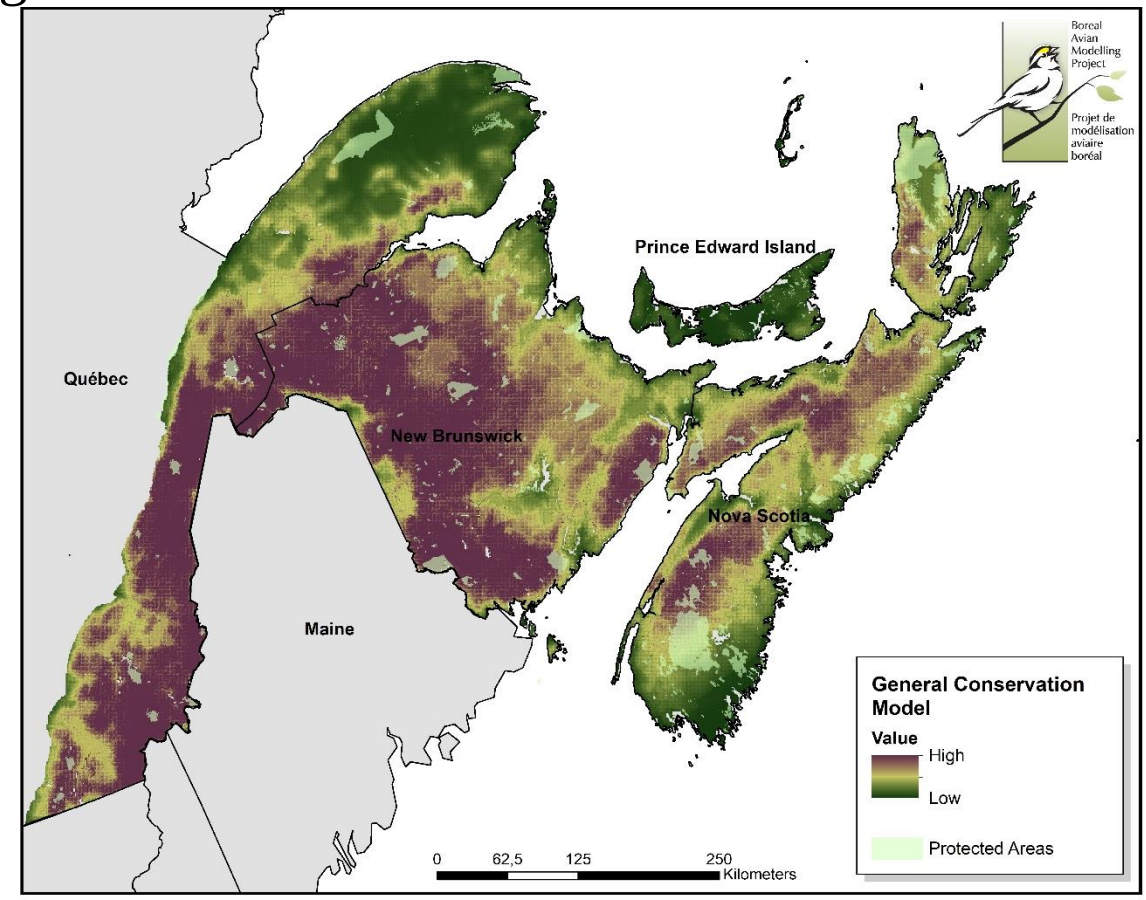
Prioritizing Areas for Canada Warbler Conservation and Management in the Atlantic Northern Forest of Canada



Acknowledgments

This project originated from work on the Canada Warbler International Conservation Initiative (CWICI) towards a full life-cycle conservation plan. These maps are intended to be paired with the accompanying Guidelines for Managing Canada Warbler Habitat in the Atlantic Northern Forest of Canada (pour la version française, cliquez ici).

The preparation of these maps was supported in part by Environment and Climate Change Canada (ECCC) with a contract to High Branch Conservation Services. We thank the fifteen conservation, wildlife, and forestry professionals from six regions (provinces and states) who provided their opinions via an expert survey.

Maps and data products in this report reflect the authors' expertise and are based on a thorough review of the relevant literature, including an analysis of habitat in western Nova Scotia and several empirical studies conducted within 150 km of the focal region in Vermont, New Hampshire, and Maine. Future updates of these maps, as well as peer-reviewed publications, should incorporate new knowledge and data from eastern Canada as they become available. Please see the website for this project for updates and to download spatial data.

Recommended Citation
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Contents

Introduction

The Canada Warbler (*Cardellina canadensis*; Figure 1) is a small landbird with a steeply declining population across its range. It is listed as Threatened in Canada and is a Species of Greatest Conservation Need in nearly every U.S. state in which it occurs. Though habitat associations differ across the range, in Bird Conservation Region 14 (BCR14; the Atlantic Northern Forest, Figure 2), this species predominantly breeds in wet deciduous and mixedwood forests, as well as moist seeps between areas of upland forest. Conservation and management of this migratory species requires a concerted, multi-jurisdictional effort. Forest managers and conservationists have similar needs: identifying locations to apply management, and determining the appropriate management action for a given location. Here, we provide tools to support a range of stewardship approaches, including spatial models for habitat conservation and management, paired with guidelines for managing Canada Warbler habitat.

Figure 1: Perched male Canada Warbler. Photo by Carl Savignac.

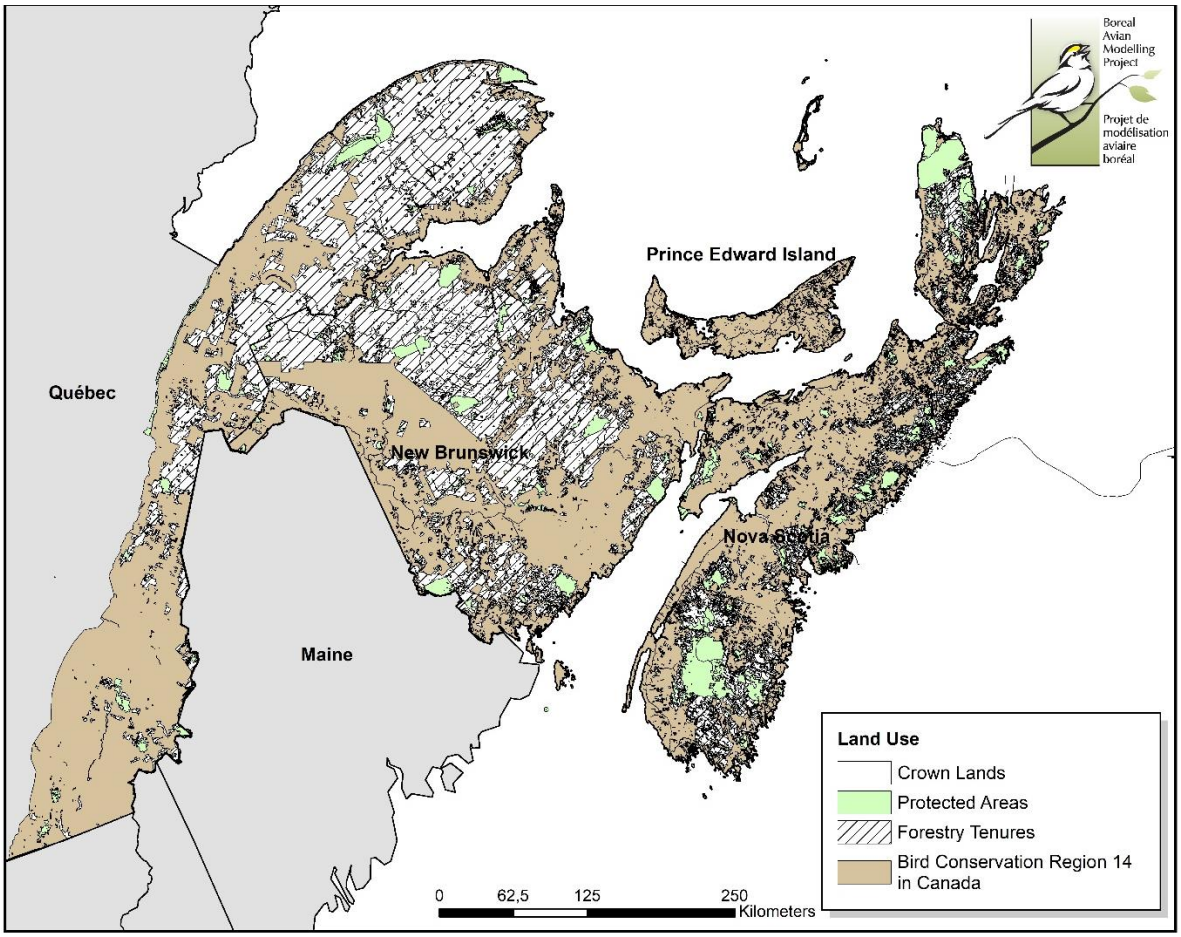

Figure 2: Land use map of the Atlantic Northern Forest in Canada.

After incorporating expert opinions from 15 surveyed professionals about habitat use, dispersal distance, and minimum habitat patch size for the Canada Warbler, we used the spatial prioritization program Zonation[1] to locate priority areas for Canada Warbler conservation and management. Data, maps, and supporting academic papers are available for download from the Boreal Avian Modelling Project, and coding scripts for modelling are available on GitHub. We encourage users to download the complementary habitat guidelines for Canada Warbler habitat management in the Atlantic Northern Forest.

Scenarios and modelling methods

In the Atlantic Northern Forest, Canada Warblers occupy both undisturbed wet habitats, as well as more upland areas 10-25 years after harvesting, depending on the size and type of cut. This presents an opportunity to implement two different management toolboxes: one suitable for long term conservation of wet-poor sites (*Long term conservation*), and another for managing upland habitat in and adjacent to harvested areas (*Habitat management*).

Zonation modelling

To identify high-value areas for conservation and management, we built spatial models across two different toolboxes using an iterative process with five preliminary models (models i-v) and six final models (models C1-3 and M1-3). Zonation can be used to identify areas of high value for conservation or management by adding desirable input features (in this case, predicted abundance of Canada Warblers), discounting undesirable features (such as prediction uncertainty or human disturbance), and using the dispersal ability of the species to assess connectivity between habitat patches on the landscape. Zonation ranks every pixel across a landscape (1 km^2) from low value for desirable features to high value (in this case, abundance of Canada warblers discounted by undesirable features). The algorithm removes the lowest-ranked pixels, and then re-calculates the ranking of remaining pixels based on their connectivity. Continuing in this way, Zonation produces a raster surface which ranks each pixel on the landscape based on the order in which they were removed from the model. Zonation-specific settings, modelling methods, and code are available on GitHub. A list of covariates used in modelling are available in Appendix I: Input data.

We began with our base layer, a species distribution model that predicts Canada Warbler abundance across Canada (updated from Haché et al. 2014[2]). Models were built by iteratively adding components (Figure 3) to produce a series of options across the two management toolboxes. We conservatively estimated a dispersal ability of 5 km for Canada Warblers, causing connectivity algorithms to increase the value of habitat patches located less than 5 km apart. The preliminary models (models i-v) began by prioritizing the base layer to highlight connected areas using the 'core area zonation' algorithm (model i), and each subsequent model added a new component: discounting anthropogenic disturbance (model ii), adding connectivity (model iii), increasing the value of areas where Canada Warblers had been observed since 2005 and 2010 (model iv), and discounting areas with high prediction uncertainty (model v). The inclusion of all these components culminates in the General Conservation Model (model v), which shows priority areas for conserving Canada Warbler habitat if no land use considerations are included.

Toolboxes

Our final models were divided into two toolboxes: *Long term conservation* and *Habitat management*. Maps of model stages are available in Appendix II: Intermediate model outputs. In this section, text descriptions of the final models are given, followed by maps.

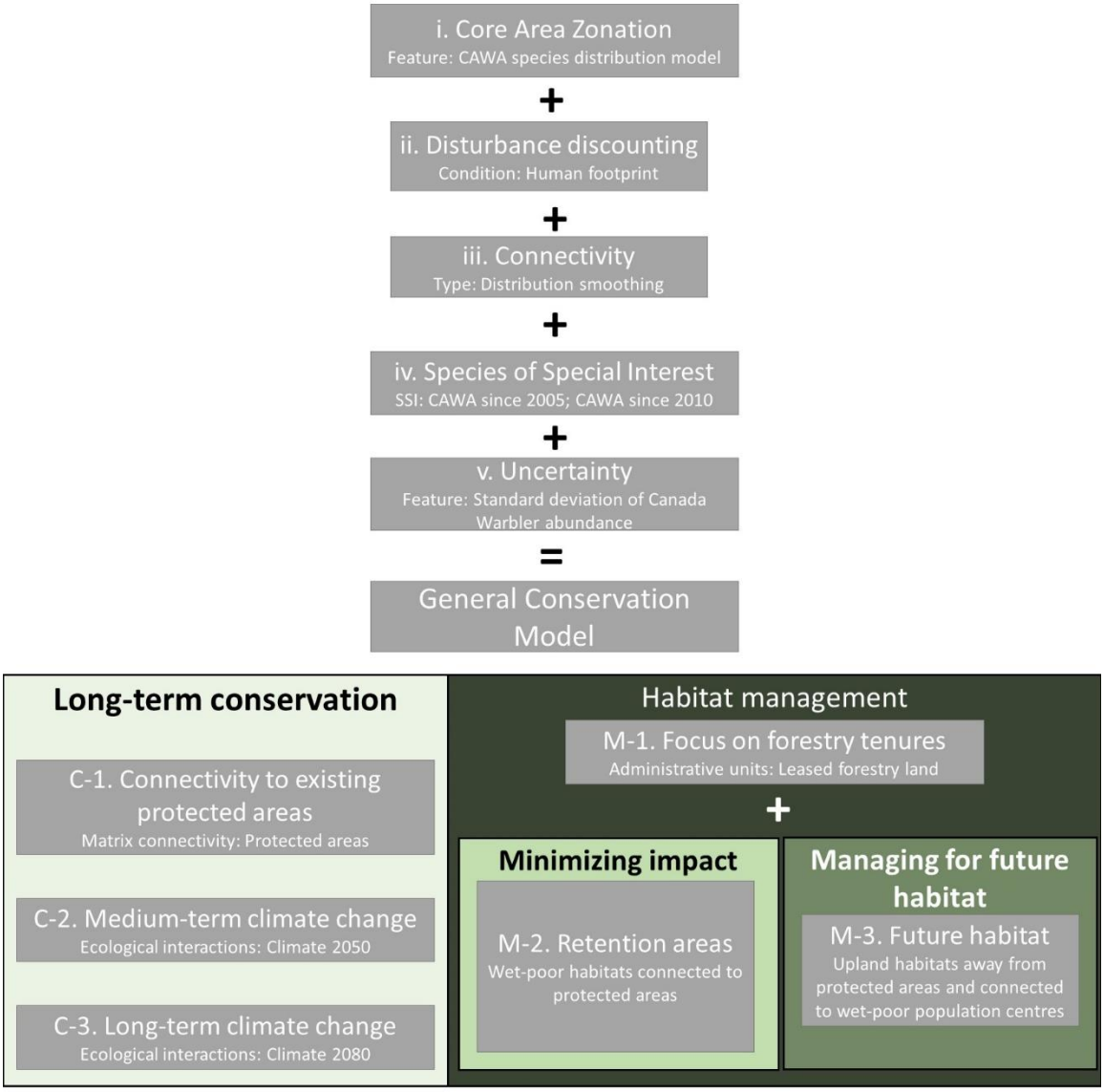

Figure 3: Intermediate and final Zonation models, including preliminary analyses (top), a toolbox for long-term conservation (left), and a toolbox for habitat management (right).

Toolbox 1: Long-term conservation

The long-term conservation toolbox intended for use by governments and land conservation trusts to identify areas of value for preserving Canada Warbler habitat in perpetuity. All three long-term conservation models were built from the General Conservation Model

Model *C-1. Connectivity to existing protected areas* results ranked the landscape not only based on connecting areas of high Canada Warbler abundance, but also connecting pixels with high Canada Warbler abundance to currently established national and provincial parks, wilderness areas, and wilderness

reserves (Figure 4). Conservation systems are most effective when conserved lands are highly connected and feature large amounts of core area. We therefore assume that "building on" these systems will benefit many other species besides the Canada Warbler. Results from this model show that land preservation efforts could especially benefit Canada Warblers in areas surrounding Kejimkujik National Park and the Tobeatic Wilderness area (NS), Fundy National Park (NB), Spednick Lake Natural Protected Area (NB), Kennedy Lakes Protected Natural Area (NB), Aire d'Aménagement de Grande-Rivière White-Tailed Deer Yard (QC), Mont-Mégantic National Park and the Samuel Brisson Ecological Reserve (QC), and La Louise White-Tailed Deer Yard (QC).

For model *C-2. Medium term climate change* (Figure 5), we incorporated both current and future climate suitability for this species (see Appendix II for climate change maps). Model C-2 used climate predictions for 2041-2070, averaged as the 2050s,[3] and assumed that Canada Warblers could disperse between the current and future climate distributions at a rate of 5 km/year. Under this scenario, relative value of habitat decreases substantially in Nova Scotia and Prince Edward Island, and remains strong in areas of higher elevation in Québec and New Brunswick. To continue to expand the existing protected areas while simultaneously conserving future habitat for Canada Warblers, the highest-value areas are those surrounding Spednic Lake Provincial Park (NB), Kennedy Lakes Protected Natural Area (NB), Mount Carleton Provincial Park (NB), Aire d'Aménagement de Grande-Rivière White-Tailed Deer Yard (QC), Mont-Mégantic National Park and the Samuel Brisson Ecological Reserve (QC), and La Louise White-Tailed Deer Yard (QC).

Using the predicted impacts of climate change on Canada Warblers in the 2080s,[3] model *C-3. Long term climate change* (Figure 6) shows a slight shift in ranking of relative habitat value with improvements in the northern part of the Gaspé peninsula and a further decline in Nova Scotia and Prince Edward Island. Highest-value areas remain similar to model C-2, with the exception of an improvement in value in lands surrounding Gaspésie National Park (QC).

Toolbox 2: Habitat management

Models for habitat management are intended for use by foresters, government managers, and woodlot owners to support identification of areas to manage for Canada Warbler habitat on Crown land and large industrial landholdings. Although maps can be used to locate potential areas for forestry activities, landowners should make their own, local assessments to avoid infractions of legal protections under the *Species at Risk Act, Migratory Birds Convention Act*, or other relevant national and provincial legislation. Furthermore, users should consult the affiliated Guidelines for Managing Canada Warbler Habitat in the Atlantic Northern Forest of Canada for information on appropriate forestry interventions for this species, as well as an overview of legal considerations.

Models in the *Habitat management* toolbox use the 'administrative units' function in Zonation, which stratifies selection of the landscape by administrative boundaries. Thus, although results emphasize habitat

management opportunities on existing forestry tenures (owned by the Crown or private companies), they do not infer that habitat in other areas is unsuitable.

It should be noted that the value of the landscape is relative rather than absolute: that is, a pixel's value is relative to all of the other pixels in the area being considered. Before engaging in decision-making based on these products, we suggest that managers download the spatial data directly and use a geographic information systems (GIS) program in order to clip the data to the boundaries of landholdings. This way, the relative value of given areas of habitat management can be ranked in their zone of interest, rather than comparing to areas in other provinces or distant landholdings.

To create the intermediate habitat management model, *M-1. Focus on forestry tenures* (Appendix II: Intermediate model outputs: Intermediate model outputs), we re-prioritized the General Conservation Model to focus within areas of large landholdings used for tenured industrial forestry purposes. We also removed discounting based on anthropogenic disturbance, as human disturbance is expected in these areas. Two separate output scenarios were then created.

Model *M-2. Retention areas in forestry tenures* (Figure 7) identifies areas of high value for buffer strips, retention patches, or other forestry interventions which retain forest cover on the landscape. This model includes weighting for recent Canada Warbler observations, and emphasizes wet-poor forest ecosystems on the landscape (which are likely to be less desirable for logging). Results of this model can give guidance for areas that could be surveyed for birds prior to harvesting. We suggest highly-ranked areas in this model could be chosen for forest cover retention on the landscape, or to be harvested at times outside of the breeding season.

Model *M-3. Managing future habitat in forestry tenures* (Figure 8) identifies priority areas that, once harvested, may be suitable for Canada Warbler in the future if managed appropriately (10-25 years after logging). This model emphasizes upland, drier forest ecosystems (likely to be more economically desirable for logging), and de-emphasizes areas where Canada Warblers have been observed since 2005 and 2010 (to minimize the impact of forestry operations on existing breeding pairs). However, it should be noted that because the pixel size is 1 km^2, a given area may contain both upland and lowland habitats. To support the ability of regenerating forest to support future populations of Canada Warbler, please see the Guidelines for Managing Canada Warbler Habitat in the Atlantic Northern Forest of Canada.

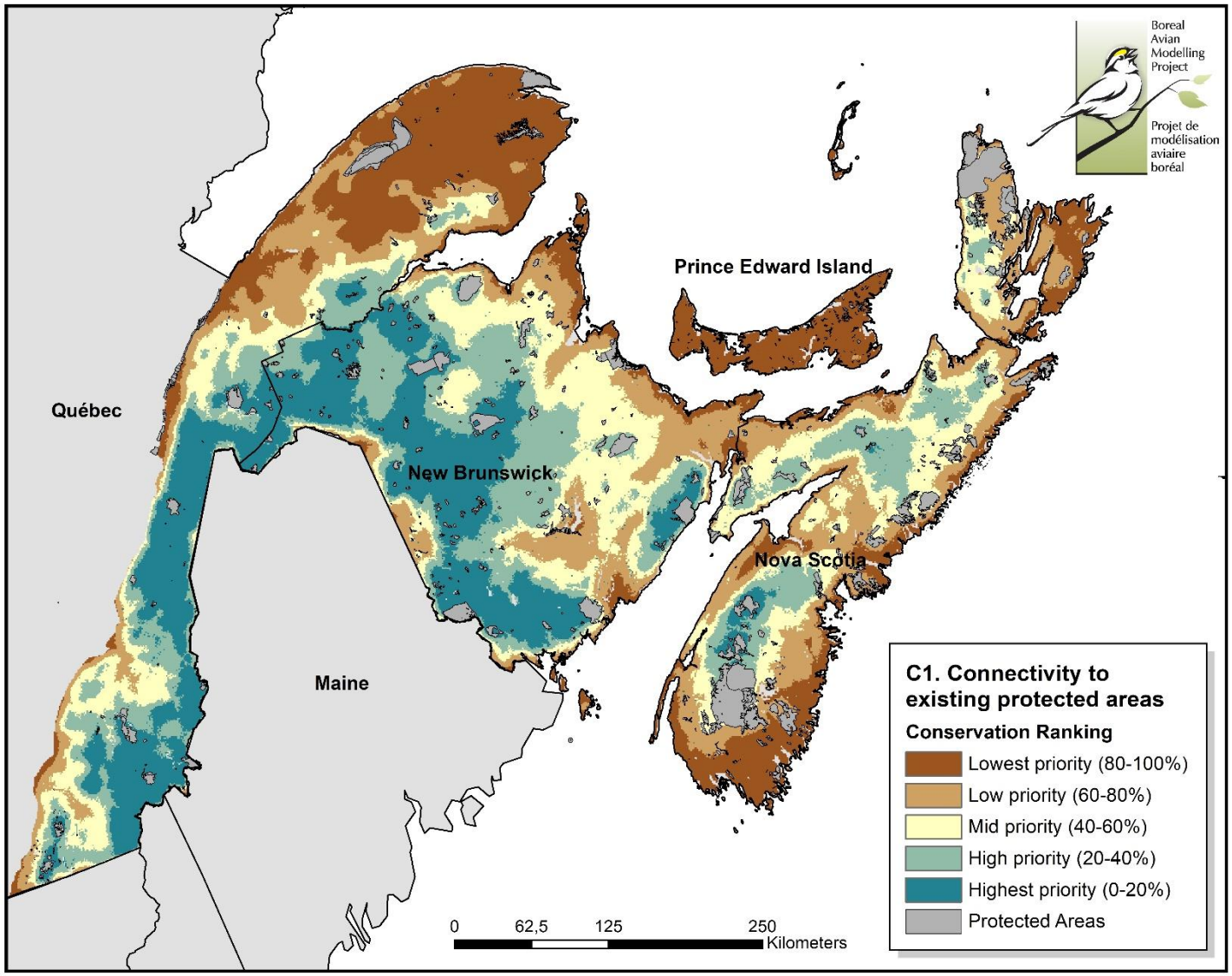

Figure 4: Relative value of land for supporting high densities of Canada Warblers, with an emphasis on areas which are connected to existing national and provincial parks, wilderness areas, and wildlife management areas (model C-1).

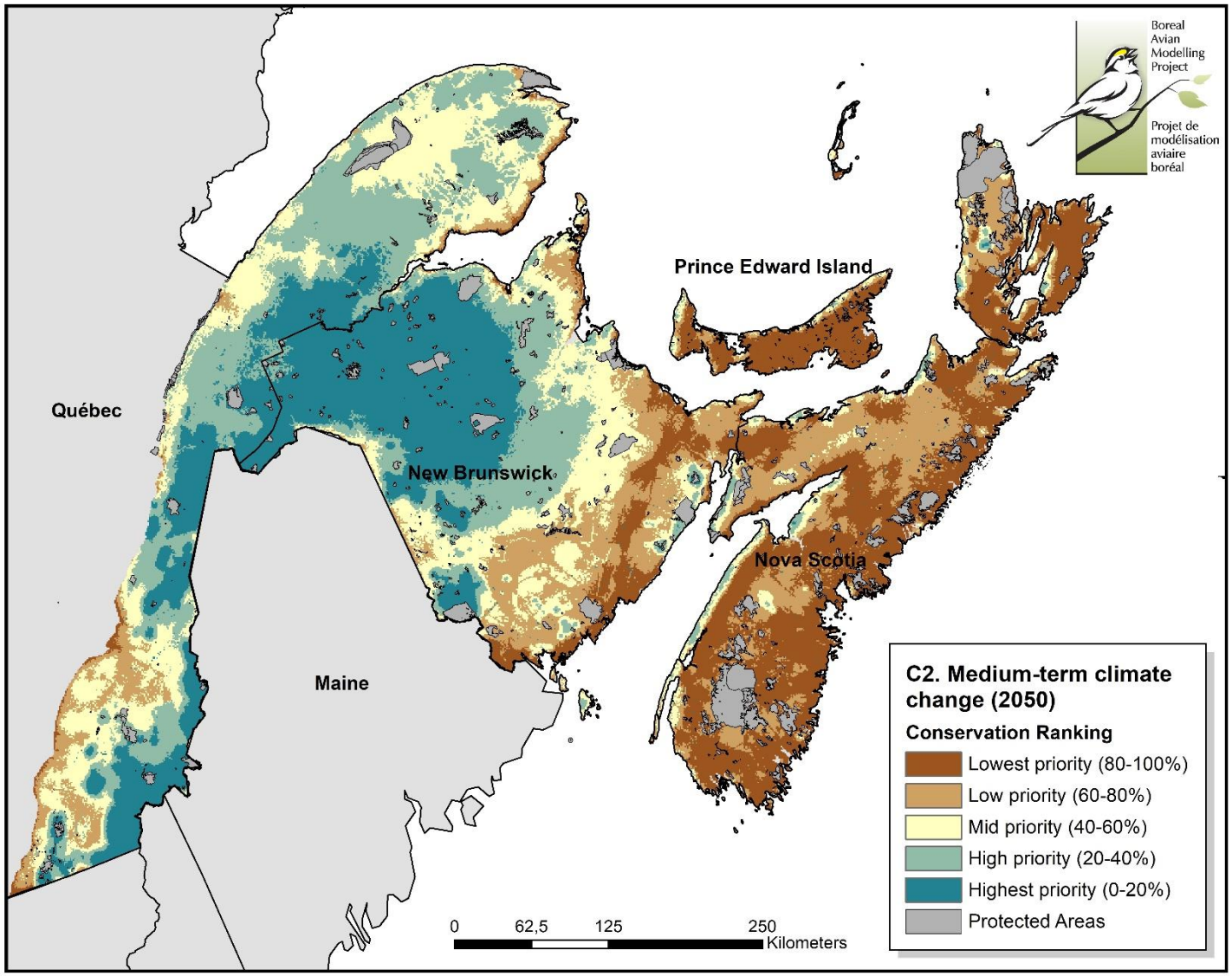

Figure 5: Relative value of land for supporting high densities of Canada Warblers within predicted areas of suitable climate in the 2050s, assuming Canada Warblers can disperse northward with changing climate at a rate of 5 km/year (model C-2).

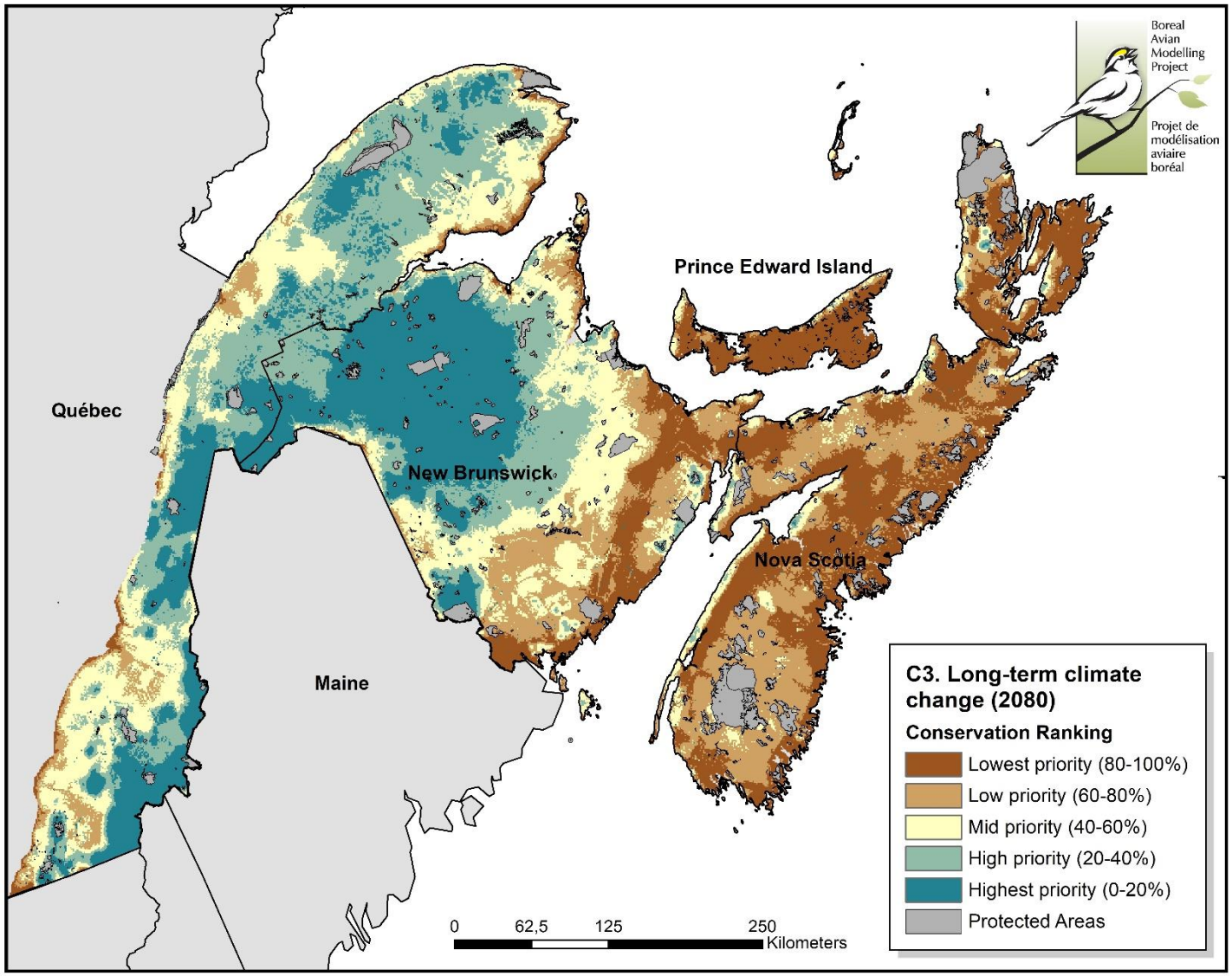

Figure 6: Relative value of land for supporting high densities of Canada Warblers within predicted areas of suitable climate in the 2080s, assuming Canada Warblers can disperse northward with changing climate at a rate of 5 km/year (model C-3).

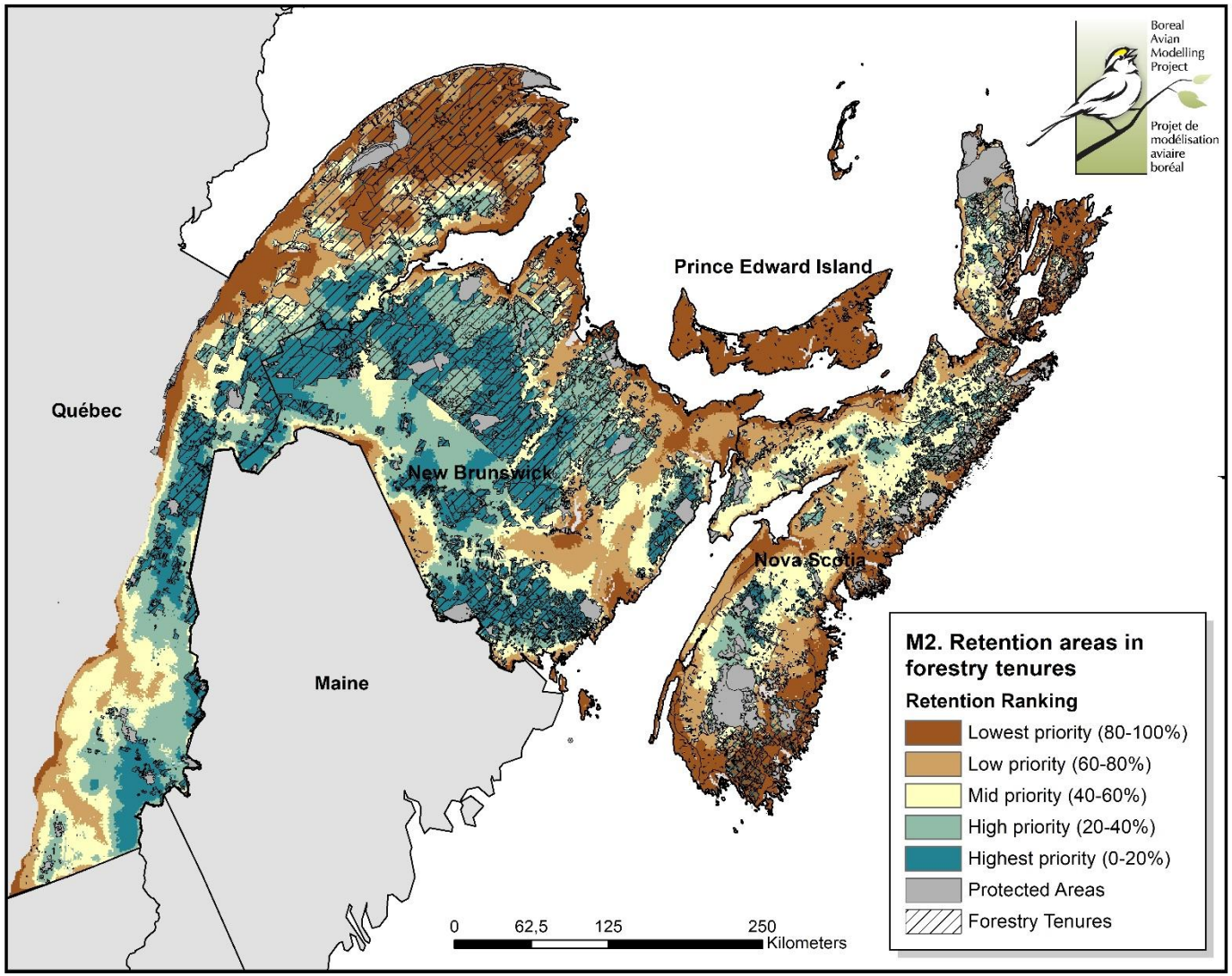

Figure 7: Relative value of land for supporting high densities of Canada Warblers with an emphasize on areas inside tenures zoned for forestry operations. Highly ranked areas may be suitable for buffer strips or leave patches to minimize impacts on Canada Warbler habitat during harvesting (model M-2).

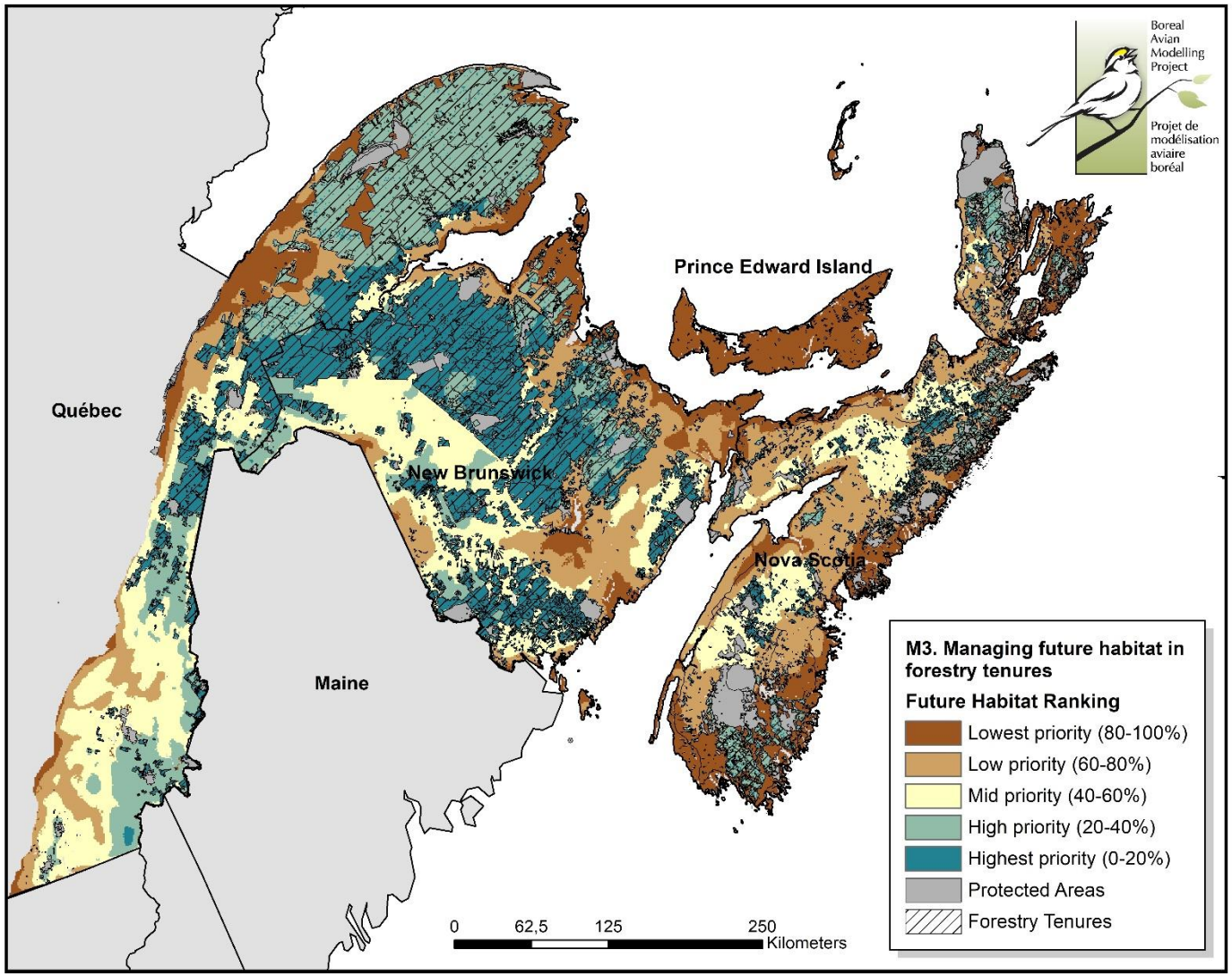

Figure 8: Relative value of land for supporting high densities of Canada Warblers with an emphasis on areas inside tenures zoned for forestry operations. Highly ranked areas may be suitable for managing for future Canada Warbler habitat after harvesting (model M-3).

Limitations and conclusions

We encourage landowners and managers to use these models to target areas for conservation and management of Canada Warblers, which should be managed to reflect recommended best practices. As spatial data can carry high levels of uncertainty, field validation is recommended before engaging in any kind of habitat alteration. It should also be noted that Canada Warblers receive legal protections under the Migratory Birds Convention Act[4] and Species at Risk Act.[5] The Government of Canada's Recovery Strategy for the Canada Warbler (*Cardellina canadensis*) in Canada contains more discussion of issues related to habitat quantity and quality.

Finally, there are many limitations inherent in this modelling process. A model's output is only as good as the accuracy of the input layers, each of which carries an inherent amount of uncertainty and error. For more information about the datasets used in this work, see Appendix I. In addition, Zonation's connectivity algorithm is constrained by the spatial extent of the available layers. As such, areas close to the U.S. Canada border as well as the Quebec border of BCR14 and the remainder of the province will contain a less accurate estimation than other areas.

In the *Habitat management* toolbox, there may be areas identified as both high priority for retention and future habitat creation. This is an effect of the relatively coarse size of map pixels (1 km^2) as compared to the small territory sizes of Canada Warblers (often 1 ha or less). Thus, aerial photography and ground surveying should be used to specifically delineate habitats when operating in these areas. We hope these guidelines are useful for government, NGO, and forestry managers alike to implement their toolkits towards conservation action and sustainable forest management to benefit the Canada Warbler. Please consult the project website for any updates and more information as it becomes available.

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Appendix I: Input data

Table 1

GIS Layer Group	GIS Layer	Description	Year	Units	Resolution (m)	Ownership
Administrative Boundaries	Protected areas (national, provincial, private)	The CARTS (Conservation Areas Reporting and Tracking System) geodatabase contains data from all federal, provincial and territorial jurisdictions, which update their protected areas data to CARTS on an annual basis.	2015	categories	N/A	Canadian Council on Ecological Areas (Link)
	BCR14 border	Canadian portion of Bird Conservation Region 14	2013	categories	N/A	NABCI (Link)
	Provincial and state boundaries	Federal, provincial, and state administrative regions	2000	categories	N/A	ESRI 2000
	Working lands (forestry tenures, private and crown)	Extent of active forest tenures	2014	categories	N/A	Global Forest Watch Canada (link); Environment Canada
	Public lands	Non-protected public hands held by the Crown or other government bodies. May be currently under lease	2013-2016	categories	N/A	Government of Nova Scotia; Government of New Brunswick, Gouvernement du Quebec, Government of Prince Edward Island
Bird Data	Population density index	Population density projected by Hache et al. 2015 using species distribution modelling, using satellite-derived landcover data from Global Forest Watch (2013)	2013	males/hectare	1000	Boreal Avian Modelling Project (link), Haché et al. 2014[6]
	CAWA presence 2010-2015	Point count locations of Canada Warbler since 2010	2015	presence	N/A	Boreal Avian Modelling Project (link), Cumming et al. 2010[7]; Barker et al. 2015[8]
	CAWA presence 2005-2010	Point count locations of Canada Warbler since 2005	2015	presence	N/A	Boreal Avian Modelling Project (link), Cumming et al. 2010[7]; Barker et al. 2015[8]
	CAWA climate refugia 2050	Mean projected population density of Canada Warbler in 2050	2014	Index	3000	Boreal Avian Modelling Project (link), Stralberg et al. 2015[3]
	CAWA climate refugia 2080	Mean projected population density of Canada Warbler in 2080	2014	Index	3000	Boreal Avian Modelling Project (link), Stralberg et al. 2015[3]
Landcover	Water bodies - lines	Provincial hydrographic features at 1:10 000 scale	2008-2014	N/A	N/A	Nova Scotia Department of Natural Resources (link); New Brunswick Department of Natural Resources/GeoNB (link); Government of Quebec; Government of Prince Edward Island (link)

GIS Layer Group	GIS Layer	Description	Year	Units	Resolution (m)	Ownership
	Water bodies - polygon	Provincial hydrographic features at 1:10 000 scale	2008-2014	N/A	N/A	Nova Scotia Department of Natural Resources (link); New Brunswick Department of Natural Resources/GeoNB (link); Government of Quebec; Government of Prince Edward Island (link)
	Northeastern habitat types	Common classification for ecosystems and habitats in the Northeast US and Atlantic Canada	2015	N/A	30	The Nature Conservancy - Eastern Conservation Science (link), Anderson et al. 2013[9]
	Human footprint	The Human Footprint (HF) of the Northern Appalachian/Acadian ecoregion measures the extent and relative intensity of human influence on terrestrial ecosystems at a resolution of 90 m using best available data sets on human settlement (population density, dwelling density, urban areas), access (roads, rail lines), landscape transformation (landuse/landcover, dams, mines, watersheds), and electrical power infrastructure (utility corridors).	2001-2006	index	90	Wildlife Conservation Society of Canada; Conservation Biology Institute; Data Basin (link); Sanderson et al. 2002;[10] Woolmer et al. 2008[11]

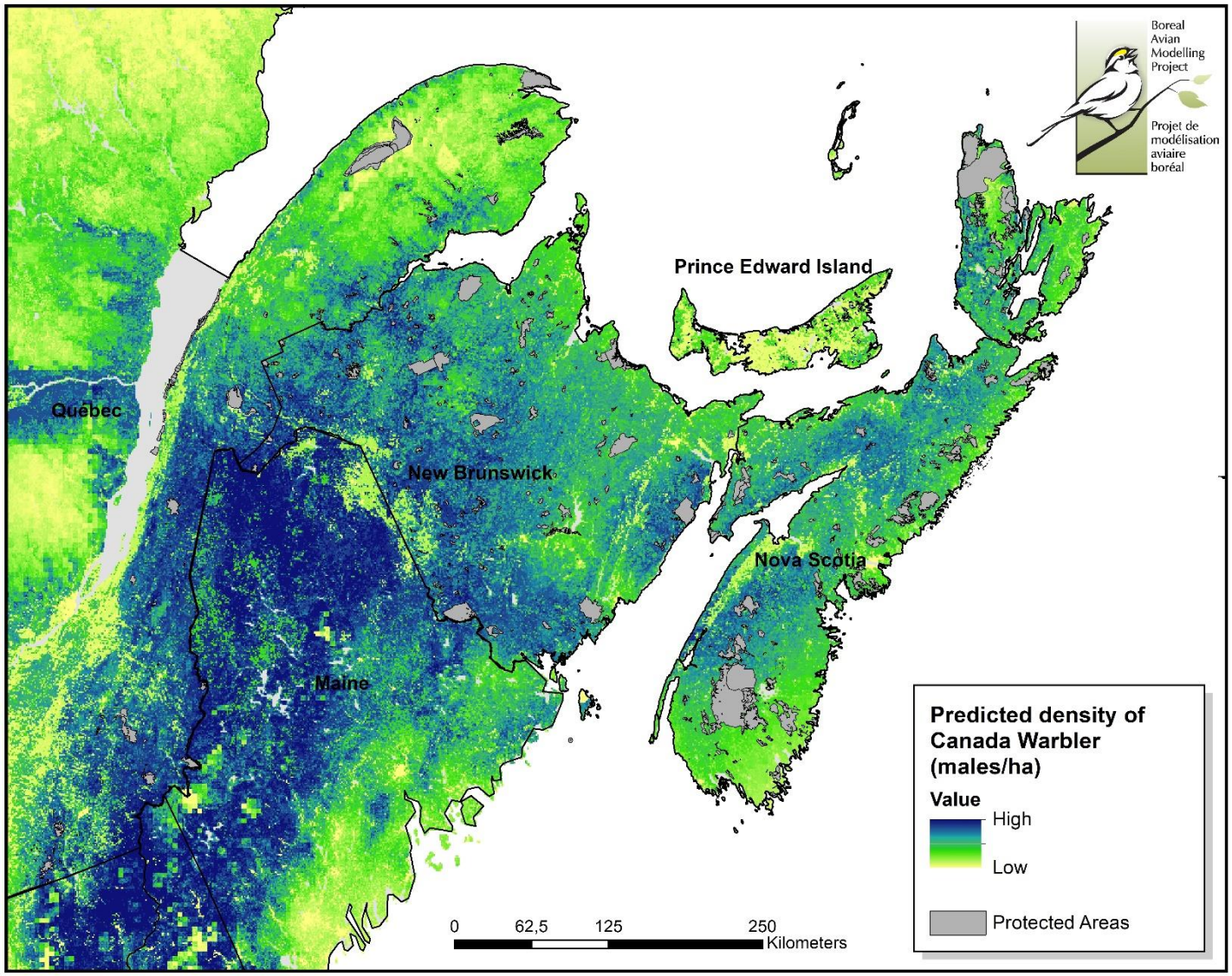

Figure 9: Average predicted population density of Canada Warbler (males/ha) in North America (updated from Hache et al. 2014).

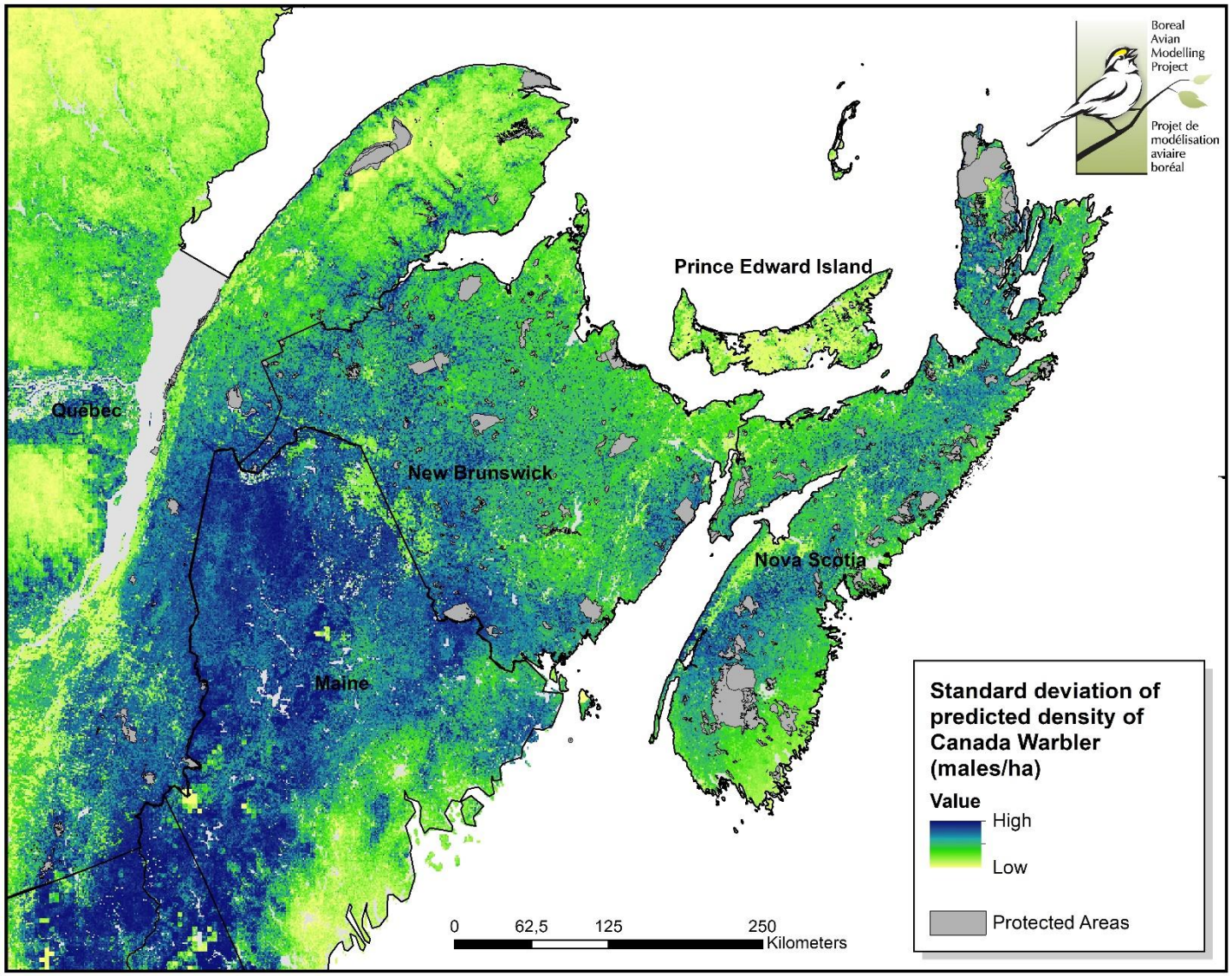

Figure 10: Standard deviation of predicted population density of Canada Warbler (males/ha) in North America (updated from Hache et al. 2014).

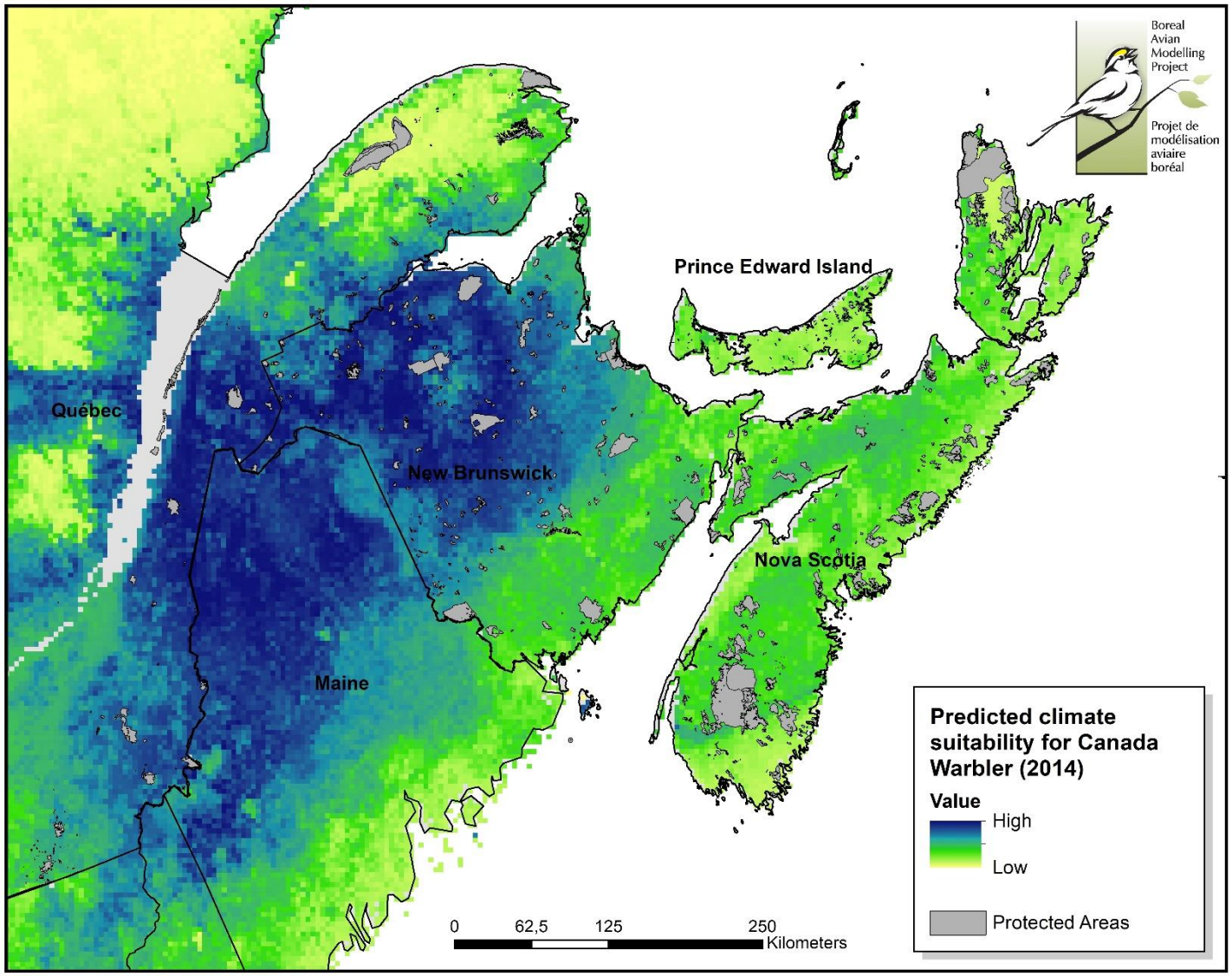

Figure 11: Predicated climate suitability for Canada Warbler in North America, year 2014 (Stralberg et al. 2015).

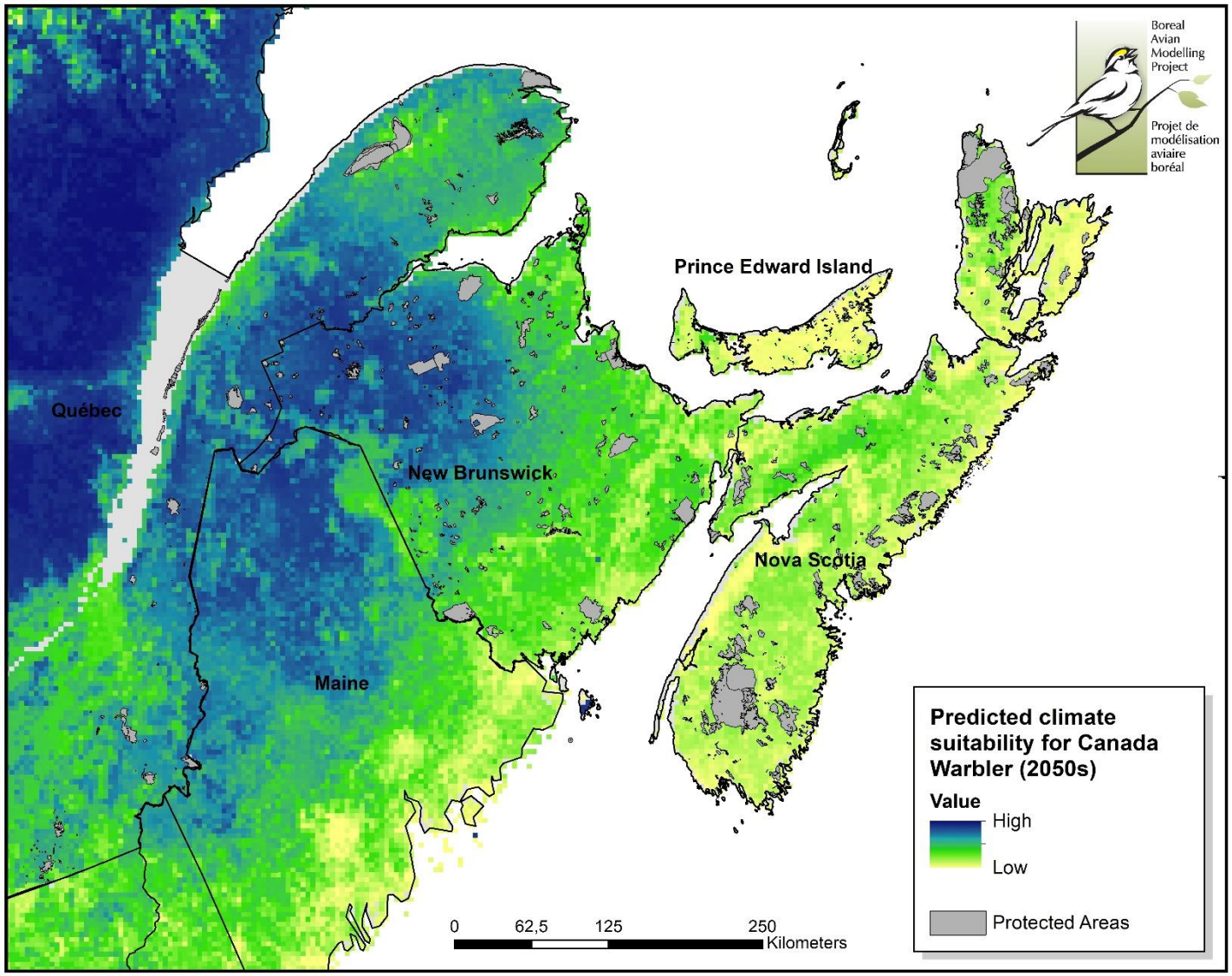

Figure 12: Predicated climate suitability for Canada Warbler in North America, averaged to the decade of the 2050s (Stralberg et al. 2015).

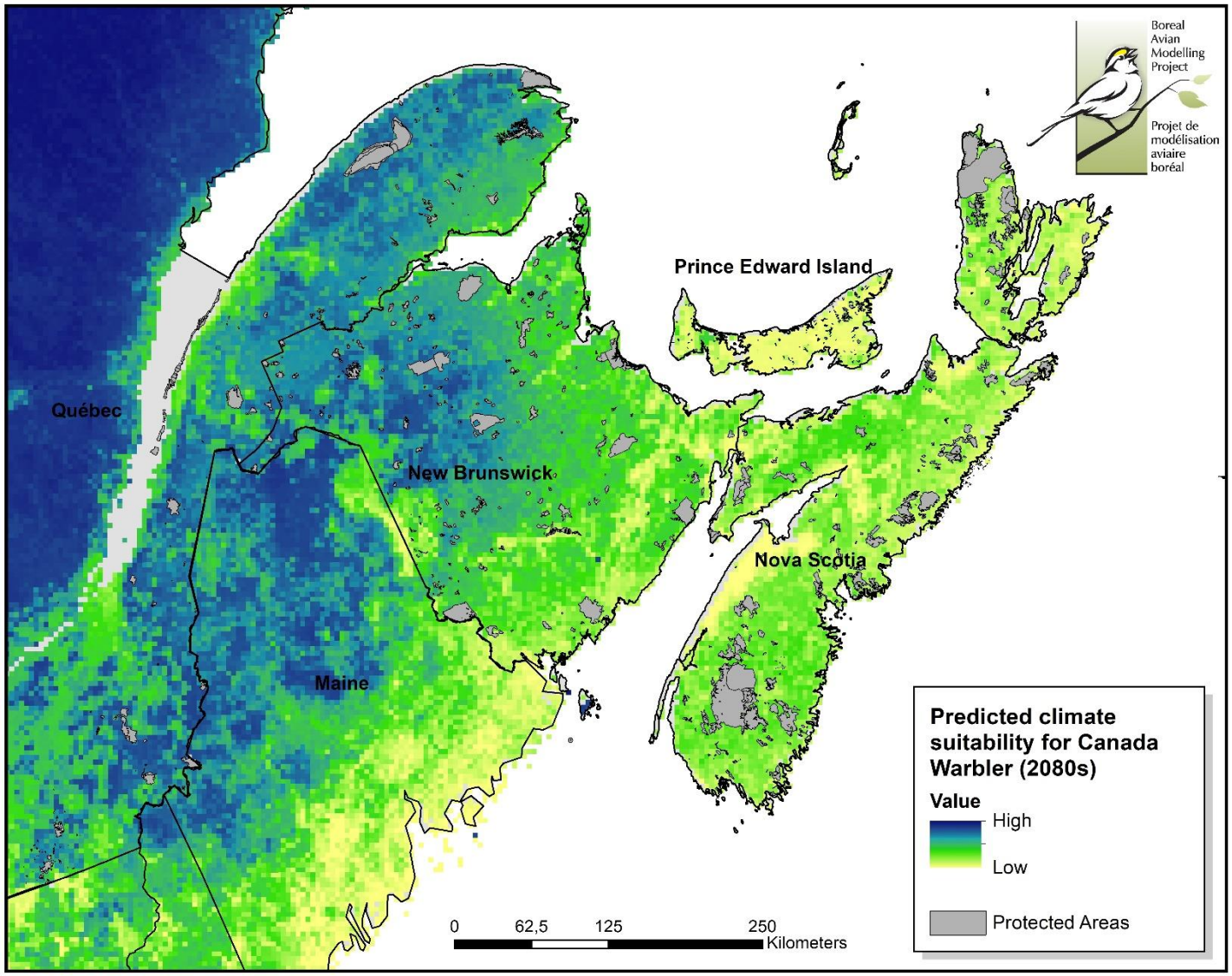

Figure 13: Predicated climate suitability for Canada Warbler in North America, averaged to the decade of the 2080s (Stralberg et al. 2015).

Appendix II: Intermediate model outputs

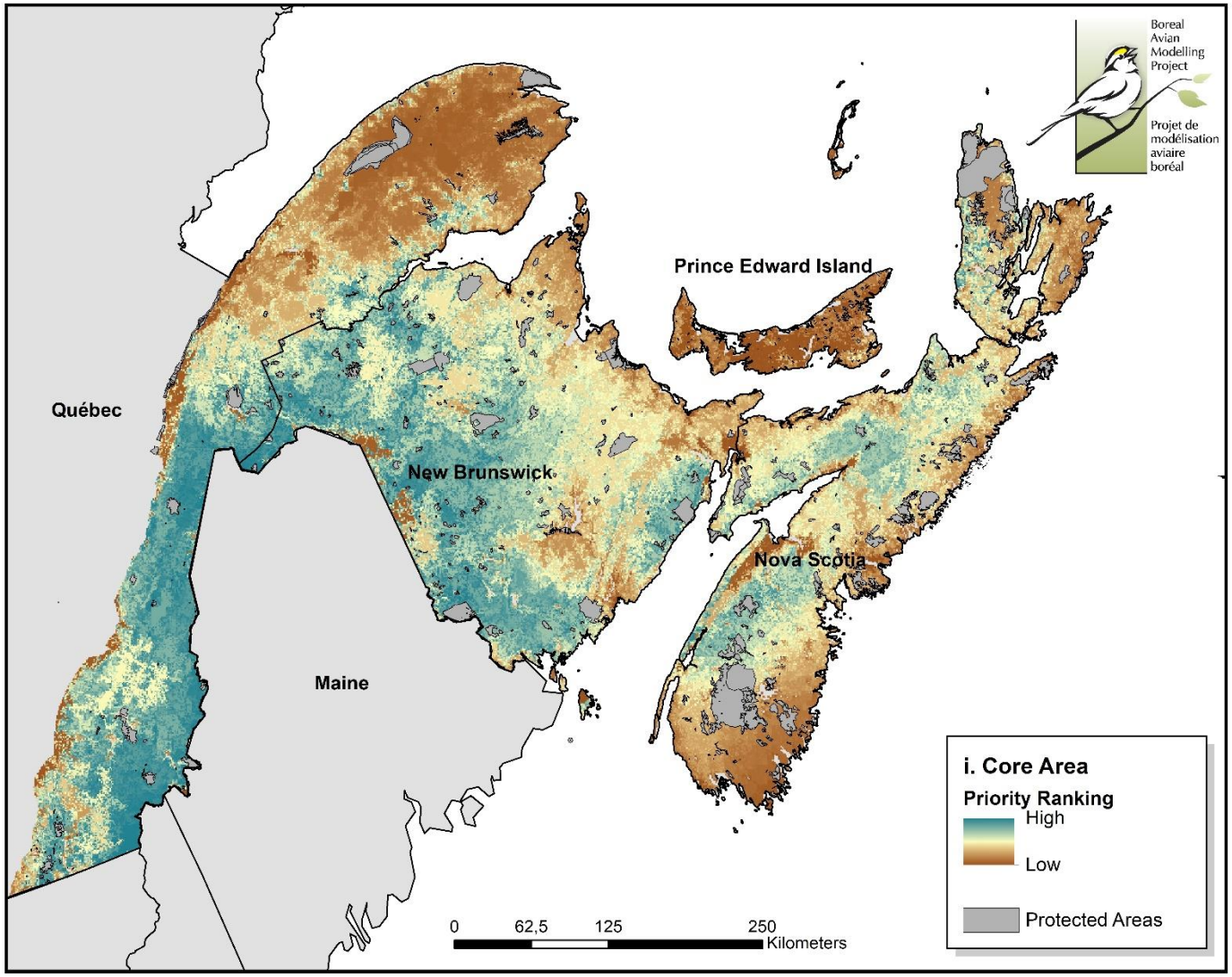

Figure 14: Relative value of land for supporting high densities of Canada Warblers emphasizing core, connected habitat patches using the core area Zonation algorithm (model i)

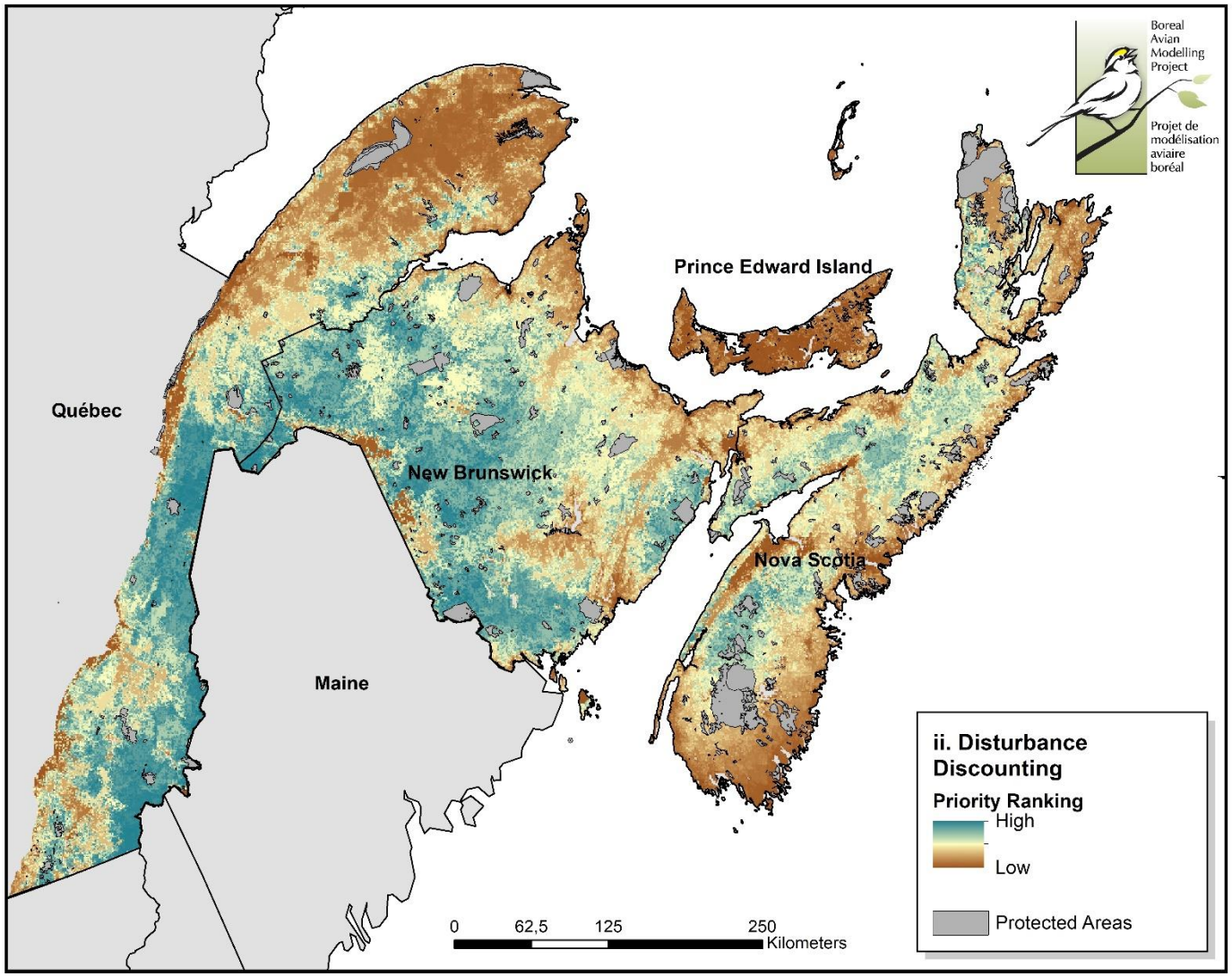

Figure 15: Relative value of land for supporting high densities of Canada Warblers in core patches discounted by anthropogenic disturbance (model ii)

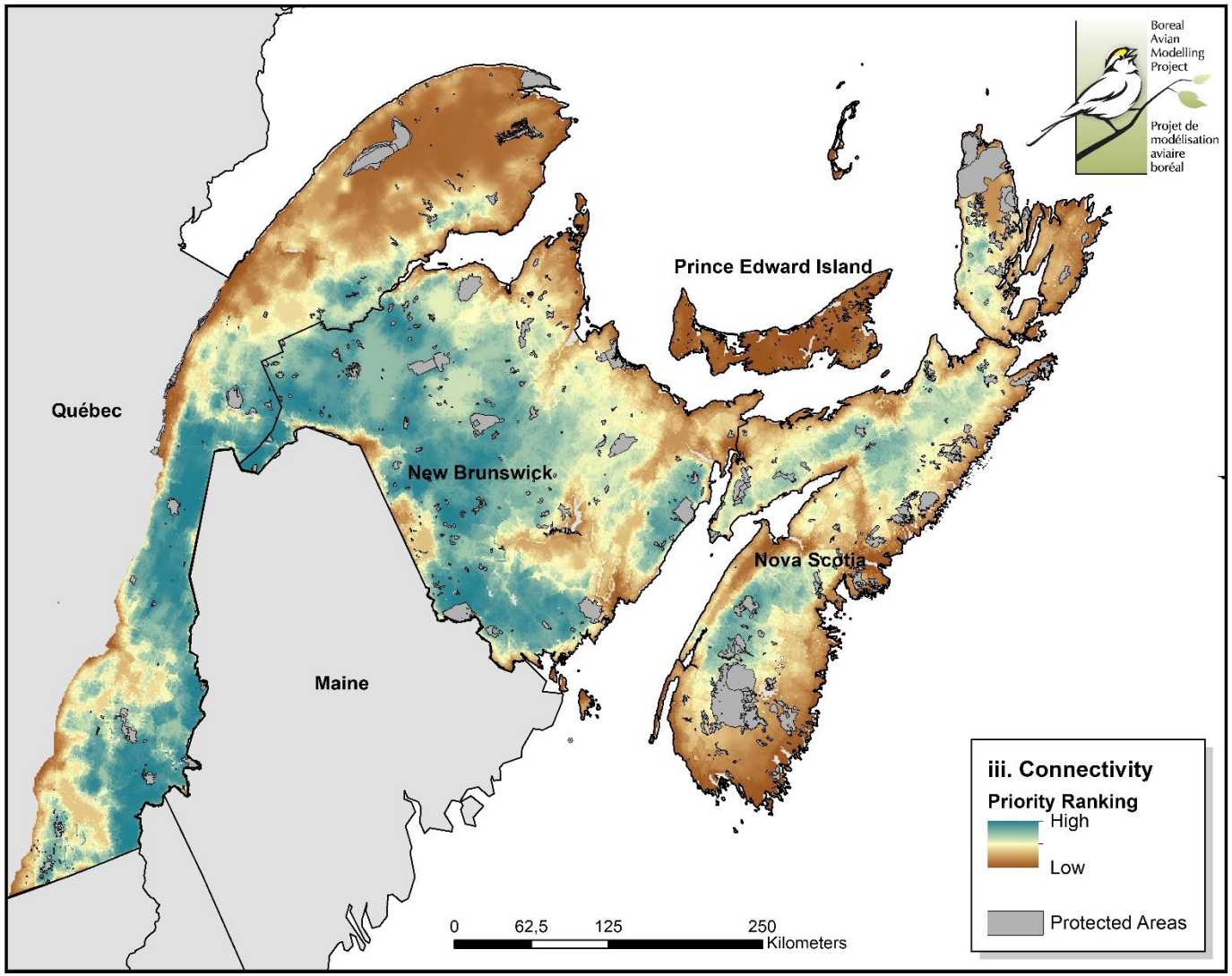

Figure 16: Relative value of land for supporting high densities of Canada Warblers emphasizing core areas, discounting anthropogenic disturbance, and applying distribution smoothing to improve connectivity (model iii).

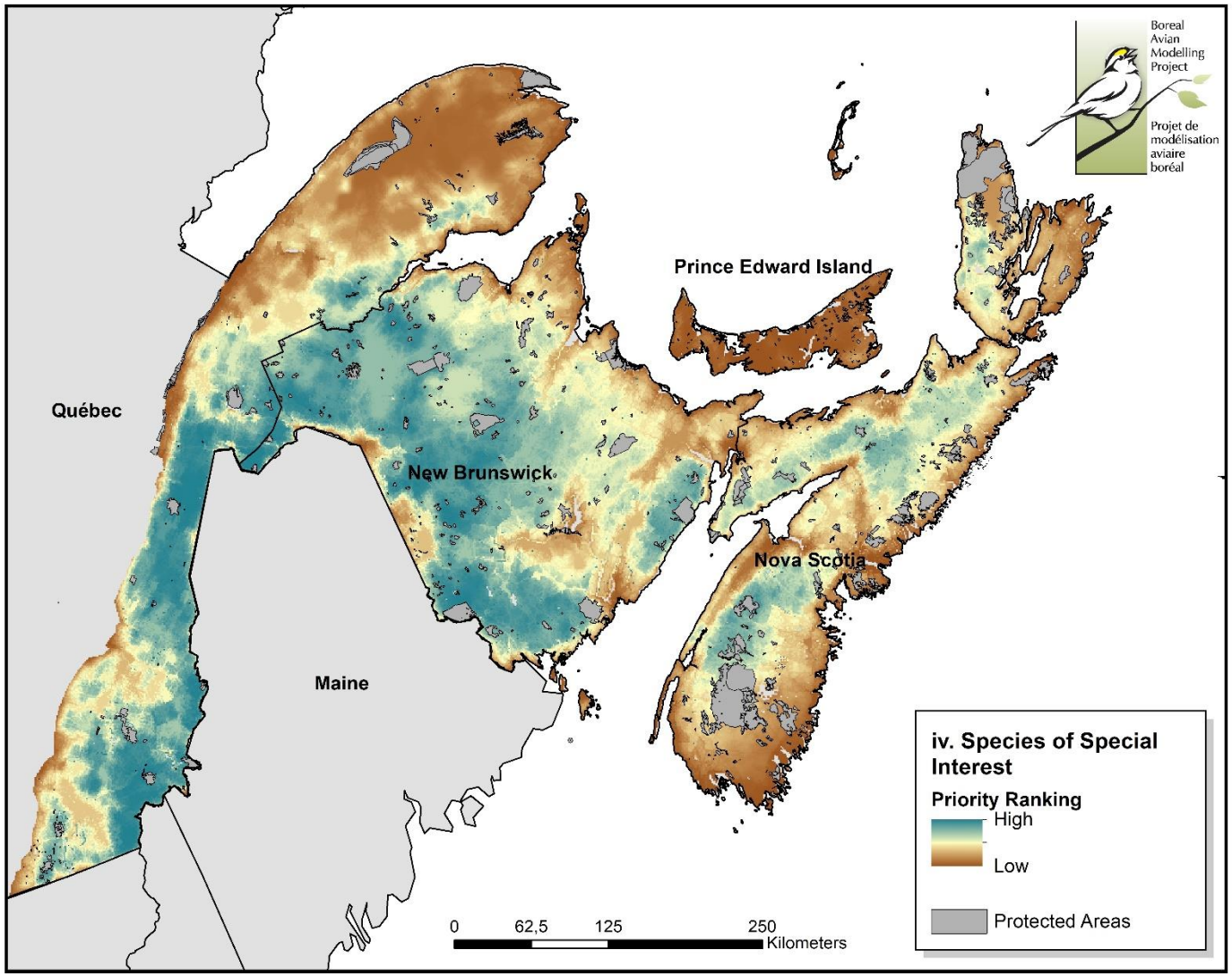

Figure 17: Relative value of land for supporting high densities of Canada Warblers emphasizing connectedness to core areas, discounting anthropogenic disturbance, and positively weighting areas with observations of Canada Warblers since 2005 (model iv).

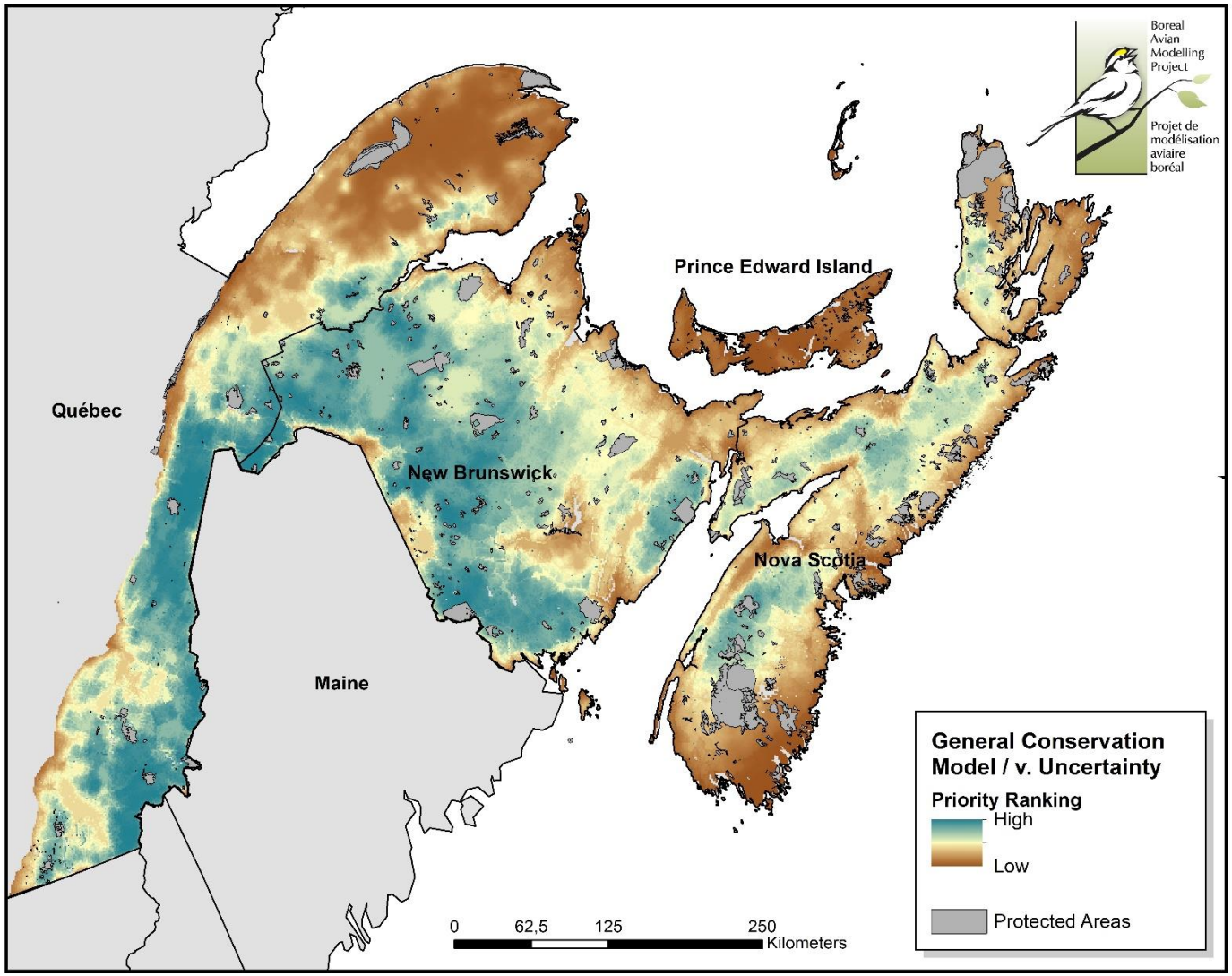

Figure 18: Relative value of land for supporting high densities of Canada Warblers emphasizing connectedness to core areas, recent observations of birds, and discounting areas of anthropogenic disturbance and uncertainty in abundance prediction (General Conservation Model/model v).

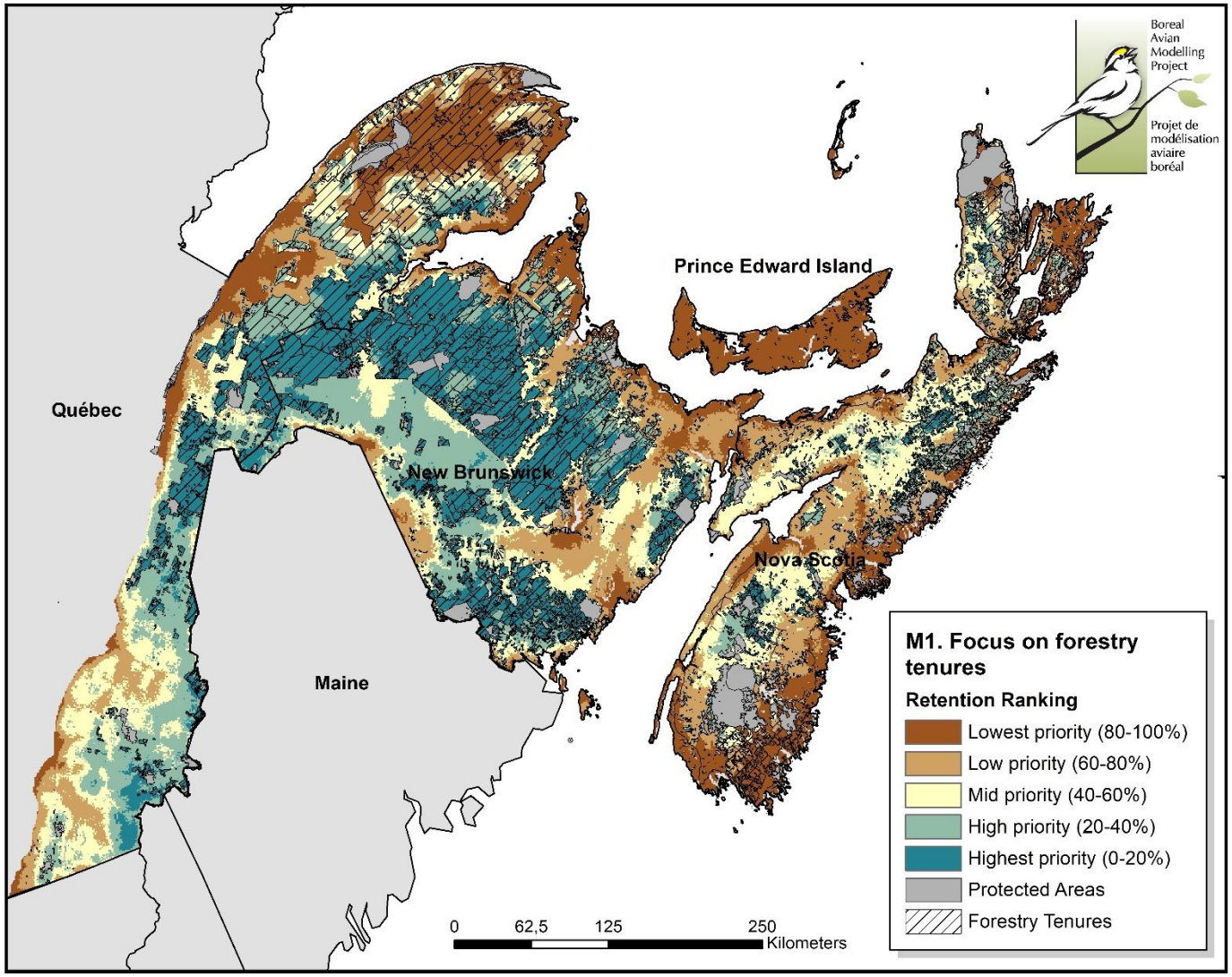

Figure 19: General conservation model adjusted using administrative boundaries to prioritize areas within forestry tenures (model M1).

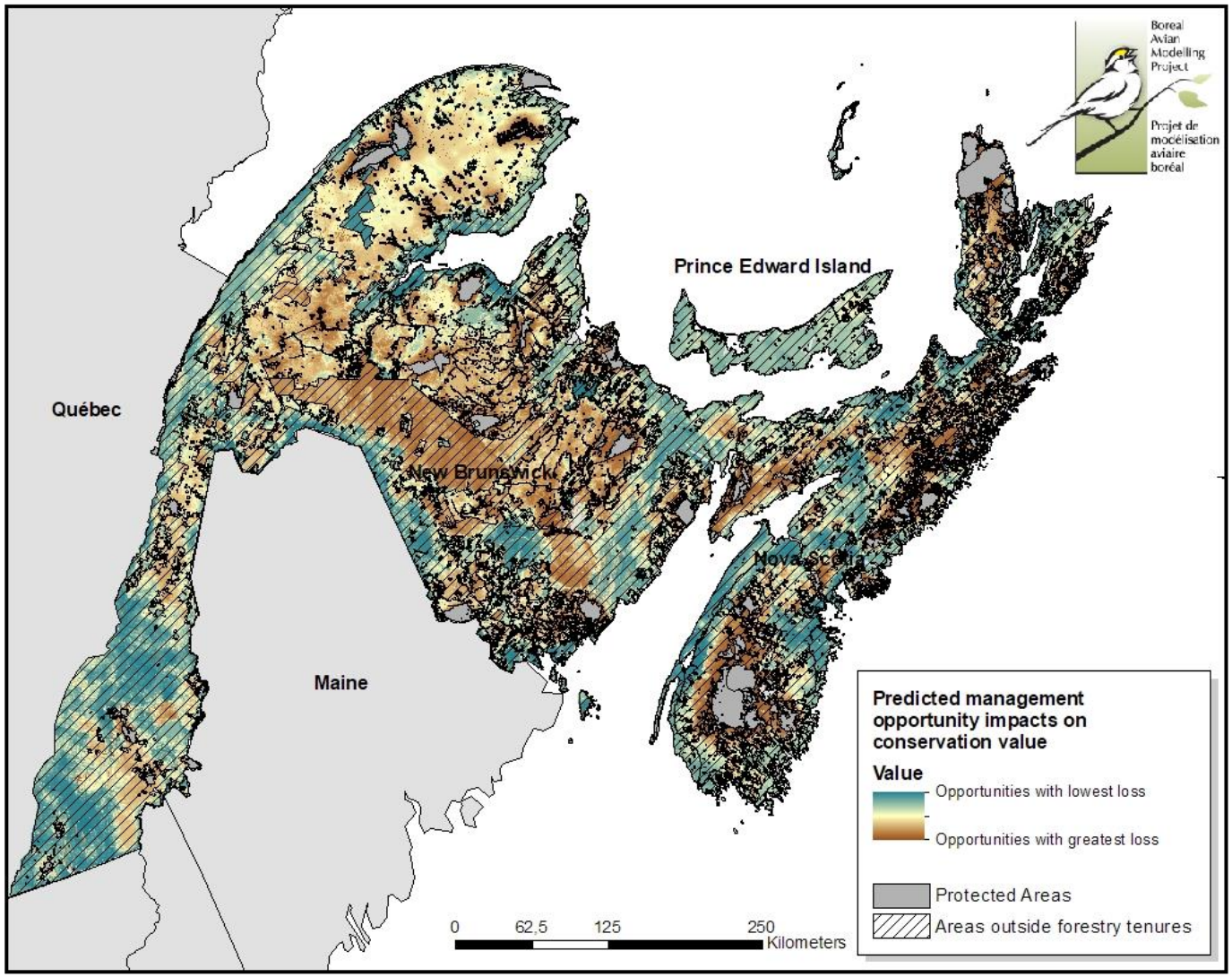

Figure 20: Map of predicted 'management opportunities' to minimize habitat loss, which subtracts areas with highest retention value (M-2) from areas with highest future habitat management potential (M-3).