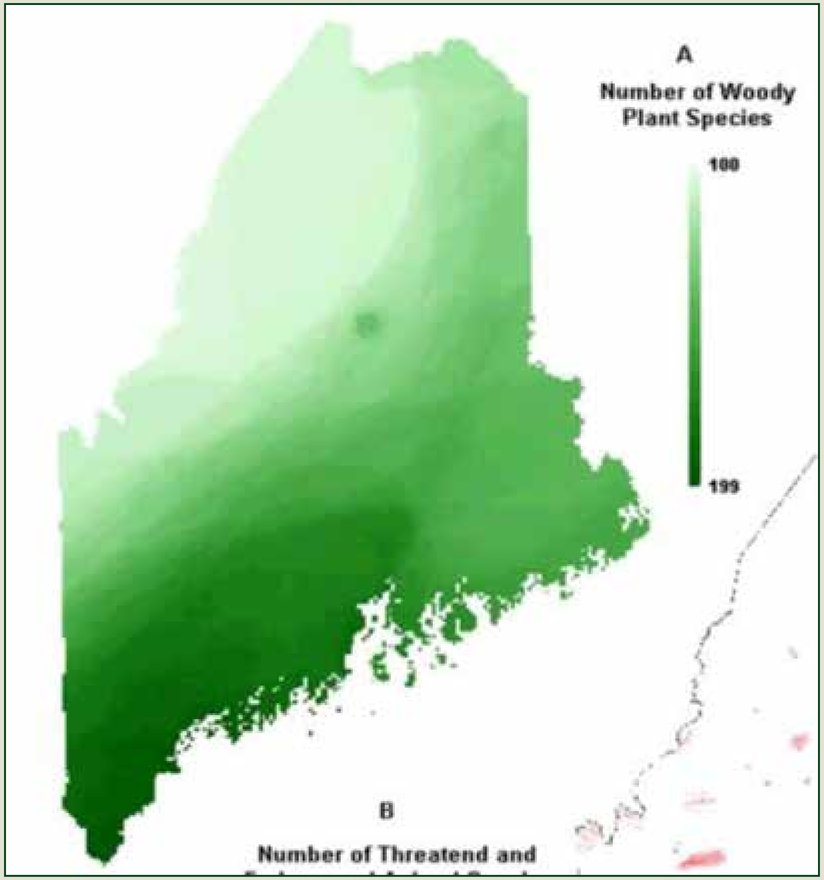
- 61% corporate
- 33% family forests

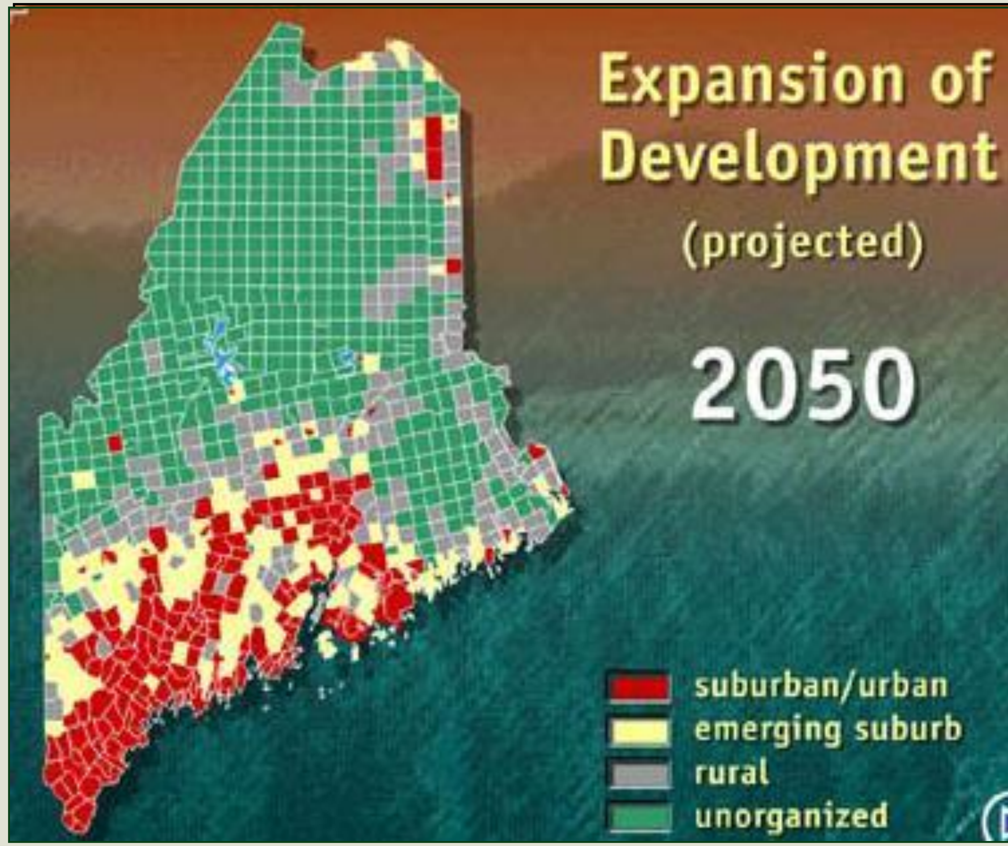
Major Habitat Types



From Element 2, 2015-2025 Maine Wildlife Action Plan

Biodiversity and Development



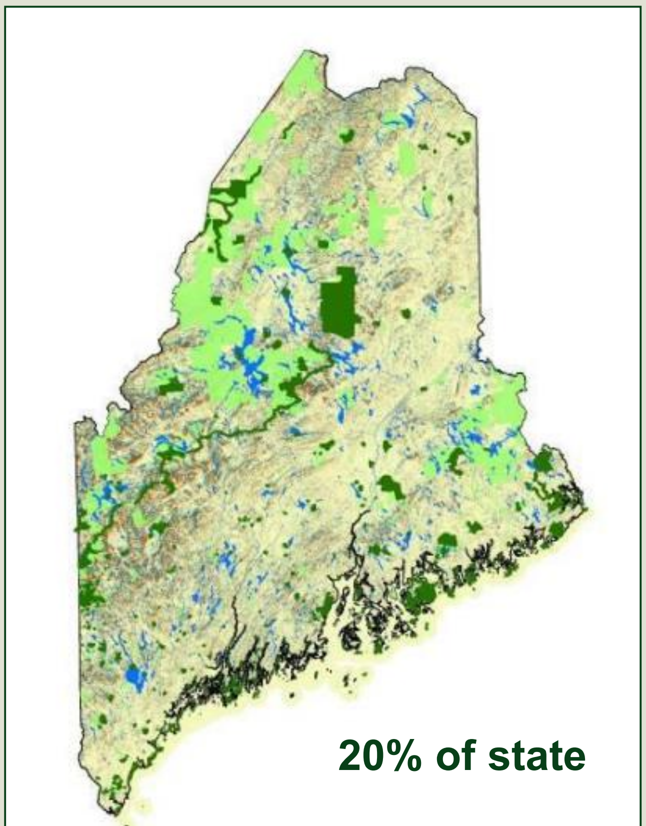


The landscape is changing the most where the highest biodiversity is

Conserved Lands*

* Conserved means fee lands and easements

Disproportionate Distribution



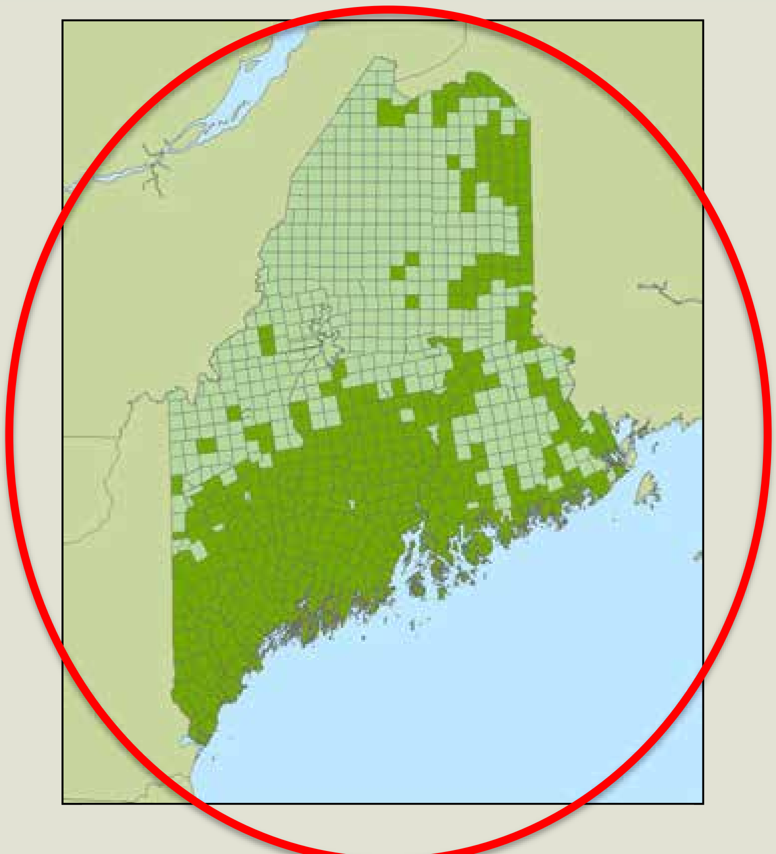
Schlawin and Cutko 2014

Disproportionate Habitats

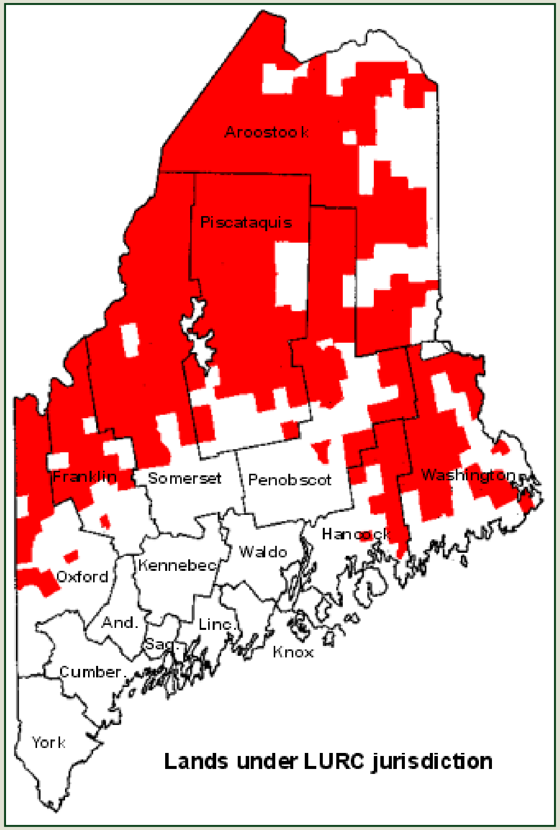
Example Habitat	% of State	% Conserved
Northern Hardwood & Conifer	39.9%	17.1%
Boreal Upland Forest	29.8%	26.0%
Emergent Marsh	1.9%	52.2%
Alpine	0.02%	99.1%

A Note on Planning

Organized Towns



Unorganized Towns



Maine: A Home Rule State

- 492 organized towns
  - Independent growth and development visions
- Most land use decisions made by volunteer boards and Code Enforcement Officers
- Local development often does not trigger resource agency involvement

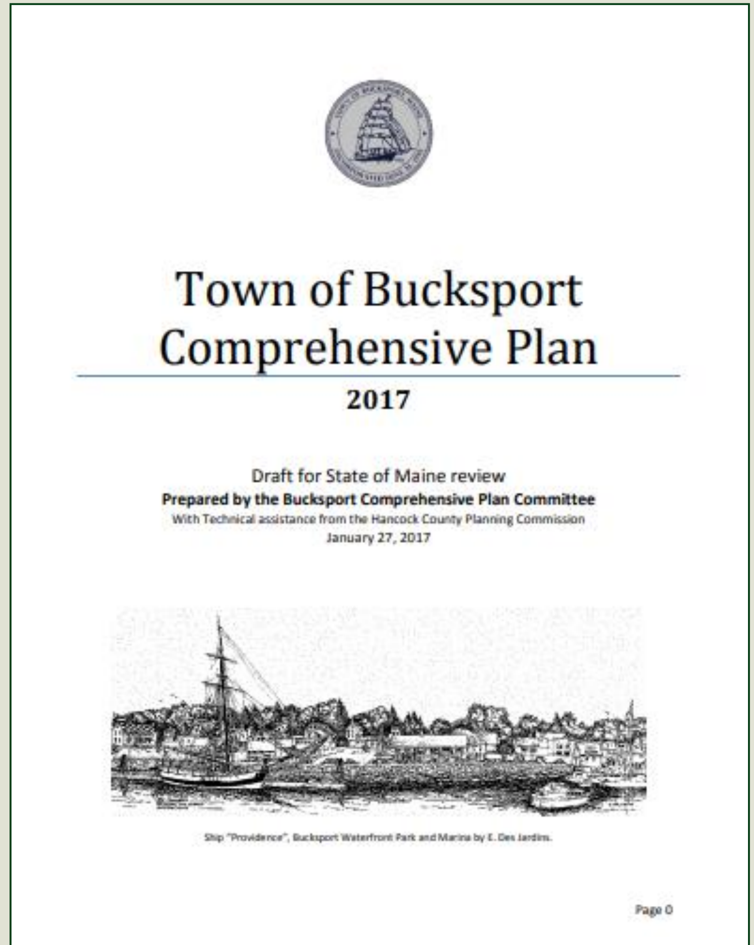
Harpswell, ME; The Forecaster

Diverse Community Visions

Balancing Growth with Conservation

Maine's Growth Management Act (1988)

- Instructs municipalities to create Comprehensive Plans
  - Critical natural resources
    - Rare species and habitats
    - Wetlands
    - Drinking water
  - Recreation
  - Transportation
  - Future land use plan
- Updated every 12 years
- Criteria last updated in 2011
  - Are we due for an update?



Town of Bucksport
Comprehensive Plan

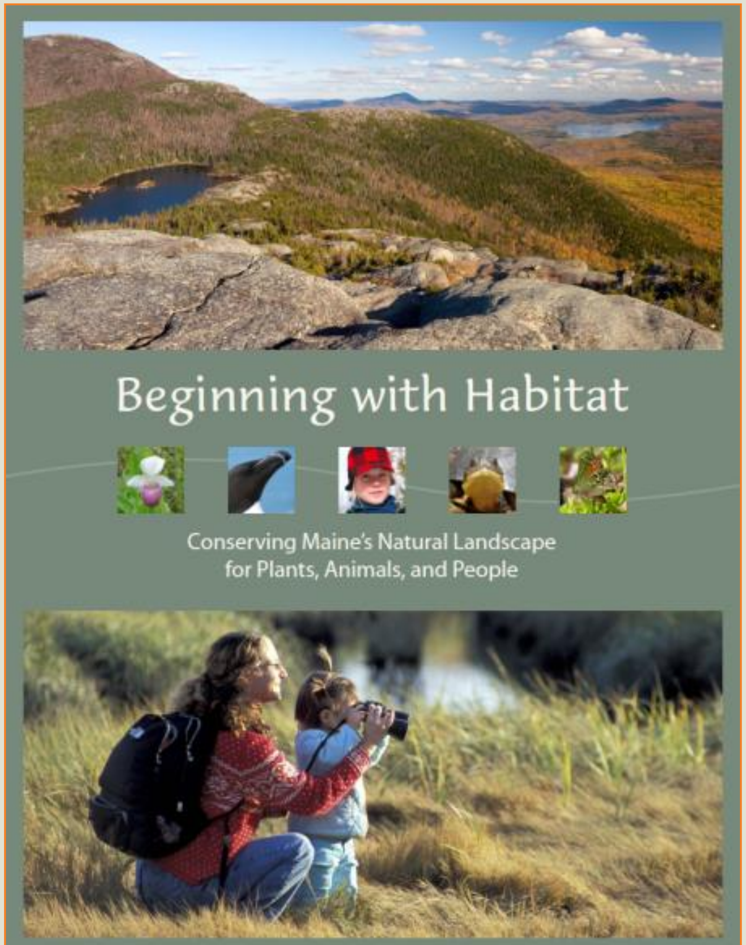
2017

Draft for State of Maine review
Prepared by the Bucksport Comprehensive Plan Committee
With Technical assistance from the Hancock County Planning Commission
January 27, 2017

Ship "Providence", Bucksport Waterfront Park and Marina by E. Des Jardins.

Page 0

A Public Resource for Nearly Two Decades: Beginning with Habitat (BwH)



Beginning with Habitat is…

A voluntary landscape-based approach to achieve meaningful conservation of all native species on a developing landscape.

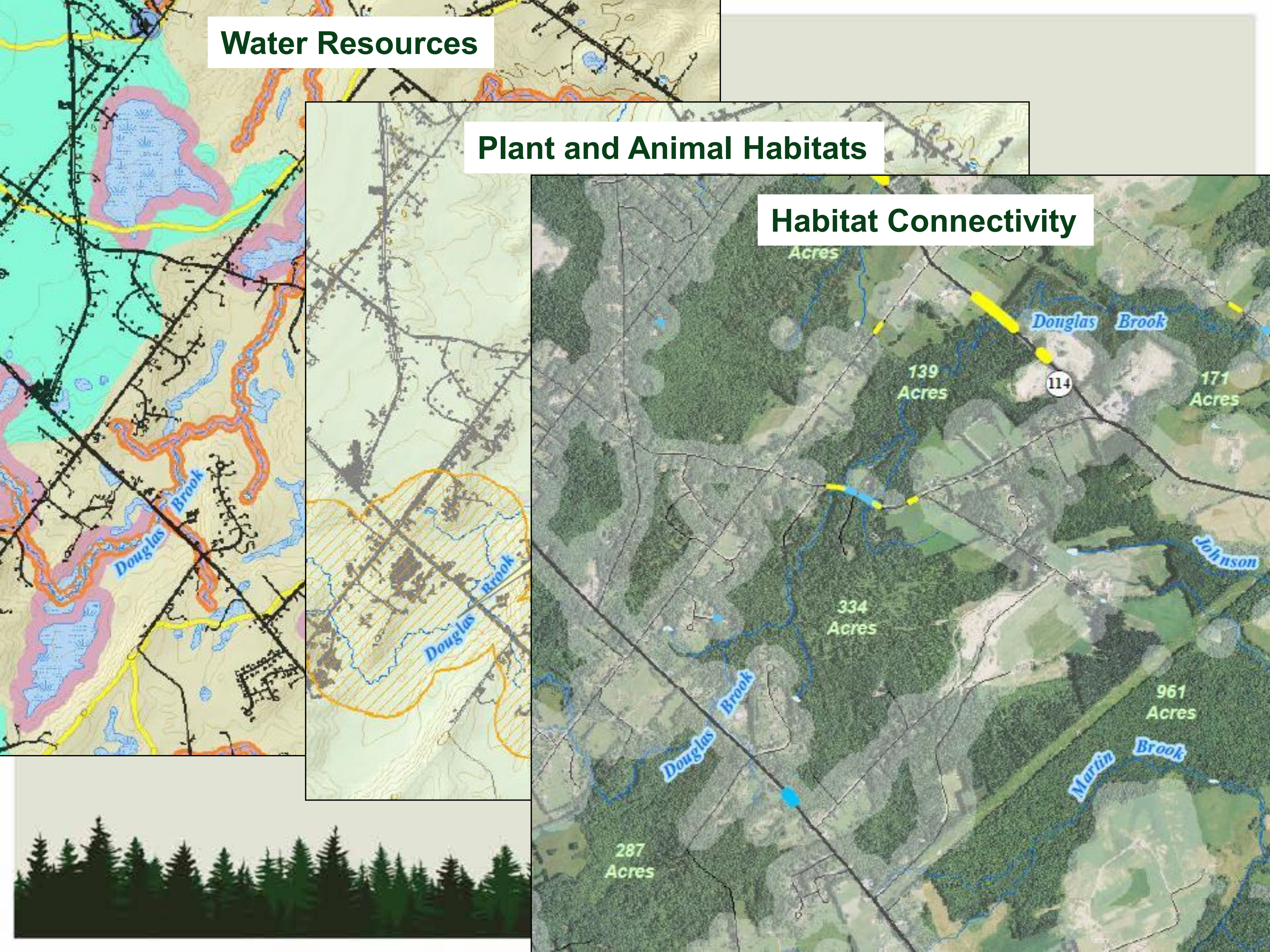
Purpose:

To provide the most up-to-date wildlife and plant habitat information available for use in Comprehensive, Open Space, and Conservation Planning.

Who were we missing???

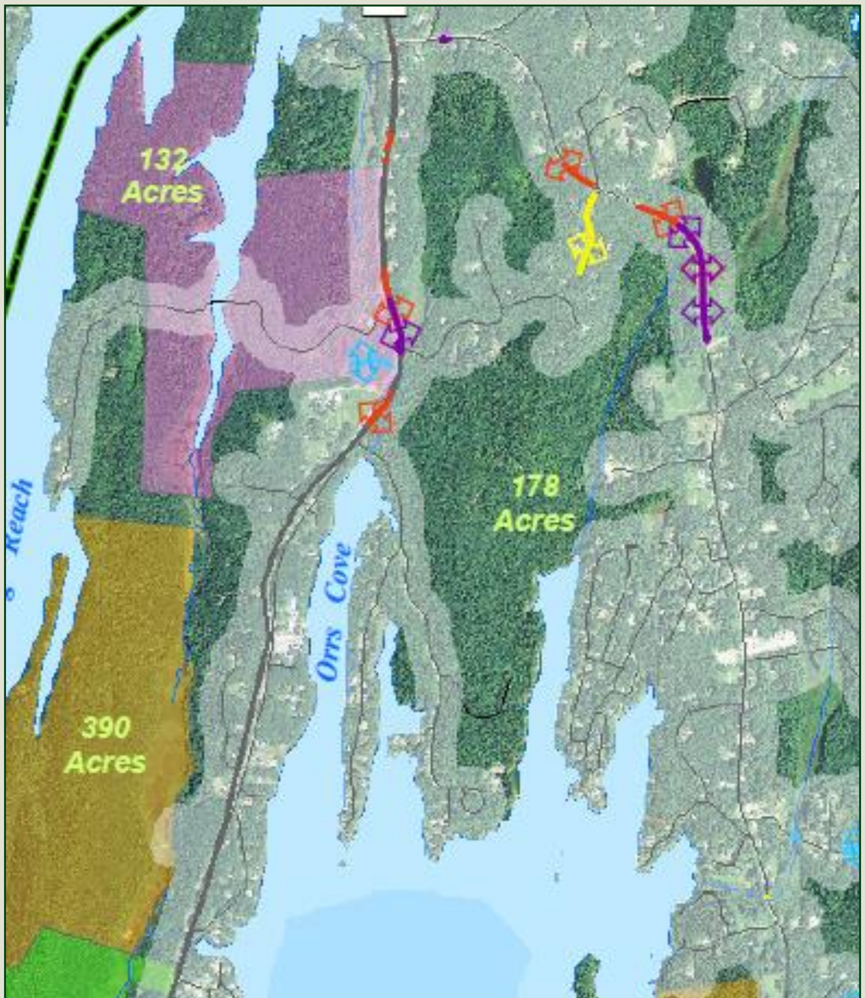
A Consistent, Transparent Partnership

- Multiple stakeholders
- One-stop shopping
- Best, most-updated available science
- Continually evolving
- Efficient
  - 2018: 200 data packages
  - 116 unique towns



Water Resources
Douglas Brook
Plant and Animal Habitats
Douglas Brook
Habitat Connectivity
Acres
Douglas Brook
139 Acres
114
171 Acres
Johnson
334 Acres
961 Acres
Douglas Brook
Martin Brook
287 Acres

Local Connectivity Planning



Terrestrial Crossings

> 2000 vehicles day^{-1}

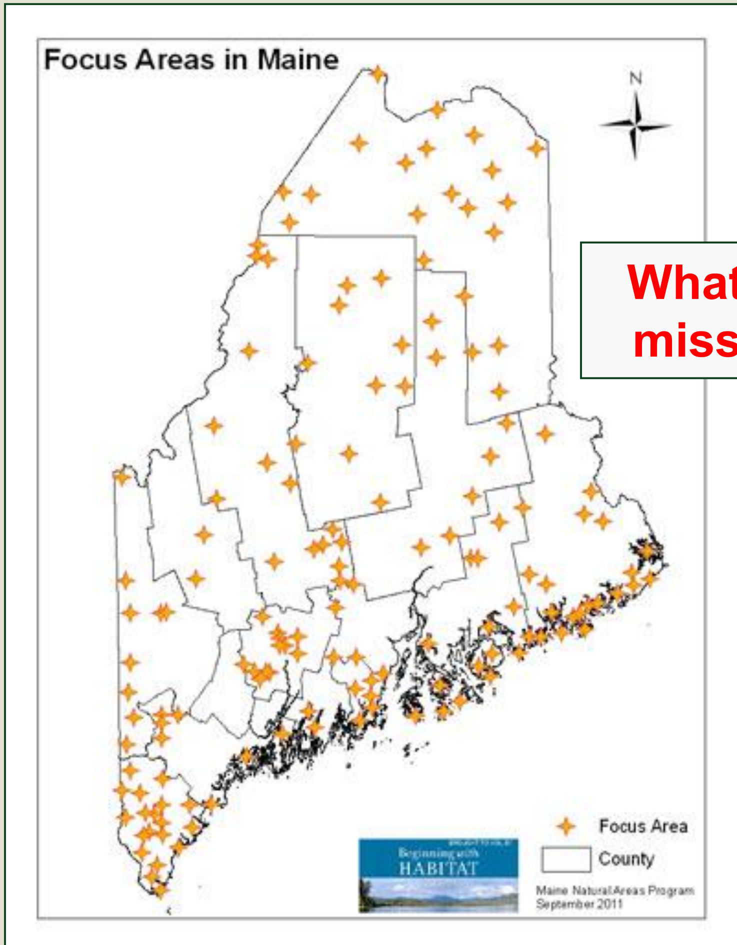
< 2000 vehicles day^{-1}

Riparian Crossings

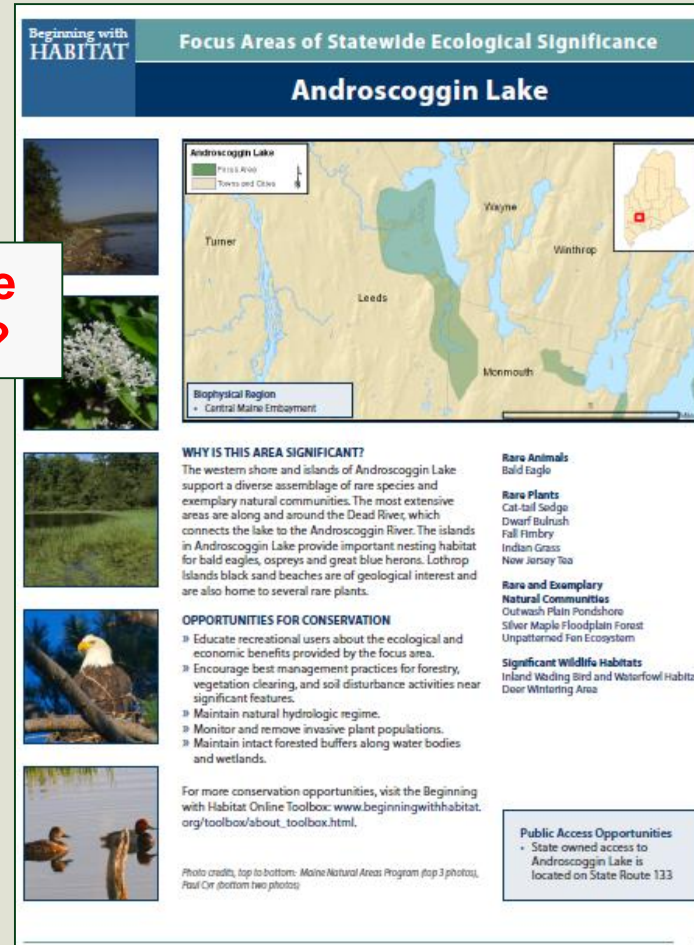
> 2000 vehicles day^{-1}

< 2000 vehicles day^{-1}

Statewide Priorities



What are we missing???



Beginning with HABITAT

Focus Areas of Statewide Ecological Significance

Androscoggin Lake

WHY IS THIS AREA SIGNIFICANT?

The western shore and islands of Androscoggin Lake support a diverse assemblage of rare species and exemplary natural communities. The most extensive areas are along and around the Dead River, which connects the lake to the Androscoggin River. The islands in Androscoggin Lake provide important nesting habitat for bald eagles, ospreys and great blue herons. Lothrop Islands black sand beaches are of geological interest and are also home to several rare plants.

OPPORTUNITIES FOR CONSERVATION

- Educate recreational users about the ecological and economic benefits provided by the focus area.
- Encourage best management practices for forestry, vegetation clearing, and soil disturbance activities near significant features.
- Maintain natural hydrologic regime.
- Monitor and remove invasive plant populations.
- Maintain intact forested buffers along water bodies and wetlands.

For more conservation opportunities, visit the Beginning with Habitat Online Toolbox: www.beginningwithhabitat.org/toolbox/about_toolbox.html.

Photo credits, top to bottom: Maine Natural Areas Program (top 3 photos), Paul Orr (bottom two photos)

Rare Animals
Bald Eagle

Rare Plants
Cat-tail Sedge
Dwarf Bulrush
Fall Fimbry
Indian Grass
New Jersey Tea

Rare and Exemplary Natural Communities
Outwash Plain Pondshore
Silver Maple Floodplain Forest
Unpatterned Fen Ecosystem

Significant Wildlife Habitats
Inland Wading Bird and Waterfowl Habitat
Deer Wintering Area

Public Access Opportunities
- State owned access to Androscoggin Lake is located on State Route 133

1

2012: Political Uncertainty

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Maine Forest Products Council

HOME | NEWS | LEGISLATIVE ACTION | ISSUES & INFORMATION |

Recent updates to IFW's Beginning with Habitat

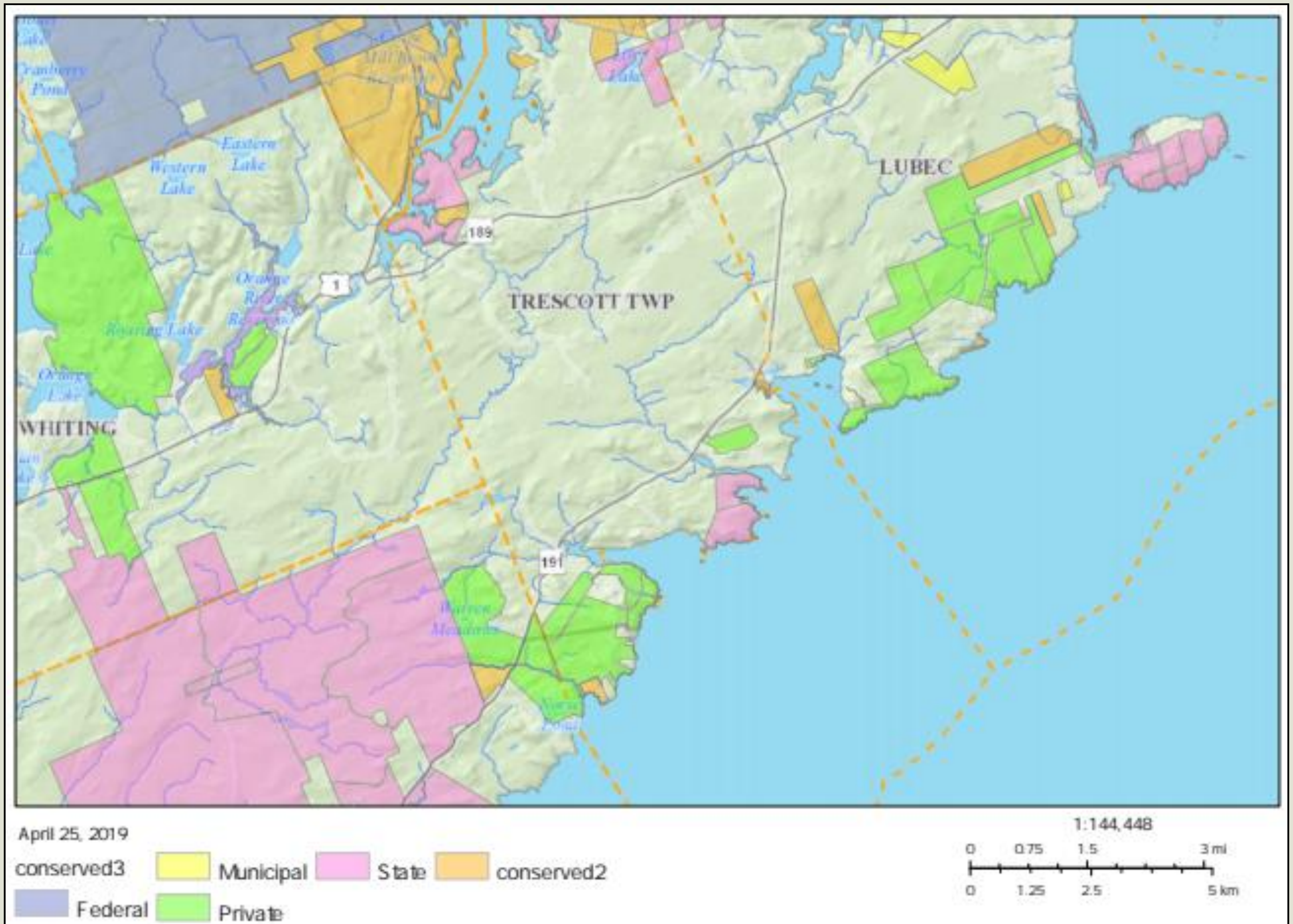
At MFPC members recent "roundtable" with Gov. Paul LePage, John Gray raised some concerns about the Beginning with Habitat program at the Maine Department of Inland Fisheries and Wildlife. IFW Commissioner Chandler Woodcock told him that a number of changes have been made to the program to address concerns from landowners. The commissioner sent the information below to explain the changes. After reading the information below, Gray said, "The best I can say is that it is a step in the right direction."

Beginning with Habitat (BwH) is a voluntary tool intended to assist landowners, resource managers, planners, and municipalities in identifying and making informed decisions about areas of potential natural resource concern to them. Department staff has conducted hundreds of presentations, and distributed hundreds of data packages. To date the

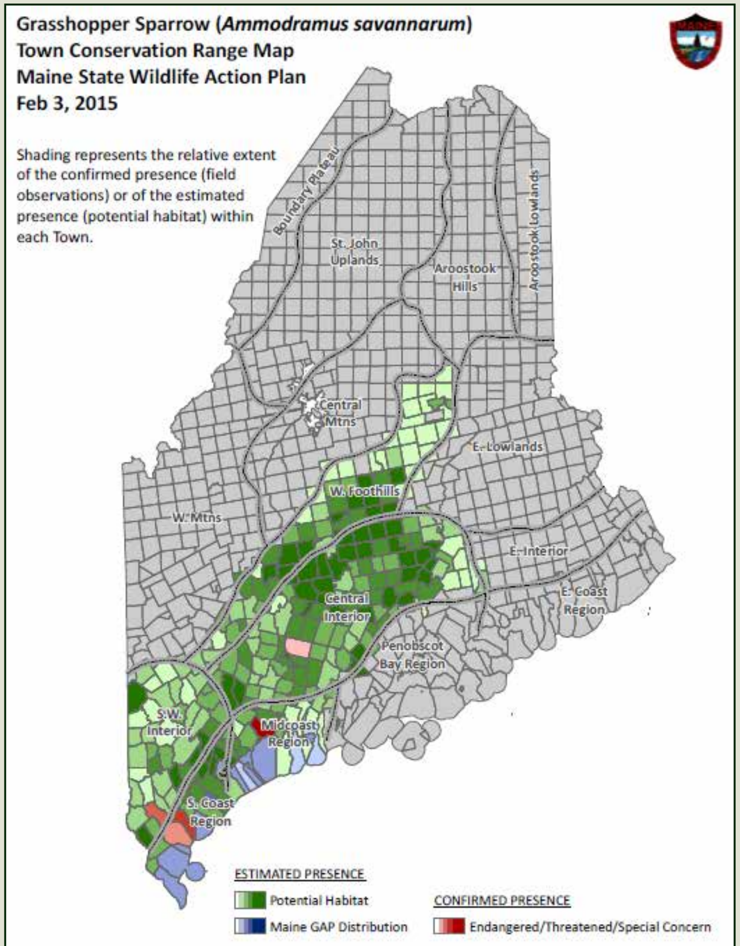
Introspection Era 2013-2016

Greater Consideration of Local Priorities

Regional Coordination and Diverse Landowners

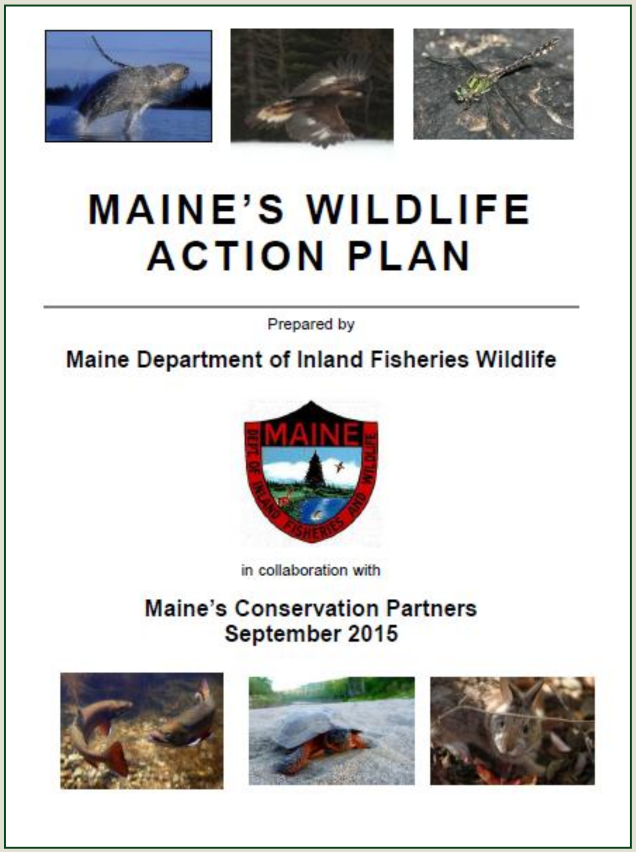


New Information and Challenges



Portland Press Herald

Evolution: The Habitat Outreach Program



MAINE'S WILDLIFE ACTION PLAN

Prepared by

Maine Department of Inland Fisheries Wildlife

in collaboration with

Maine's Conservation Partners
September 2015

Beginning *with* HABITAT

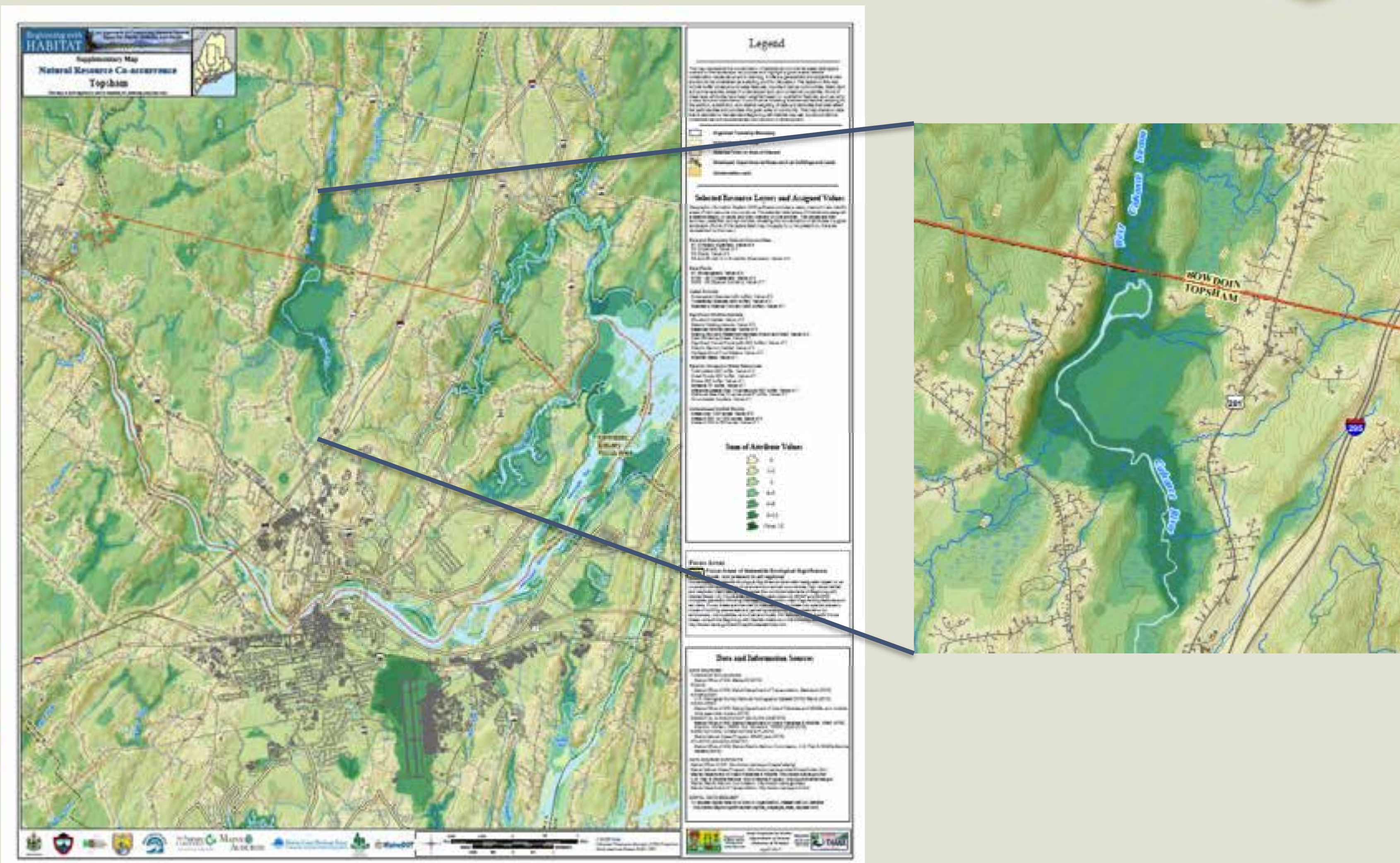
2016 on….

Cultivating State Partnerships

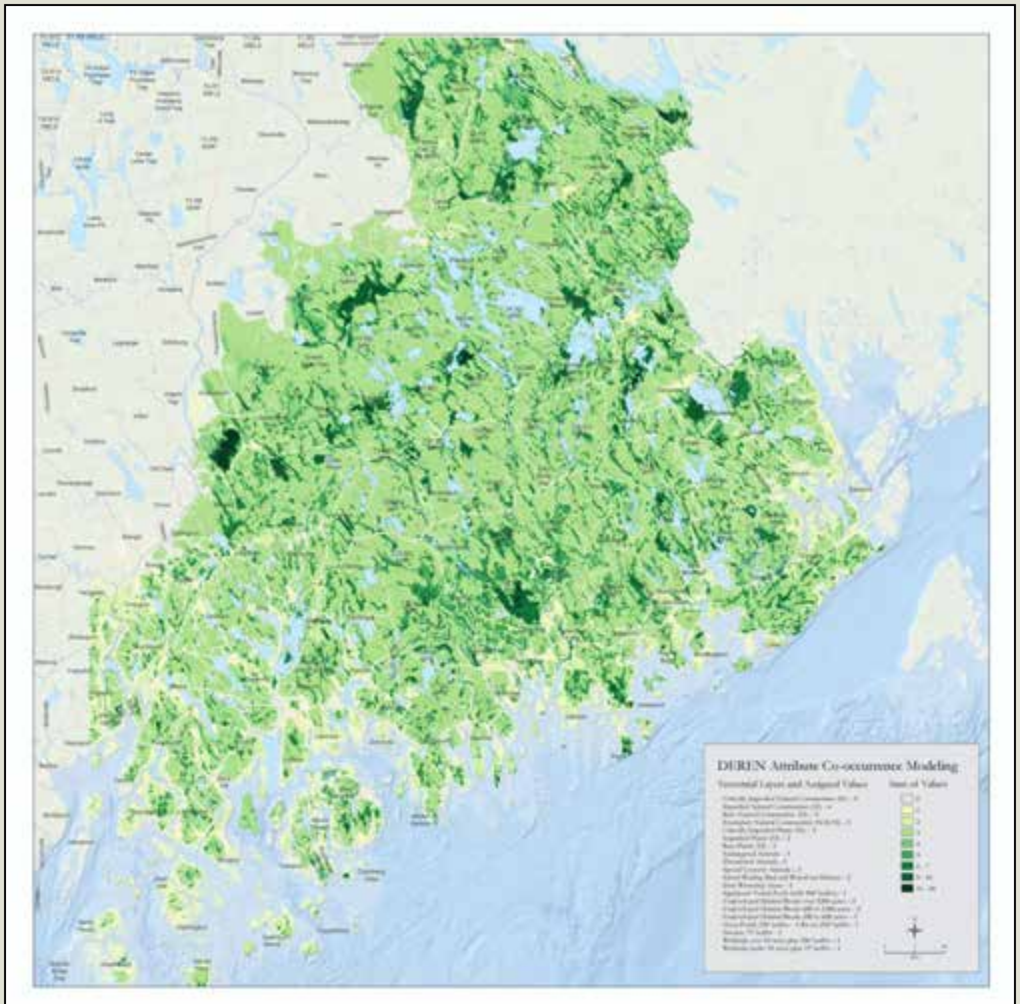
- Municipalities
  - Needs assessment
  - Climate change
  - Connectivity
  - Transportation planning
- Land trust and conservation commission engagement
- Interagency partnerships
  - Climate change
  - Transportation planning
- Landowner engagement

MaineDOT

New Ways to View Local Information



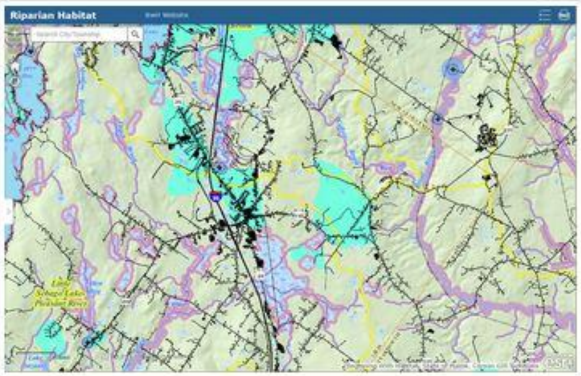
New Regional Models



Greater Online Accessibility to Data

Beginning With Habitat BwH Website

Map Viewers



Map 1- Riparian Habitats

Beginning with Habitat Map 1 depicts major surface water features and drainage areas, associated shoreline habitats and riparian zones, and aquifers and wells that supply public drinking water.

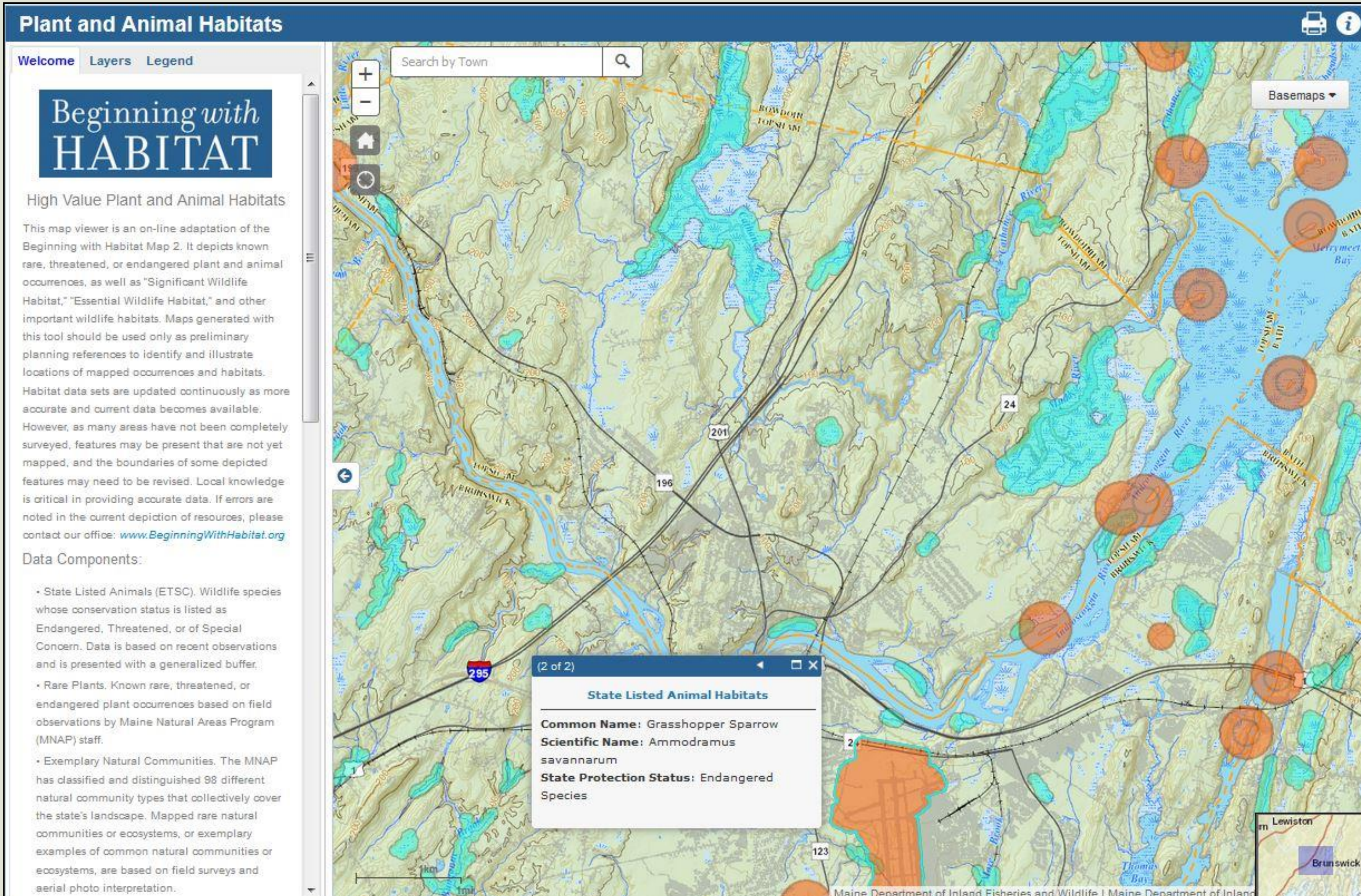
Open Viewer

Map 2- Plant and Animal Habitats

Beginning with Habitat Map 2 depicts known rare, threatened, or endangered plant and animal occurrences, as well as “Significant Wildlife Habitat,” “Essential Wildlife Habitat,” and other important wildlife habitats.

Open Viewer

http://webapps2.cgis-solutions.com/beginningwithhabitat/


Plant and Animal Habitats
Welcome
Layers
Legend
Beginning with HABITAT
High Value Plant and Animal Habitats
This map viewer is an on-line adaptation of the Beginning with Habitat Map 2. It depicts known rare, threatened, or endangered plant and animal occurrences, as well as "Significant Wildlife Habitat," "Essential Wildlife Habitat," and other important wildlife habitats. Maps generated with this tool should be used only as preliminary planning references to identify and illustrate locations of mapped occurrences and habitats. Habitat data sets are updated continuously as more accurate and current data becomes available. However, as many areas have not been completely surveyed, features may be present that are not yet mapped, and the boundaries of some depicted features may need to be revised. Local knowledge is critical in providing accurate data. If errors are noted in the current depiction of resources, please contact our office: www.BeginningWithHabitat.org
Data Components:
• State Listed Animals (ETSC). Wildlife species whose conservation status is listed as Endangered, Threatened, or of Special Concern. Data is based on recent observations and is presented with a generalized buffer.
• Rare Plants. Known rare, threatened, or endangered plant occurrences based on field observations by Maine Natural Areas Program (MNAP) staff.
• Exemplary Natural Communities. The MNAP has classified and distinguished 98 different natural community types that collectively cover the state's landscape. Mapped rare natural communities or ecosystems, or exemplary examples of common natural communities or ecosystems, are based on field surveys and aerial photo interpretation.
Search by Town
Basemaps
(2 of 2)
State Listed Animal Habitats
Common Name: Grasshopper Sparrow
Scientific Name: Ammodramus savannarum
State Protection Status: Endangered Species
Lewiston
Brunswick
Maine Department of Inland Fisheries and Wildlife | Maine Department of Inland

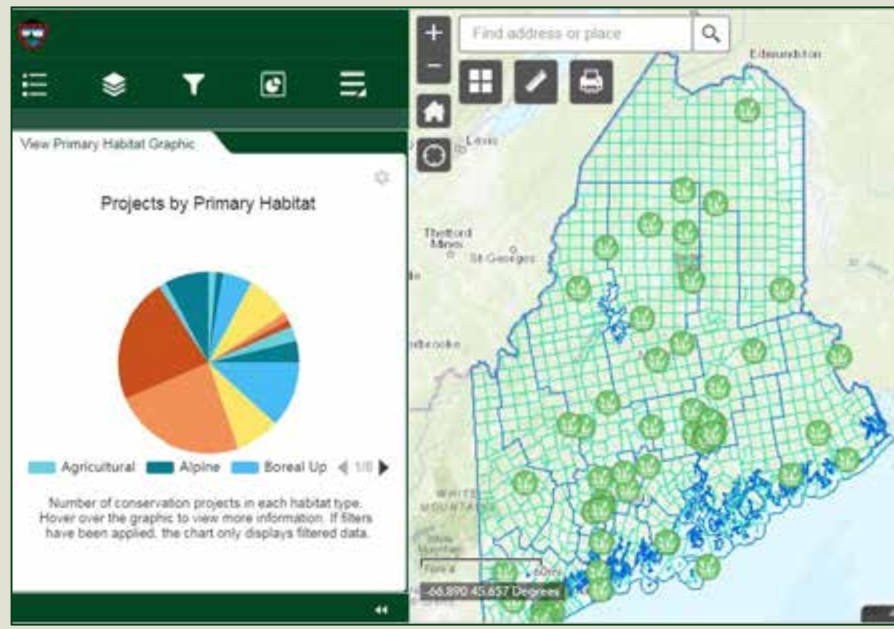
Cultivating Regional Partnerships

- Staying Connected Initiative
- NEG-ECP Resolution 40-3 Workgroup
- Northeast Wildlife Action Plan Coordinators

MaineDOT

New Ways to Track Progress

The Maine SWAP CAT



Mainewildlifeactionplan.com

Challenges and Opportunities Remain

Beginning *with* HABITAT

home | about bwh | community involvement | the maps | toolbox | map viewer | olbe | newsletters | faq

About Beginning with Habitat

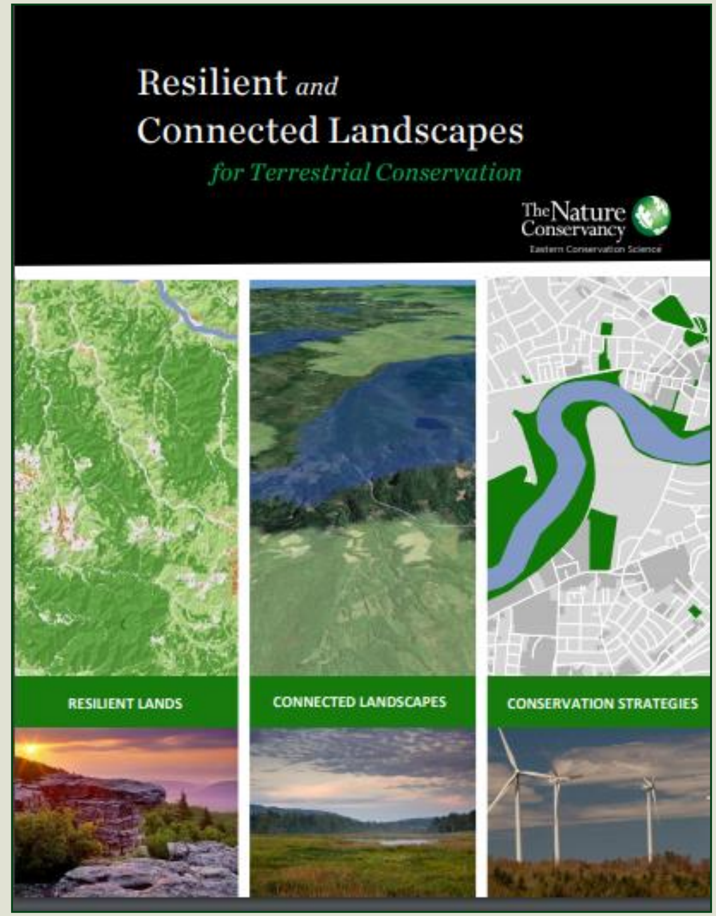
Beginning with Habitat (BwH), a collaborative program of federal, state and local agencies and non-governmental organizations, is a habitat-based approach to conserving wildlife and plant habitat on a landscape scale. The goal of the program is to maintain sufficient habitat to support all native plant and animal species currently breeding in Maine. BwH compiles habitat information from multiple sources, integrates it into one package, and makes it accessible to towns, land trusts, conservation organizations and others to use proactively. Each Maine town is provided with a collection of maps, accompanying information depicting and describing various habitats of statewide and national significance found in the town, and with tools to implement habitat conservation in local land use planning efforts. BwH is designed to help local decision makers create a vision for their community, to design a landscape, and to develop a plan that provides habitat for all species and balances future development with conservation.

Since its inception in 2000, BwH has met with and provided information to more than 140 cities and towns and 35 land trusts and regional planning commissions within the state. Many towns and land trusts have incorporated the information they have received from BwH into their comprehensive plans an

Program Overview

The Beginning with Habitat (BwH) landscape approach to habitat conservation was initially developed by t Research Unit (CFWRU) under the direction of the Department of Inland Fisheries and Wildlife (MDIFW) (I communities, and wildlife habitats of national interest were later added by the Maine Natural Areas Progra (USFWS).

By overlaying maps of the habitat needs of all of Maine's vertebrate species with Maine's primary land cov information system (GIS), the CFWRU reports that 80-95% of all of Maine's terrestrial vertebrate species



Lessons Learned: Connecting People and Nature

Connectivity Means Many Things

- Multiple scales and definitions
- Other messages
  - Public safety
  - Infrastructure
  - Economy
  - Healthy communities
  - Hunting
  - Fishing
  - Recreation
  - Identify
  - Serenity

Embracing an Expanded Model

ALL IN FOR THE MAINE OUTDOORS

MAINE

DEPT. OF INLAND FISHERIES AND WILDLIFE

mefishwildlife.com

Thank You

Amanda Shearin
Habitat Outreach Coordinator
Maine Dept. of Inland Fisheries and Wildlife
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41 State House Station
Augusta, ME 04333
207-287-5260
amanda.f.shearin@maine.gov
www.beginningwithhabitat.org

Many thanks to: BwH Partners and Steering Committee Members, Maine's Wildlife Action Plan Partners and Steering Committee Members, and BwH staff (Bethany Atkins, Bill Hancock, John Maclaine, Steve Walker)