A Prioritization Tool for the Conservation of Coastal Douglas-fir Forest and Savannah Habitats of the Georgia Basin and Puget Sound Lowlands

HTTP://ARCESE.FORESTRY.UBC.CA/MARXAN-TOOL/

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PREFACE

This document is a tutorial and introduction to an online Marxan-based planning tool that employs integer linear programming to return optimal solutions to user-defined problems in area prioritization for biodiversity conservation in coastal Douglas-fir and oak savannah habitats of the Georgia Basin region. This tool is in 'beta-release' and will benefit from the input of users and, especially, the inclusion of additional biodiversity data and layers to more fully represent the distributions of particular focal species or communities. We thank users in advance for input on the tool, its component layers and output. Instructions for accessing the tool are included in this document. Please direct correspondence to Peter.Arcese@ubc.ca or:

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CONTENTS

1. BACKGROUND INFORMATION

1.0 THE NORTH PACIFIC LANDSCAPE CONSERVATION COOPERATIVE

Figure 1: The extent of the North Pacific Land Conservation Cooperative and the region established for the Georgia Basin conservation prioritization project

The North Pacific Landscape Conservation Cooperative (NPLCC) is a partnership of government agencies, non-government organizations, First Nations, and universities. The overarching goal of the cooperative is to inform landscape-level conservation and sustainable resource management for the coastal region that spans from Northern California to Alaska.

1.0.1 THE GEORGIA BASIN

The planning tool described in this manual focuses on the Strait of Georgia, Puget Lowland, and Willamette Valley ecoregions in British Columbia, Washington, and Oregon. These areas support a very diverse and globally unique mix of dry forest and savannah habitats now critically-threatend due to land conversion, exotic species invasion and altered disturbance regimes. Known broadly as the Georgia Depression-Puget Lowlands, this region includes threatened Coastal Douglas-fir forest and Oak-Savannah habitats, also referred to as Garry oak ecosystem or Puget Prairie. We refer to this region as the Georgia Basin, but note that the project area includes all ecoregions falling within the climate envelope of the Coastal Douglas-fir biogeoclimatic Zone (courtesy Dr. Tong Li Wang, Climate BC/WNA) (Figure 1). Our overall objective is to deliver a Marxan-based, GIS tool to prioritize land acquisition and conservation investment throughout the Georgia Basin and facilitate scenario development around alternate land use plans likely to maximize the integrity and persistence of focal communities in future.

1.1 WHY USE CONSERVATION OPTIMIZATION TOOLS?

Conservation optimization tools are increasingly employed to help inform decisions on landscape-scale conservation planning. As part of the systematic planning process, optimization tools such as Marxan can contribute to a transparent, inclusive and defensible decision making process. Historically, conservation decision-making has often evaluated parcels opportunistically as they became available for purchase, donation or subject to threat. Such decisions may not maximize the long-term persistence of target species or communities, or the biodiversity returns on dollars invested, in the absence of a landscape-level understanding of the distribution of target species and communities.

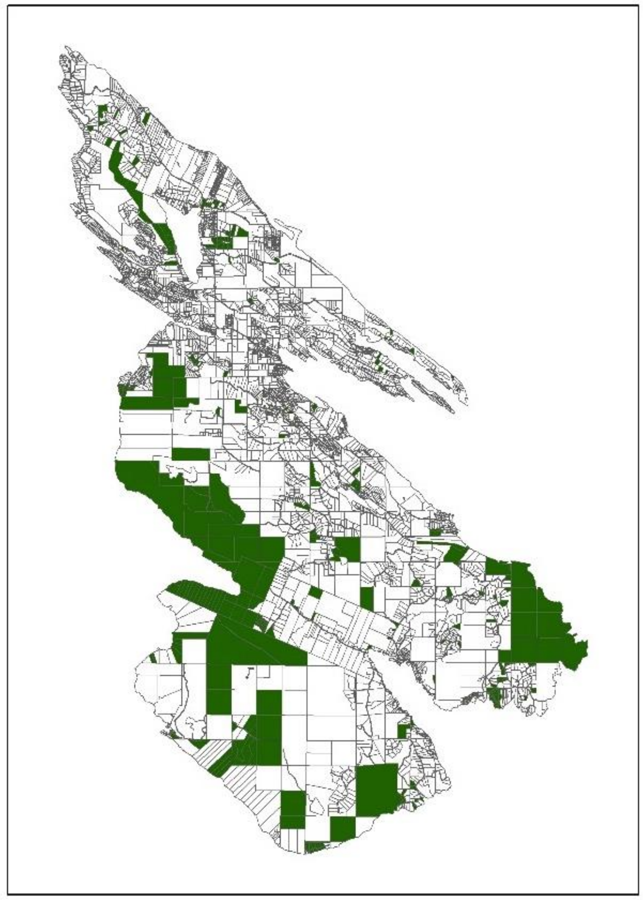


Figure 2: Example of a typical optimization output. Selected properties on Salt Spring Island, British Columbia, are shown in green.

Optimization tools like the one introduced here are meant to help planners simulate alternative reserve designs over a host of biodiversity and management targets to help prioritize parcels and conservation actions. Such tools allow you to specify biodiversity targets such as focal or indicator species richness and ecosystem representation, while minimizing overall costs of land acquisition measured in various ways. In this tutorial we introduce a tool specific to planning in the Georgia Basin (Figure 1), which we refer to as the NPLCC tool. This tutorial will show you how to use the tool to identify (1) existing gaps in biodiversity protection, (2) candidate areas to include in a growing reserve system, and to (3) provide decision support based on repeatable conservation targets represented as more and less desirable bird and plant communties.

1.2 WHAT *IS* THE NPLCC TOOL?

The NPLCC tool is a web-based, graphical user interface that follows the same principles as Marxan planning software to find near-optimal solutions to problems in conservation prioritization (Ball et al. 2009). Marxan is a computer application that runs an algorithm on a user-defined data set, and returns a solution as a table of land parcels (or planning units) ranked by how well they meet user-defined biodiversity targets, while minimizing the costs of land acquisition or other, user-controlled costs (also known as the *objective function*, see section 1.3.1). Prior versions of this tool were designed for a much more restricted planning area in British Columbia, of interest to the Coastal Douglas-fir Conservation Partnership area (CDFCP), using “**simulated annealing**” as the soluiton algorithm, and returning a number of ‘near optimal’ solutions over ~290,000 parcels for consideration by users. More information on the CDFCP tool is found in the CDFCP user tutorial (Schuster, Morrell & Arcese 2015; see section 4).

In contrast, the current NPLCC tool uses **“integer linear programming” (ILP)** to return a single optimal solution over ~3 million parcels distributed from BC to northern OR. ILP represents the state-of-the-art approach to optimization problems, being faster and more efficient than simulated annealing, but only recently becoming available with the advent of fast computer algorithms (Beyer et al. 2016). The ILP algorithm employed here is capable of analyzing large, complex datasets to find an optimal solution to user-defined biodiversity goals, subject to user-defined costs, both explained in detail below. For additional information see section 1.3. Please note that the algorithms employed in this tool are proprietary, and made available for research use only (Gurobi Optimization Inc., 2016). As a consequence, all users are asked to provide a short project description and a brief summary of experience as ‘beta users’, working to improve tool use and application. An open (not password-protected) version of the tool will be made available with beta-user feedback incorporated.

Overall, this tool allows you to set parameters and view results directly from the web interface, and to save results in a spatially-linked solution file that you can download to a desktop GIS application (see Section 2 for instructions). The goal of this tutorial is to introduce you to the NPLCC tool, explain how to manipulate key variables, and explore how to inspect and apply output files in support of your planning decisions. It is not essential that you understand how the algorithm works to use the tool, but those wishing to gain a better technical understanding should consult resources provided in Section 4.

1.3 HOW DOES IT WORK?

Before a conservation optimization tool can run, it needs to know the project objectives and project area under consideration. While this information is typically provided by the user, the NPLCC interface described in this tutorial already contains numerous cost and biodiversity layers that were developed following stakeholder consultation at meetings and workshops in British Columbia and Washington State with local, regional and federal land managers. The following list provides an overview of typical input requirements for a standard optimization tool, and the options included in the NPLCC tool are described in detail below and accompanying appendicies:

1. **The project area and a list of all of the planning units contained within it**

   Examples of planning units within a project area include a map of parcel boundaries (a ‘cadastral layer’), delineated watersheds, or a user-defined grid placed over the project area.

2. **The cost associated with each planning unit**

   Because minimizing the costs of conservation is generally a goal of stakeholders, each planning unit must have an associated cost. Types of costs vary with the goals of each project and are ultimately limited by the cost metrics available for planning and thus by those included in the optimization tool. Some examples of cost metrics include: 1) the total land area included in the solution (ha), 2) the estimated costs of managing or restoring acquired parcels, 3) the opportunity costs of displaced commercial activity, industry, tourism, or recreational access, and 4) the costs of acquiring land.

3. **A list of biodiversity features**

   'Biodiversity features' may refer to bird and plant communities, specific habitat types, or special elements identified and mapped within the planning area of interest. These data are organized as tables within the planning software, wherein each planning unit is associated with an index of abundance, a probability of occurrence, or the presence/absence of a particular biodiversity feature of interest.

4. **A user-defined target for the amount and quality of habitat to be conserved**

   'Targets' are simply user-defined values (often proportions) of a given biodiversity feature that must be represented in the final solution. For example, if a user wanted to identify the optimal reserve configuration that protects 30% of remaining old forest in the Georgia Basin, one would set a target of 30% of that layer (or a sub-set of that layer if e.g., only 'high quality' habitat were of interest). By design, targets are always met in the current NPLCC tool. However, the costs of meeting those goals may rise exponentially as the targets for particular targets become more challenging to meet (e.g., reserving 90% of existing old forest habitat).

Overall, because each planning unit in the NPLCC tool has an associated cost and a biodiversity value associated with it, based on the data layers currently available, users can set targets with minimal technical expertise. However, we do recommend that users attempt to gain a thorough understanding of the potential limits of the predictive mapping layers used in the NPLCC tool before attempting to apply particular scenarios obtained.

For several practical reasions, the Georgia Basin NPLCC project area was divided into 1-hectare grid cells, each representing one planning unit. However, the solutions produced by the NPLCC tool group these 1ha planning units by property boundaries (the cadastral layer) so that users can make realistic decisions about land acquisition strategies based on parcel size, location, biodiversity value and tax-assessed value (2014 values for BC; 2015 values for WA and OR).

More details of the cost and biodiversity layers available to users are provided in Section 2, and the methods regarding their development are provided in supplementary appendices and peer-reviewed papers cited therein. If you decide to build additional layers for use in the tool, it will be important to understand how to organize your data into input files so they can be added efficiently to our existing platforms as a feature or cost layer. Information on how to organize input data can be found in the linked resources highlighted in Section 4 of this tutorial.

1.3.1 THE OBJECTIVE FUNCTION

After you specify targets for biodiversity features of interest, and run the tool, a configuration of selected planning units is saved to a file for downloading by the user. This configuration represents the “solution” that best satisfies the **objective function**, which seeks to minimize costs while simultaneously meeting biodiversity targets. The objective function has the additional constraint that the selection of planning units must be binary – i.e. you cannot choose a portion of a planning unit. The objective function can be expressed mathematically as:

Minimize $\sum Cost_{selected\ planning\ units}$;

Given that $\sum Biodiversity\ features_{selected\ units} \geq user\ defined\ targets$;

and $selected\ planning\ units = (0,1)$

This function itself is conceptually straightforward, but its solution becomes exponentially more complex in areas like the Georgia Basin, where over 3 million parcels are available for selection, and users are able to define targets for several biodiversity features. Given the complexity of such problems, sophisticated algorithms such as integer linear programming provide the ability to find an optimal solution.

1.3.2 INTEGER LINEAR PROGRAMMING IN A NUTSHELL

The integer linear programming algorithm works by initially calculating an “unconstrained solution”, which is the best possible solution to the objective function if the condition of binary selection was not required (i.e. partial planning units could be selected). This represents the lowest possible summed cost that still meets the targets. The binary condition is then reintroduced one planning unit at a time and the summed cost of the unconstrained solution is used as a baseline to compare against. This essentially looks like a decision tree, where each node represents a planning unit that is either selected (1) or not selected (0), until every planning unit in the area is assigned a binary value. Each endpoint of the tree represents a configuration of planning units with a specific summed cost. As you can probably imagine, this tree becomes impossibly large when you consider millions of planning units. However, the power of the ILP algorithm is that it is able to exclude large sections of the tree before it fully explores them, because it anticipates that these sections will have a higher summed cost than the unconstrained solution. Because ILP uses several additional techniques to trim down the sample space (not all discussed here), the incorporation of ILP into the NPLCC tool means that an optimal solution can be found in as little as 1-2 minutes, as opposed to several hours to days using simulated annealing. Please note however, that the NPLCC tool uses an ILP platform developed in large part by Gurobi, an online optimization engine (Gurobi Optimization Inc., 2016). This proprietary routine is available for research use as we elicit input from Beta users before removing password protection to the tool.

2. USING THE INTERFACE

2.1 GETTING STARTED

To use the NPLCC tool you will need an internet connection. Solutions are viewable directly in the web-interface, though we urge patience as it can take up to several minutes to view solutions on-line. GIS software such as ArcMap or QGis will be necessary to examine property features in detail after downloading scenario output.

The interface we have provided to users is linked to an external server that contains all of the input layers for the Georgia Basin region within the North Pacific Landscape Conservation Cooperative planning area (NPLCC; Figure 3). These include costs, existing parks, and biodiversity indexes such as old forest birds, human commensal birds, and exotic vegetation under present and future climate change scenarios. To connect to the server, go to http://arcese.forestry.ubc.ca/marxan-tool/ in your Internet browser. To obtain a password to access the tool, please send an e-mail to Peter.Arcese@ubc.ca to: 1) identify your host organization, 2) your intended use of the tool and its outputs, and 3) to confirm that you will only use the tool and its products for research and planning purposes, rather than for commercial consultations or products.

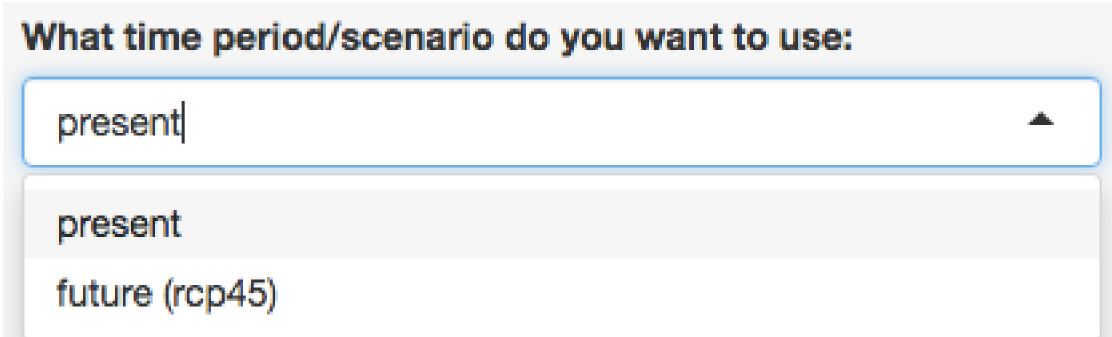
Figure 3: The Georgia Basin region within the NPLCC planning area. This is the extent of coverage available in the NPLCC tool.

2.2 MANIPULATING KEY VARIABLES

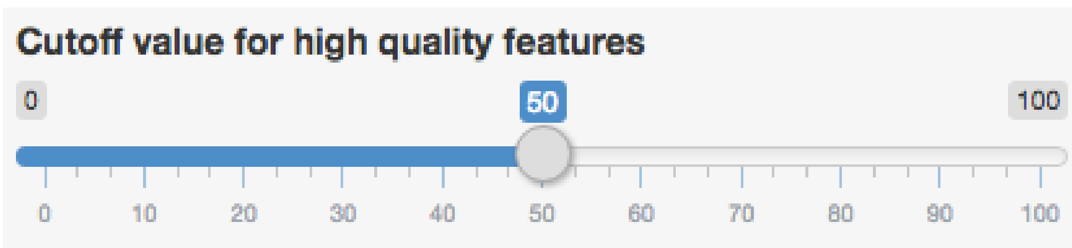
Once you've accessed the NPLCC tool following instructions in section 2.1, you're ready to manipulate the parameters that the tool uses to produce solutions. These manipulations are made in the grey sidebar on the left hand side of the screen, and in each cell of the 'Percent' column of the table displayed under the 'Edit Target' tab in the middle of the page. Each user-defined parameter provides the prioritization algorithm with basic instructions on how it will run (see section 1.3). Information for each user-defined parameter is explained below.

2.2.1 GLOBAL PARAMETERS

The parameters detailed below are found in the grey sidebar under the 'Global parameters' heading.

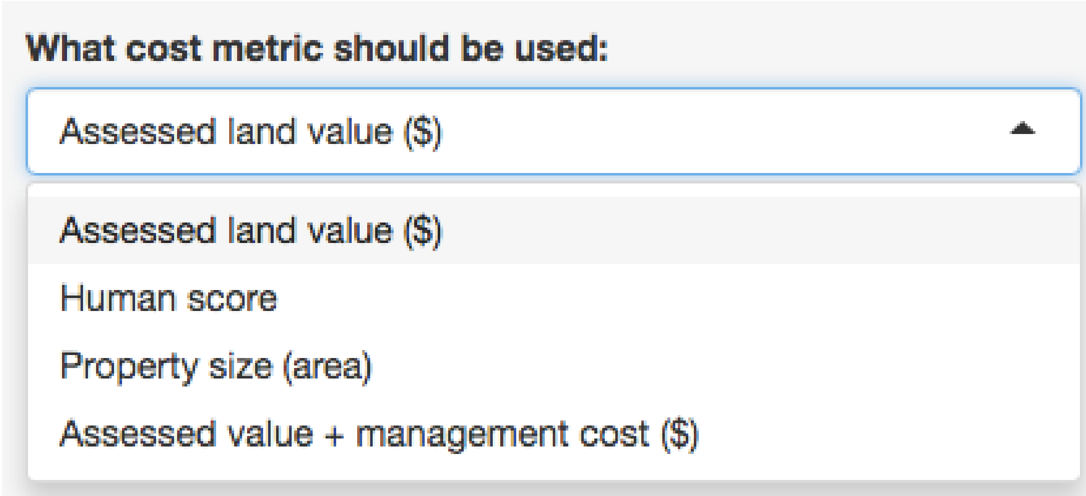


Specify which time period you would like to use for the prioritization analysis. You can either use 'present', in which case the tool will use present day distributions of the input layers available, or 'future (rcp45)', which will cause the tool to use the future, predicted distributions of focal communities in 2055, based on the representative concentration pathway RCP 4.5. RCP 4.5 represents a stabilization scenario wherein total radiative forcing is stabilized before 2100 by using a range of technologies and strategies for reducing greenhouse gas emissions (Clarke et al. 2007). (Radiative forcing is the difference between insolation, or sunlight, absorbed by the Earth, and the energy that radiates back to space).



This slider allows users to specify a minimum or 'cutoff' value, which effectively limits the tool to selecting planning units with only this or high-quality habitat, wherein 'quality' is estimated as the probability that the community is present at the site. Thus, if users only want to include 'high quality' planning units in the solution, the slider can be set appropriately for each input feature from 0 (all habitats with the feature potetnially present) to 100% (only planning units 'certain' to include the target community).

Once set, the optimization algorithm will only consider planning units that have at least the target value specified or higher in its solutions. However, please note that by using a cutoff, you are reducing the total fraction of the planning area which can contribute to meeting a given target. For example, let's say we have 10 planning units, 8 of which have biodiversity values of 40% or less and 2 with values over 80% (0.4 and 0.8, respectively, as recorded in data tables). Setting the slider to 50% will eliminate from consideration all 8 units with values below 50%. Thus, if we were to set a target to protect 50% of this habitat, the NPLCC tool would only need to select one of the two high value planning units (assuming they are of equal size) to meet the target. However, setting the slider to 0 and target to 50% would result in a solution that includes 50% of all potential habitat, rather than half of all high quality habitat. Put differently, to obtain a solution that includes 100% of all habitat predicted to be 50% or more likely to include the target community, users would set the target to 100 and slider to 50.



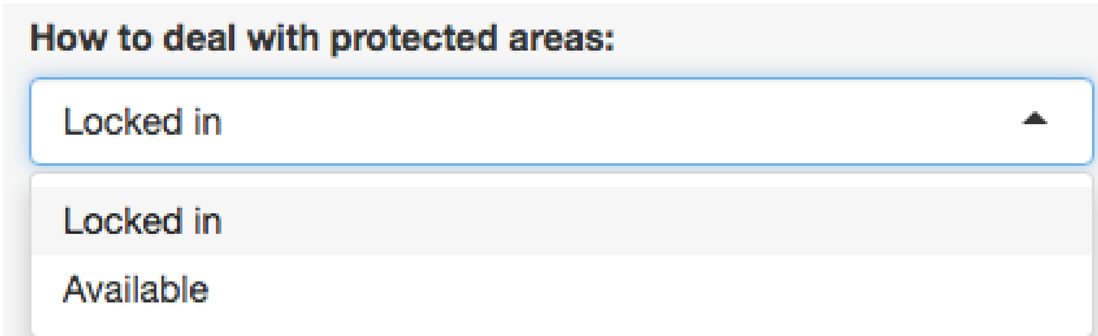
This feature allows users to select the cost metric that best suits the goals of their project. For example, those working on a fixed budget for acquisitions may wish to use assessed value as the cost, or assessed value plus estimated management costs to restore the parcel to a condition of high native plant species cover. In contrast, users interested in minimizing the total area reserved may wish to use property size (indicating total reserve area). Last, some users may wish to minimize the likelihood of human commensal species presence in planning units. Each of these cost layers are described briefly below, and in more detail in appendices.

Assessed land value is generated using a combination of cadastral data and 2014/15 land value assessments (BC Assessment 2015; ICIS 2015 State of Oregon 2015; Washington County Oregon 2015). This metric is most easily translated into acquisition costs and useful for projects with constrained budgets. NOTE: Currently, the assessed value of properties in Canada and the USA were incorporated at face value and at par. Future versions of this tool will include an option to input the current exchange rate as these differences have the potential to dramatically affect outcomes in trans-national planning efforts under a budget.

Human score is based on an expert-elicited weighting of bird species distribution models by expert scores for urban and rural areas. As this metric identifies human impact rather than monetary value, only select if you wish to focus on biodiversity value regardless of acquisition cost. When this metric is selected, the solution cost (ie. Cost_out; see Table 2) will be the total area associated with human commensal birds. One might consider this cost metric when trying to prioritize acquisition of areas with the lowest human scores, and thus areas with potentially higher biodiversity.

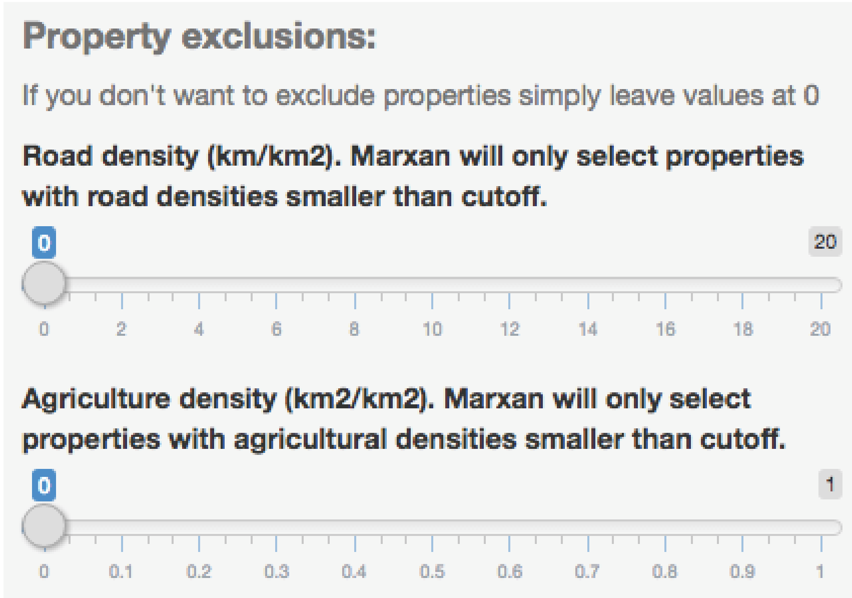
Property size uses land area (in ha's) as a proxy for cost and is useful if you are interested in biodiversity values regardless of monetary property cost (note: each planning unit is 1ha). Using the area cost metric attempts to minimize total hectares included in the solution.

Assessed value + management cost combines assessed land values (described above) with the cost of managing exotic vegetation. Management costs were estimated by combining predictions of exotic plant species community occurrence with expert-elicited estimates of the costs to remove exotic species and maintain exotic cover at < 5% over 10 years (based on expert elicitation in collaboration with D. Polster, P. Dunwiddie, T. Ennis, I. Banman, and R. Walker). Estimates take into account current state of invasion at a patch (probability of the exotic species community), and the probability of re-invasion based on the area of urban land cover within 1km of the planning unit. We emphasize to users that these costs are primitive as applied here, but intended to provide a clearer sense of the potential long-term costs of scenario outputs.



This slider allows you to specify whether or not you want the NPLCC tool to ‘force’ all existing protected areas and parks into the optimal solution. The two options on the dropdown menu are “Locked In” and “Available” (see above). By choosing “Locked In”, solutions will include all planning units currently protected within state, provincial and federal parks (but not municipal parks, which often include ball fields and other amenties of uncertain biodiversity value). Locking in parks is useful if you wish to identify areas to add to an existing reserve system (e.g., if your objective were to increase the area protected in parks from 6% to 17%). However, because the optimization algorithm used in the NPLCC tool always meets specified biodiversity targets (see section 1.3.2), and existing protected areas may be located in areas of relatively low conservation value, selecting ‘locked-in’ may result in solutions with higher overall costs than un-constrained solutions (i.e., selecting ‘available’). This is because the solution will have to compensate for protected areas of low biodiversity (i.e. conservation) value by increasing the total area included in the solution in order to meet targets, which is likely to also increase costs. We recommend that all users employ both options when comparing scenarios so that they become fully aware of the value of existing reserves and the potential for enhancing conservation outcomes under alternative models (see Appendix F).

2.2.2 PROPERTY EXCLUSIONS



This section allows you to specify features of the planning units you want included in the solution. Leaving any of the sliders at 0 causes the tool to consider all planning units, regardless of their proximity to roads or agricultural land.

ROAD DENSITY

This parameter is measured as kilometers of road per square kilometer (km/km^2) and calculated for each 1ha planning unit using OpenStreetMaps data (Geofabrik GmbH Karlsruhe 2014; see Appendix C). As an example, empirical data from 700 locations across the Coastal Douglas-fir region in British Columbia, Canada, indicate that the probability of encountering the old forest bird community begins to decline at road densities over 1 km/km^2 (Figure 4; Schuster & Arcese 2013 and *unpublished results*). Substantial variation in this relationship may be partly explained by the fact that rural roads can act as gaps in the forest canopy, thus promoting the abundance and diversity of old-forest species that rely on understory plants (Figure 2). After this point, however, fragmentation due to roads may decrease biodiversity (Heilman et al. 2002). Excluding properties with high road density (e.g. >1-3km/km^2) may help fine-tune your solution away from roaded areas, but may also dramatically constrain your solution in human-dominated landscapes. **NOTE**: the negative relationship between road density and many native bird and plant communities is also indicative of the predictive species maps used to identify target communities (e.g. Old-forest and Savannah birds; see Appendix A). Thus, by setting protection targets for native birds and plants, you are effectively putting constraints on road density, to the extent that those species become less common as roadedness increases. We therefore suggest that you explore the utility of this parameter by running the tool with and without road density values included to compare results. We find that setting higher targets for planning units with a high probability of including old forest or savannah birds and native meadow plants tends to return solutions with relatively low road density and agricultural land use.

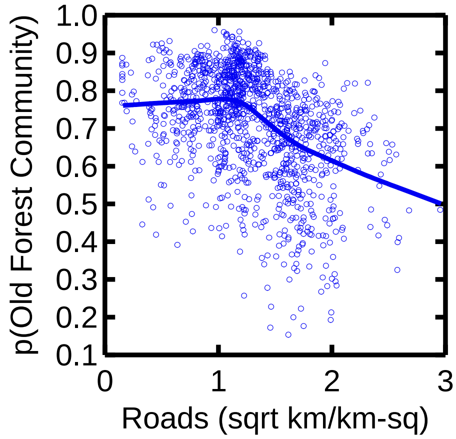


Figure 4: An empirical relationship showing the effect of road density on the occurrence of the old-forest bird community in forest stands ≥80 years of age. The y-axis is an estimate of the probability of old-forest bird community occurrence (n = 1248 old-forest stands; Schuster & Arcese 2013; and unpublished results).

AGRICULTURE DENSITY

Agriculture may include cultivated fields, orchards, vineyards, golf courses, and greenhouses, and is measured as the square kilometers of agriculture per square kilometer of land. Agricultural area was estimated from Terrestrial Ecosystem Mapping (Province of British Columbia 2015) and National Land Cover Database 2011 data (MRLC 2015; see Appendix C). As an example, empirical data from 700 locations across the Coastal Douglas-fir region in British Columbia, Canada, suggest that the probability of encountering old-forest bird communities declines by ~50% in areas comprised of >3 ha of agriculture per km^2 (Figure 5; Arcese & Schuster, *unpublished results*). Excluding parcels with a lot of agricultural land may enhance the value of your designs for forest bird species, but may de-emphasize your focus on savannah species. This is because many savannah birds in the Georgia Basin now rely on agricultural habitats in the absence of native savannah. Overall, however, your final parameterization should reflect your conservation goals.

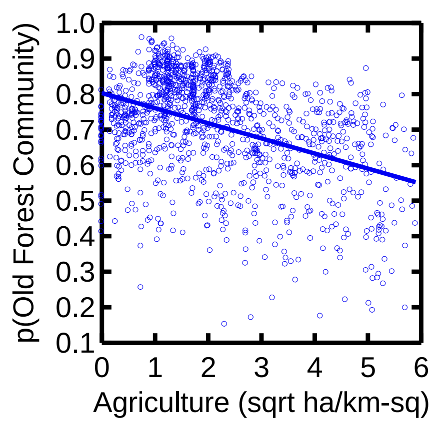


Figure 5: An empirical relationship showing the effect of agricultural area on the occurrence of the old-forest bird community in forest stands ≥80 years of age. The y-axis is an estimate of the probability of old-forest bird community occurrence (n = 1248 old-forest stands; Arcese & Schuster, unpublished results).

2.2.3 PROTECTION TARGETS

Edit Target | Input Layers

	id	Percent	name
1	1	17	OF
2	2	0	SAV
3	3	0	SHR
4	4	0	WET
5	5	0	HUM1
6	6	0	NAT
7	7	0	EXO1
8	8	0	TREE

Protection targets are specified in the table under the 'Edit Target' tab in the NPLCC tool interface (pictured above). You can specify your overall objectives by changing the percent value next to each of the biodiversity features (e.g. Wetland, Old-Forest, etc., detailed in Table 2). As an example, one might want to protect 17% of remaining old-forest in the entire Georgia Basin, following Target 11 from the Aichi Biodiversity Targets established at the Convention on Biological Diversity (2010).

In the 'Input Layers' tab next to the 'Edit Target' tab, you can view the probability of occurrence maps for three commonly used biodiversity feature layers: Old-forest (OF), Savannah (SAV), and Human commensals (HUM; see Table 2). You have the option of selecting/deselecting each feature layer against your basemap of choice (OSM, Aerial, or Terrain). The scale used for each biodiversity layer is a measure of 'probability of occurrence' of that biodiversity feature being found in areas of the Georgia Basin. Higher values indicate higher probabilities of occurrence. Use this feature to conceptualize how the NPLCC tool uses biodiversity feature layers to generate solutions, as well as to generally view the probable occurrence of these feature layers in the Georgia Basin planning area.

2.2.4 RUNNING MULTIPLE SCENARIOS

Many NPLCC tool users will want to run several optimizations with a range of parameter values, or 'scenarios', to compare outputs. In multi-stake-holder planning session, such runs may be used to identify the parcels consistently selected in all scenarios, and thus acceptable to all parties. Fortunately, there are two ways you can do this using the current NPLCC tool interface.

First, click the check box next to 'Run Multiple Scenarios' in the grey sidebar of the interface. Then select among the options described below.

Option 1 is described in the grey sidebar after clicking the box. This option allows you to upload a .csv file specifying the parameters of each scenario by row. The headings that must be included in the uploaded .csv file are given by example in the table to the right of the grey sidebar. The possible values that can be entered for each header column are provided in Table 1. Blank cells or those with anything but the terms allowed (Table 1) will prevent the optimization from running (an error message will populate saying "application unexpectedly exited"). After you upload your .csv file, it should populate under the 'Scenario List' tab, replacing the example table that was originally there, and confirming that you have successfully uploaded your .csv file.

Option 2 involves building your scenarios directly in the tool interface. To the right of the grey sidebar you will see a table with 1 row populated called 'template'. This is simply an example row, so you can change the parameters specified in this row to suit your own user-defined scenario. You can name each scenario as you like. For the 'time', 'cost', and 'protected' columns, you can double-click the cells to select allowable values. To add another scenario, right click on any cell in the first row and select 'Insert Row Below' from the dialogue box that appears. You should now see a new row where each cell is specified as "NA". Change each "NA" to a value that defines your 2nd scenario. Repeat this step for as many scenarios as you like. **NOTE**: if you are encountering inexplicable error messages, try refreshing the website and starting again.

Table 1: Summary of values that can be specified for each scenario when running multiple scenarios

Scenario	Any name you specify
Time	"curr", or "rcp45"
Cost	"dollar", "area", "human", or "management"
Protected	"locked", or "avail"
FTcutoff	Any value between 0 - 100
OF, SAV, SHR, WET, HUM1, NAT, EXO1, TREE	Any value between 0 - 100

Table 2: Descriptions of the biodiversity feature layers included in the NPLCC tool. Target values for each of these layers can be specified in the table found under the 'Edit Target' tab in the NPLCC tool interface.

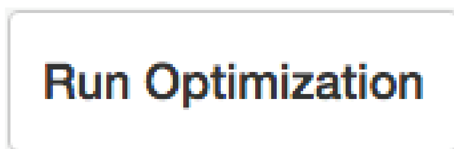
Old Forest Birds (OF)	A composite distribution map based on probability of occurrence of birds associated with old forest habitat (Schuster and Arcese 2014). See Appendix A.
Savannah Birds (SAV)	A composite distribution map based on probability of occurrence of birds associated with savannah habitat (Schuster and Arcese 2014). See Appendix A.
Shrub Birds (SHR)	A composite distribution map based on the probability of occurrence of birds associated with shrub habitat. See Appendix A.
Wetland Birds (WET)	A composite distribution map based on probability of occurrence of birds associated with wetland and riparian habitats (Schuster and Arcese, unpublished). See Appendix A.
Human Commensal Birds (HUM1)	A composite distribution map based on probability of occurrence of birds associated with urban and rural human landscapes (Schuster and Arcese, unpublished). When targets are set for this feature, the tool will seek planning units least likely to host commensal species. See Appendix A.
Native Plants (NAT)	A composite distribution map based on probability of occurrence for the 20 most common native plants of Garry Oak/Maritime Meadow ecosystems (Bennett 2014). See Appendices A & B.
Exotic Plants (EXO1)	A composite distribution map based on probability of occurrence for the most common exotic plants of Garry Oak/Maritime Meadow ecosystems (Bennett 2014). When targets are set for this feature, the tool will seek planning units least likely to host exotic plants. See Appendix A.

Tree Species Indicators (TREE)	A composite climate envelope map for 3 common native trees characteristic of Garry Oak/Coastal Douglas fir ecosystems (Wang, *in prep*). See Appendix A.

AN IMPORTANT NOTE ABOUT SCALE:

Currently, the NPLCC tool provides solutions for the entire Georgia Basin within the NPLCC planning area defined (Figure 1). Future versions will allow users to subset areas of this region so that planning decisions can be made at smaller spatial scales (e.g., within municipal districts or counties). However, *it must be noted* that the spatial scale selected is likely to have a large effect on the solutions produced by the tool. For example, a small planning area (eg. Orcas Island) will include fewer planning units (PU's), more limited opportunities to meet targets, and thus may force the tool to consider PU's with lower conservation value in order to meet user-specified targets. Expanding the planning area (e.g., San Juan Islands) should increase the availability of high quality PU's, but may take the focus of conservation investments away from your particular area of interest. As user demand develops for this or later versions of the NPLCC tool, we would recommend running scenarios using the same parameter sets at different spatial scales, to identify those parcels which are selected consistently, and therefore likely to be of enduring regional and local value.

2.3 RUNNING THE NPLCC TOOL AND INTERPRETING RESULTS



Once all of the parameters have been defined for 1 or more scenarios, click on the 'Run Optimization' button at the top of the grey sidebar. Please be patient as results will take 1 – 3 minutes to produce. In most browsers, a status bar will appear at the top of the page to give you an idea of progress. A text box will also appear at the top right of the page saying "Calculation in Process", which will then change to "Post Processing", and will then disappear when the optimization is complete. **NOTE**: NPLCC tool users are not limited by computational capacity on their own computer in running optimizations because calculations are done on an external, virtual server hosted at the University of British Columbia by Prof. Peter Arcese, FRBC Chair in Applied Conservation Biology (Arcese lab). Scenario results are populated in the 'Results + Download' and the 'Result Map' tabs. Detailed explanations of how to download, view, and interpret results are provided below.

2.3.1 SUMMARY TABLES

After the optimization has finished running, you will find a summary table of the optimal solution(s) in the 'Results + Download' tab. The Result Summary Table will display the optimal solution for each scenario by row (if you only ran one scenario, there will only be one row in the table). **NOTE**: you will have to scroll right to see the entire table. You can also download the Result Summary Table as a .csv file by clicking the 'Results download' button. Explanations for all the Result Summary Table column headers are provided in Table 3.

2.3.2 VIEWING RESULTS

You can view a map of each optimal solution in 2 ways:

Option 1: Click on the 'Result Map' tab after your optimization has finished running. Here you will see a standard basemap of the Georgia Basin region overlain by your solution(s). You can change the basemap shown by selecting StreetMap, Aerial, or Terrain on the legend provided. The legend associated with your solution(s) is called 'selected', where selected planning units are displayed in blue (1), and unselected units in red (0). If you ran more than one scenario, each named scenario will populate in the legend box so you can select/deselect each one for comparison.

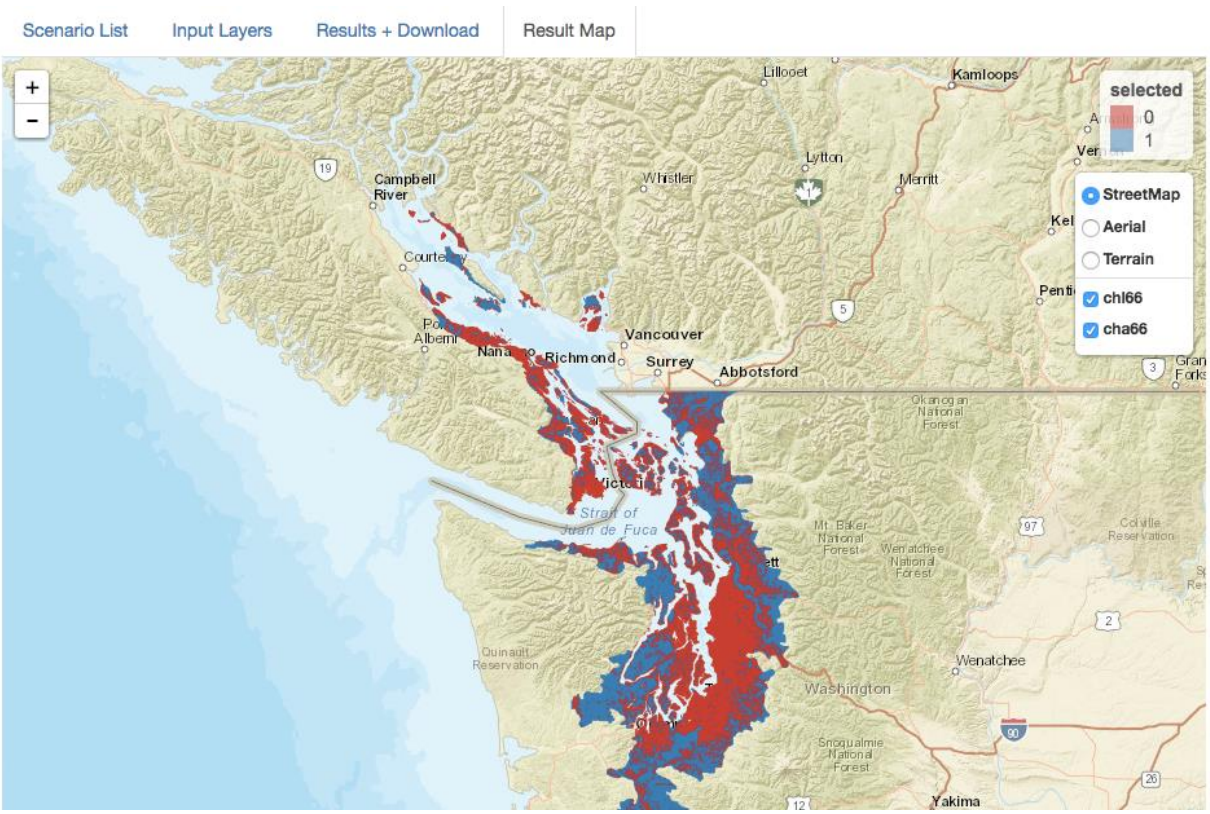


Figure 6: Example result map as viewed from the NPLCC tool interface after running two land prioritization scenarios (depicted on legend as "chl66" and "cha66"). Selected planning units coloured in blue, unselected units in red.

Option 2: Click on the "Download output raster" button in the "Results + Download" tab. This will initiate the download of a zip file containing the result in .tiff raster format. Unzip the folder onto your local harddrive. If you have ArcGIS, open ArcMap and use the Catalog sidebar to drag the .tiff file from its location on the harddrive into the viewing pane. The raster should display properly when viewed in a blank map template. However, you may need to use the Project Raster tool if you are using other layers with a different coordinate system and projection (the tool uses NAD 1927 UTM Zone 10N). It may also be necessary to change the Symbology to correctly display selected planning units. To do this, right click on the raster in the Layers sidebar and go to Properties→ Symbology. The default display setting is 'stretched', but we recommend changing this to 'classified' using the selection pane on the left side of the Properties dialog box. Ensure that one class contains 0, and the other class contains 1. Here you can also change the colour display.

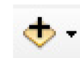
If you wish to add additional layers but do not have any, we recommend adding a defaut basemap available from ESRI. Click on the Add Data pulldown menu and click “Add Basemap”.  This will open a dialog box where you can choose a basemap.

Table 3: Result summary table headers and explanations.

Scen	The name of each scenario. Can be user-specified when running multiple scenarios, or defaults. Default names are populated using 1-letter abbreviations for the time, cost, protected areas, and high quality features cutoff. E.g. ‘chl66’ = [time = **c**urrent] + [cost = **h**uman] + [protected areas = **l**ocked-in] + [HQF cutoff = **66**]
Time	The time period specified. Options are: ‘curr’, and ‘rcp45’, which correspond to ‘present’ and ‘future (rcp45)’, respectively.
Cost	The cost metric specified. Options are: ‘dollar’, ‘area’, ‘human’, and ‘management’.
Protected	Corresponds to how you dealt with protected areas in the optimization. Options are: ‘locked’ or ‘avail’, which correspond to ‘Locked in’ and ‘Available’, respectively.
FTcutoff	Corresponds to the cutoff value specified for high quality features. Can be any number between 0 – 1.
Status	This lets the user know whether the optimal solution was found. If so, the status will be “OPTIMAL”.
Runtime	Time (in seconds) that it took to run the optimization.
Cost_out	The resultant cost of the scenario specified. Units depend on the cost metric selected (see **Cost** above): acquisition and management costs are in dollars ($); human score assesses cost as the amount of commensal habitat included in the solution (see section 2.2.1 for details); setting cost to area attempts to minimize total hectares reserved.
Area	Area of the solution (ha).
OF_Tar, SAV_Tar, SHR_Tar, WET_Tar, HUM1_Tar, NAT_Tar, EXO1_Tar, TREE_Tar	User defined targets for each biodiversity feature layer.
OF, SAV, SHR, WET, HUM1, NAT, EXO1, TREE	The amount of each biodiversity feature (%) included in the optimal solution. User-defined targets are always met in the optimal solution, whereas undefined targets will vary based on their representation in the optimal solution.

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4. ADDITIONAL RESOURCES

1. Marxan User Manual:

Game, E. T. and H. S. Grantham. (2008). Marxan User Manual: For Marxan version 1.8.10. University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

2. Marxan Good Practices Handbook:

Ardron, J. H.P. Possingham and C.J. Klein (Eds.),Version 2, 2010. Marxan good practices handbook. University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

3. Simulated annealing in greater detail:

http://www.uq.edu.au/marxan/tutorial/toc.html

4. A basic overview of Integer Linear Programming on the Gurobi website:

http://www.gurobi.com/resources/getting-started/mip-basics

5. Marxan Tutorial for the CDFCP Study Area

http://peter-arcese-lab.sites.olt.ubc.ca/files/2015/10/Marxan-Tutorial-2.0.pdf

5. APPENDICES

APPENDIX A. GENERAL METHODS FOR CREATING COMPOSITE DISTRIBUTION MAPS OF BIODIVERSITY FEATURES

Each biodiversity feature used in the NPLCC tool is a map of the probability of that feature occurring within the study region. We refer to these as 'composite distribution' maps because they were created using a combination of (1) presence/absence data for plant and bird species, and (2) associated landscape and/or climate features to predict species occurrence. Data sources and general methods are provided for each biodiversity feature below.

BIRD COMMUNITY MAPS

Old Forest (OF), Savannah (SAV), Wetland (WET), Shrub (SHR), and Human (HUM) biodiversity features were created following Schuster & Arcese (2013) to map bird species distribution for 73 species, using presence-absence data from ebird (http://ebird.org/content/ebird/about/; Sullivan et al. 2009). Briefly, bird species were determined to be members of specific communities that represented each biodiversity feature using expert elicitation (Schuster & Arcese 2013). A total of 11 professional ornithologists were consulted to associate the relative 'reliance' of each bird species being found in the habitats described (in pictures and words). Species maps were developed using a suite of landscape covariates known to influence bird species occurrence (e.g., road density, stand age, tree species presence, proximity to other land uses; Schuster & Arcese 2013), and the results of these 'occupancy models' were used to predict species occurrence across the entire study region for 73 bird species using over 90,000 observations of species presence/absence provided from ebird (Sullivan et al. 2009). Occurrence probabilities for individual species were then compiled into composite maps representing target communities using the weightings assigned by experts (Schuster & Arcese 2013).

PLANT COMMUNITY MAPS

The Exotic (EXO) and Native (NAT) biodiversity features were created using similar methods as above (bird community maps). However, plant species occurrence data were drawn from several sources (Boag 2014; Dr. E Gonzales; Dr. Joe Bennet; E-Flora BC 2013). We used data for the 20 most abundant native and exotic plant species (40 species total) identified by Bennett (2014) to map the NAT and EXO communities, respectively (see Appendix B for species list).

INDICATOR TREE SPECIES MAP

The TREE biodiversity feature was created by mapping the distribution of three common tree species characteristic of Garry Oak/ Coastal Douglas-fir ecosystems: Arbutus (*Arbutus menziesii),* Garry oak (*Quercus garryanus*), and Douglas-fir (*Pseudotsuga menziesii*). Presence/absence data were derived from permanent botanical plots, and distributions were mapped using bioclimatic envelope models to predict occurrence (Tong Li Wang et al. *in prep*).

APPENDIX B: PLANTS USED IN THE NAT AND EXO BIODIVERSITY FEATURE LAYERS

	Latin Name	Common Name
Native Species	Camassia leichtlinii	Great camas
	Festuca rubra	Red fescue
	Brodiaea coronaria	Crown brodiaea
	Galium aparine	Cleavers/stickyweed
	Camasia quamash	Common camas
	Brodiaea hyacinthina	Fool's onion
	Achillea millefolium	Yarrow
	Sanicula crassicaulis	Pacific blacksnakeroot
	Plectriris congesta	Seablush
	Elymus glaucus	Blue wild rye
	Collinsia parviflora	Maiden blue-eyed Mary
	Polypodium glycyrrhiza	Licorice fern
	Luzula multiflora	Common woodrush
	Cerastium arvense	Field mouse-ear/chickweed
	Lotus micranthus	Desert deervetch
	Ranunculus occidentalis	Western buttercup
	Danthonia californica	California oatgrass
	Carex inops	Long-stolon sedge
	Trifolium willdenowii	Tomcat clover
	Lomatium utriculatum	Common lomatium/spring gold
Exotic Species	Aira praecox	Early hairgrass
	Hypochaeris radicata	Hairy cat's ear
	Anthoxanthum odoratum	Sweet vernalgrass
	Rumex acetosella	Sheep sorrel
	Vicia sativa	Common vetch
	Holcus lanatus	Common velvet-grass
	Bromus diandrus	Ripgut brome
	Vulpia bromoides	Barren fescue
	Cytisus scoparius	Scotch broom
	Stellaria media	Chickweed
	Bromus hordeaceus	Soft brome
	Bromus sterilis	Barren brome
	Geranium molle	Dovefoot geranium
	Dactylis glomerata	Orchardgrass
	Vicia hirsuta	Hairy vetch
	Veronica arvensis	Wall speedwell
	Cynosurus echinatus	Hedgehog dogtail
	Myosotis discolor	Common forget-me-not
	Poa pratensis	Kentucky bluegrass
	Aphanes arvensis/australis	Field/small-fruited parsley-piert

APPENDIX C: ROAD DENSITY AND AGRICULTURAL AREA CALCULATIONS

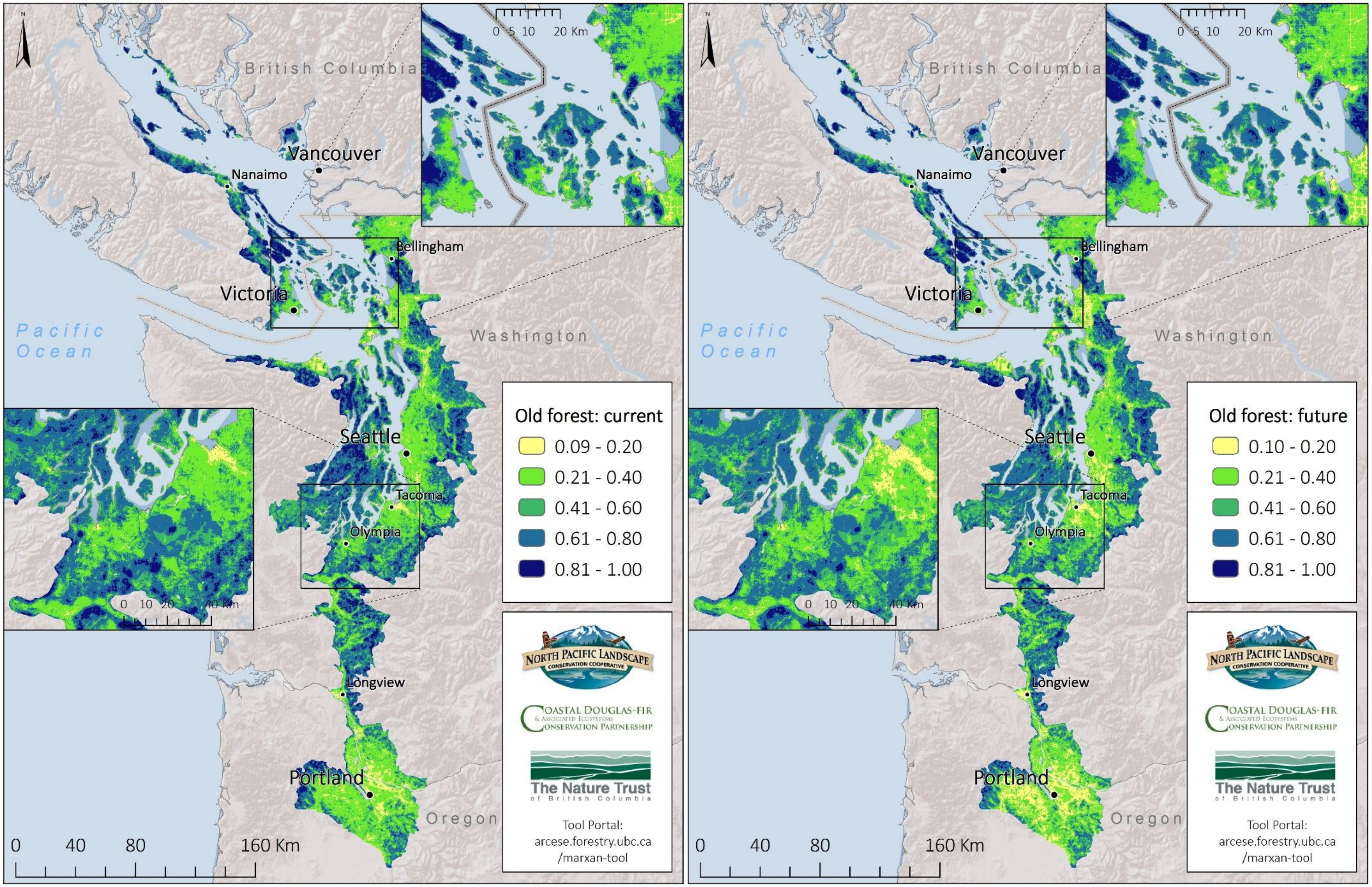
Road and agricultural densities were calculated per 1ha planning unit using feature types from several data sources detailed in the table below.

	Source	
Parameter	**Canada**	**USA**
Road Density	OpenStreetMaps[1] features: bridge, bus_stop, construction, living_street, motorway, motorway_link, primary, primary_link, residential, secondary, secondary_link, service, tertiary, tertiary_link, trunk, trunk_link, abandoned, bridleway, cycleway, footway, path, pedestrian, road, social_path, steps, track, trail, unclassified	
Agriculture Density	TEM[2]: Cultivated Field, Cultivated Orchard, Cultivated Vineyard	NLCD[3]: Class 81 Pasture/Hay, 82 Cultivated Crop

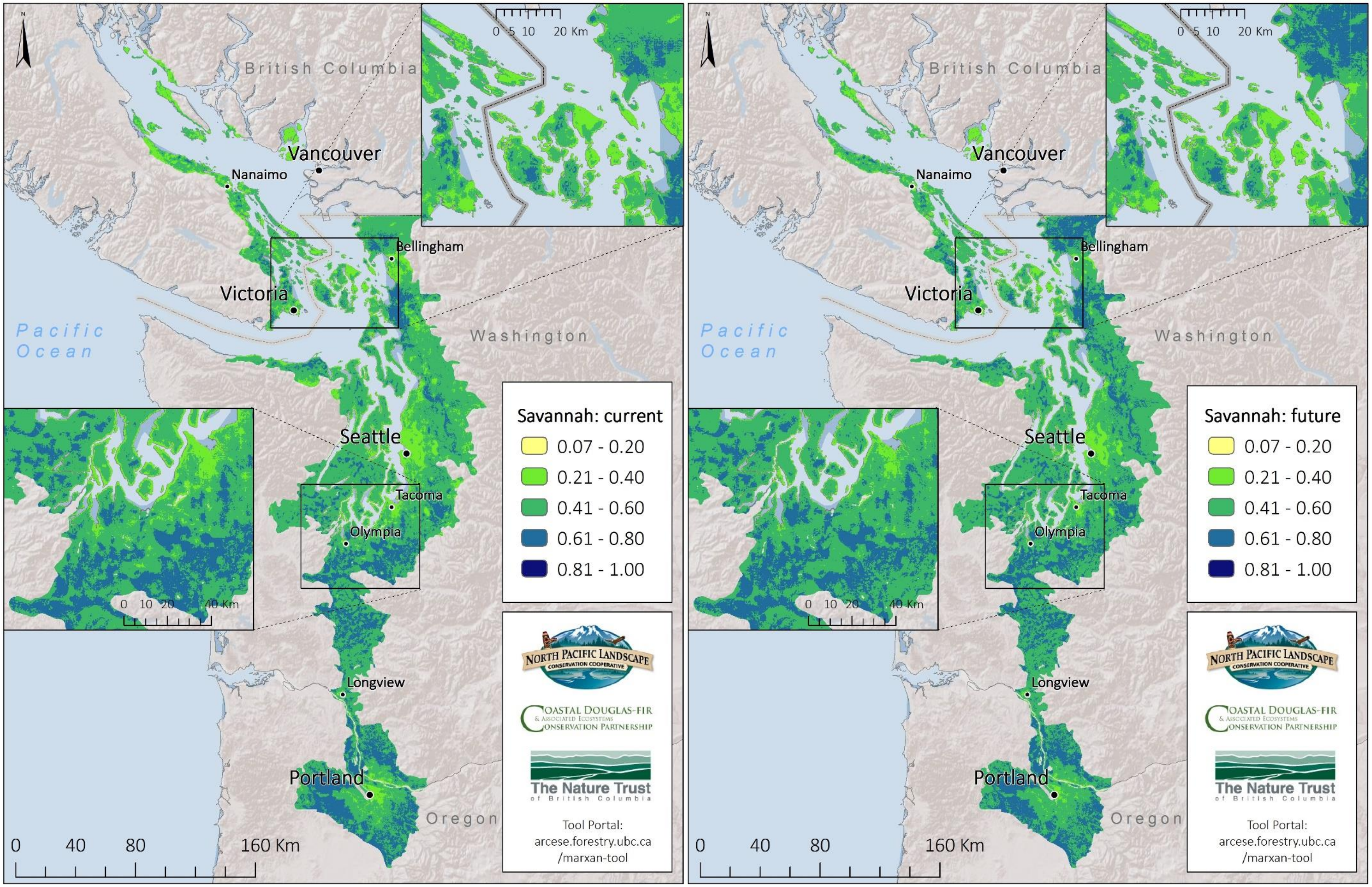
[1] OpenStreetMap data extracts, http://download.geofabrik.de (accessed 2015-09-17)

[2] Terrestrial Ecosystem Mapping (TEM) of the Coastal Douglas-fir Zone of British Columbia, http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=15273 and http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=40896 (accessed: 2011-10-20)

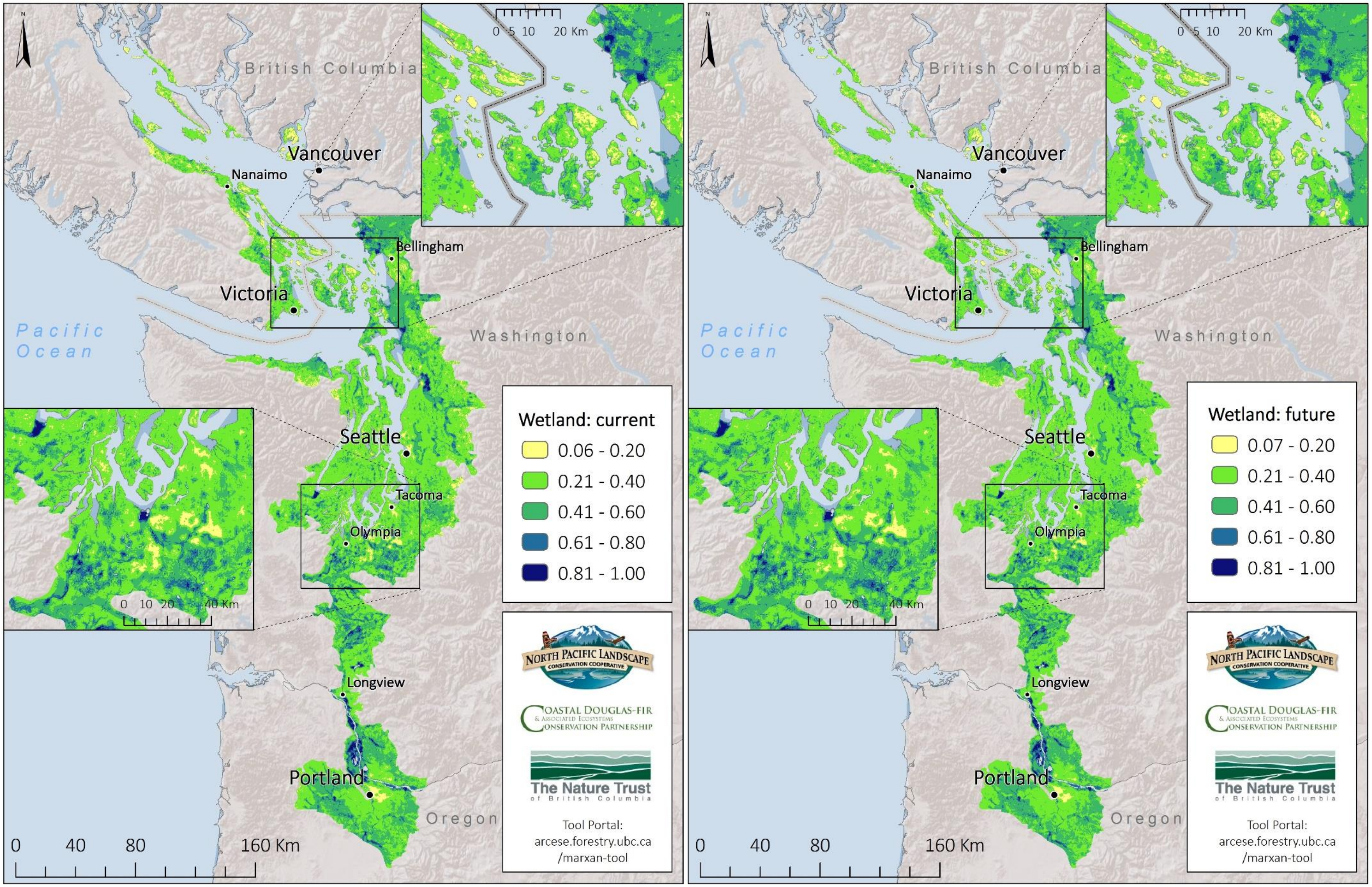
[3] National Land Cover Database 2011, http://www.mrlc.gov/index.php (accessed: 2015-09-15)



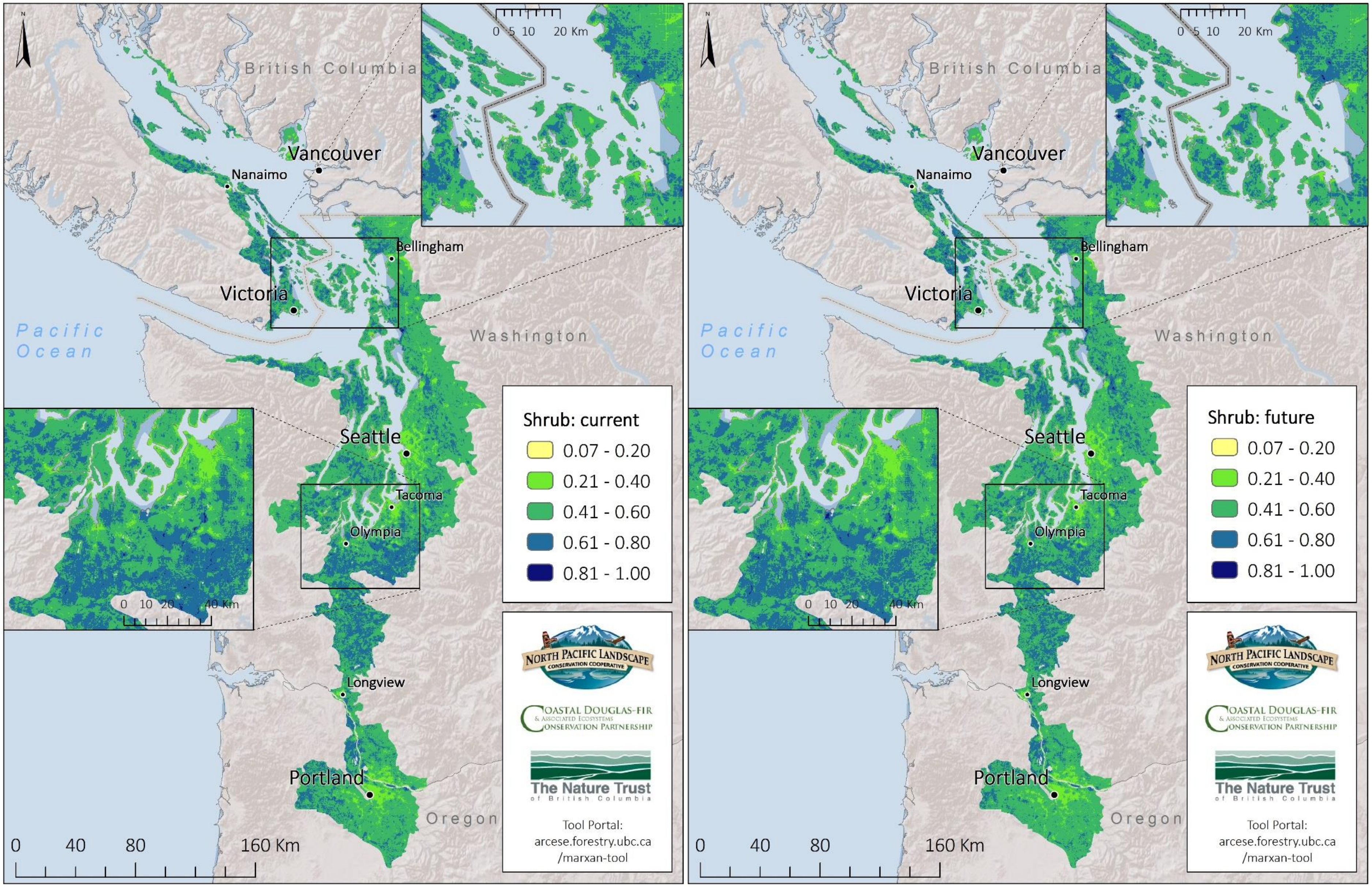
Current and future predicted distribution maps for the old forest community.



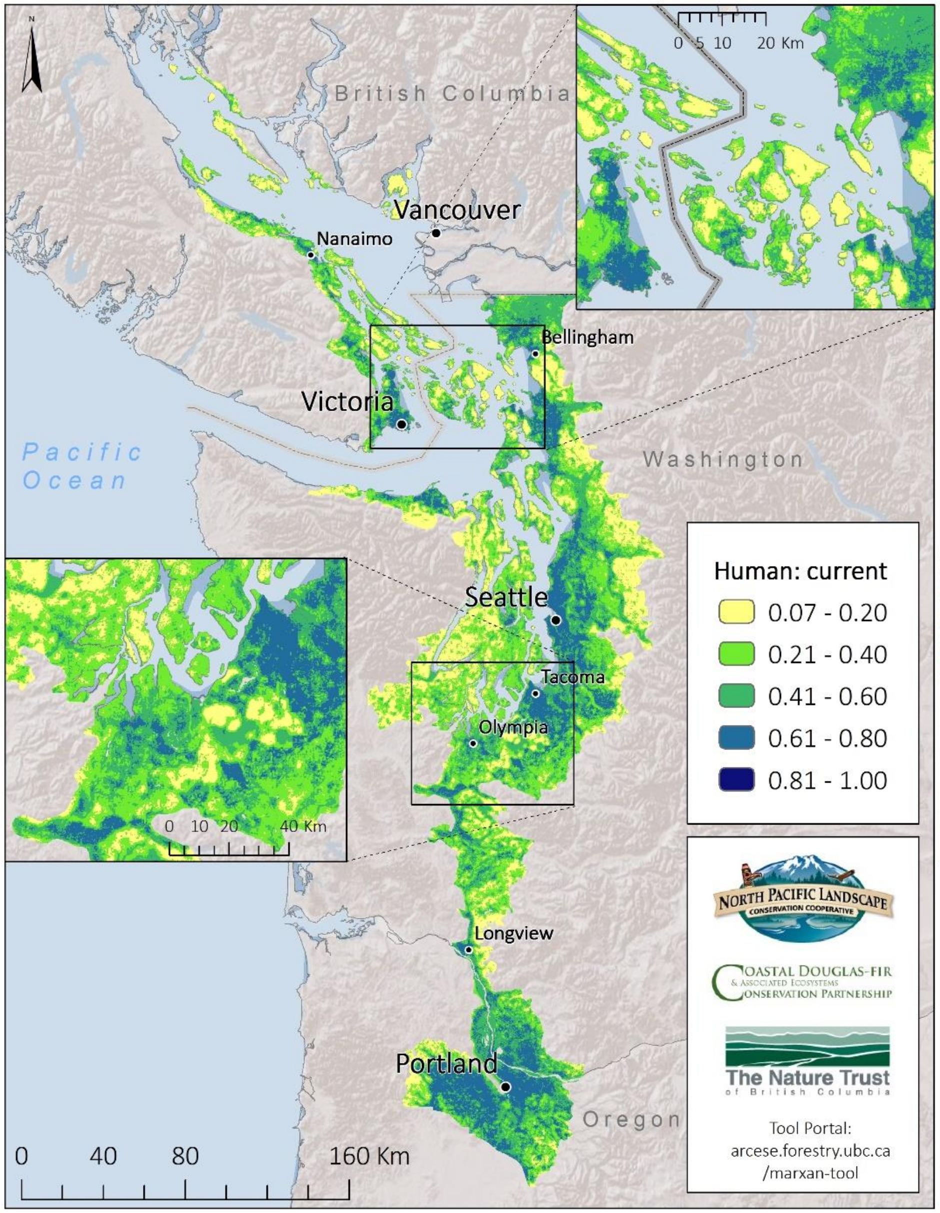
Current and future predicted distribution maps for the savannah bird community.

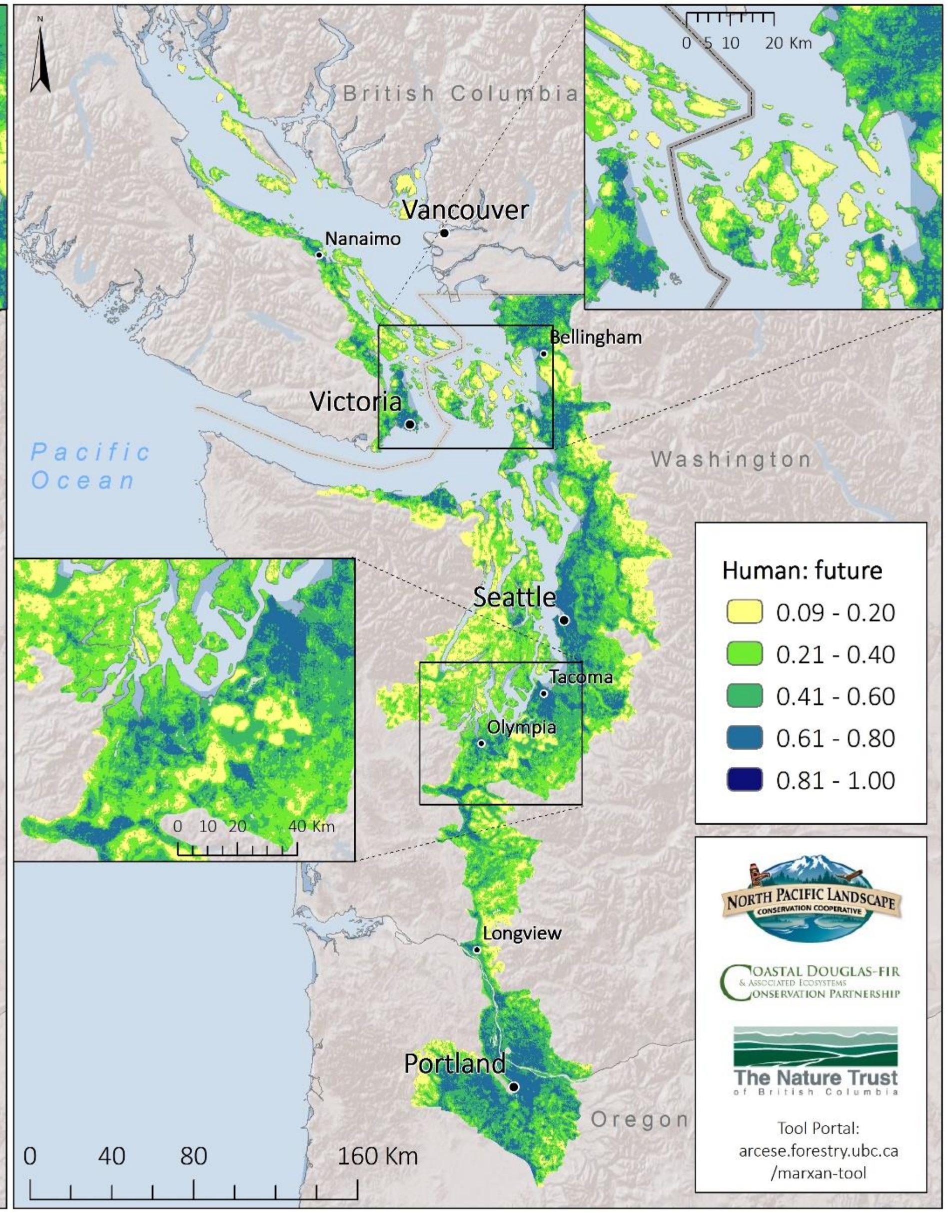


Current and future predicted distribution maps for the wetland bird community.

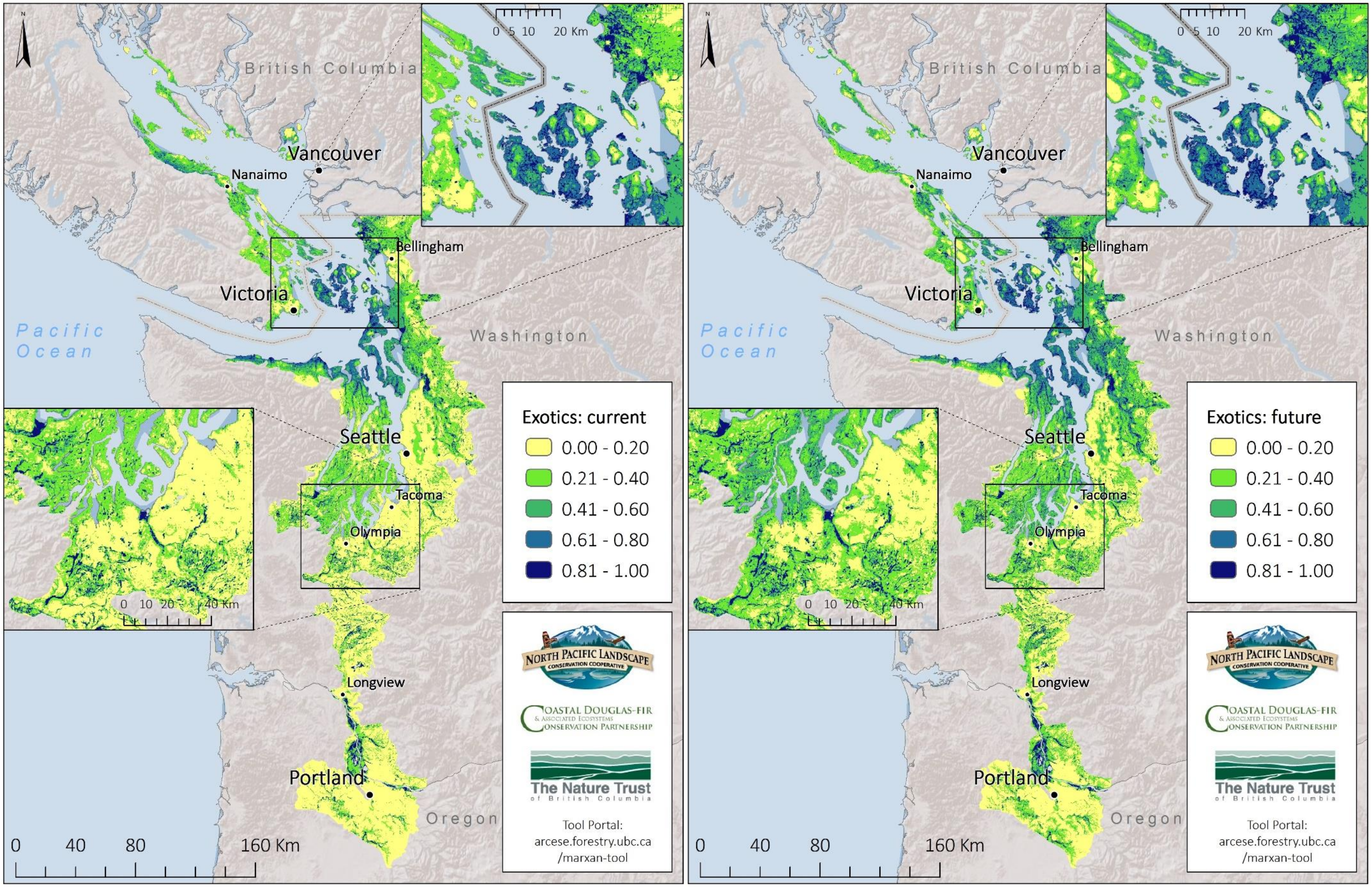


Current and future predictive distribution maps for the shrub bird community.

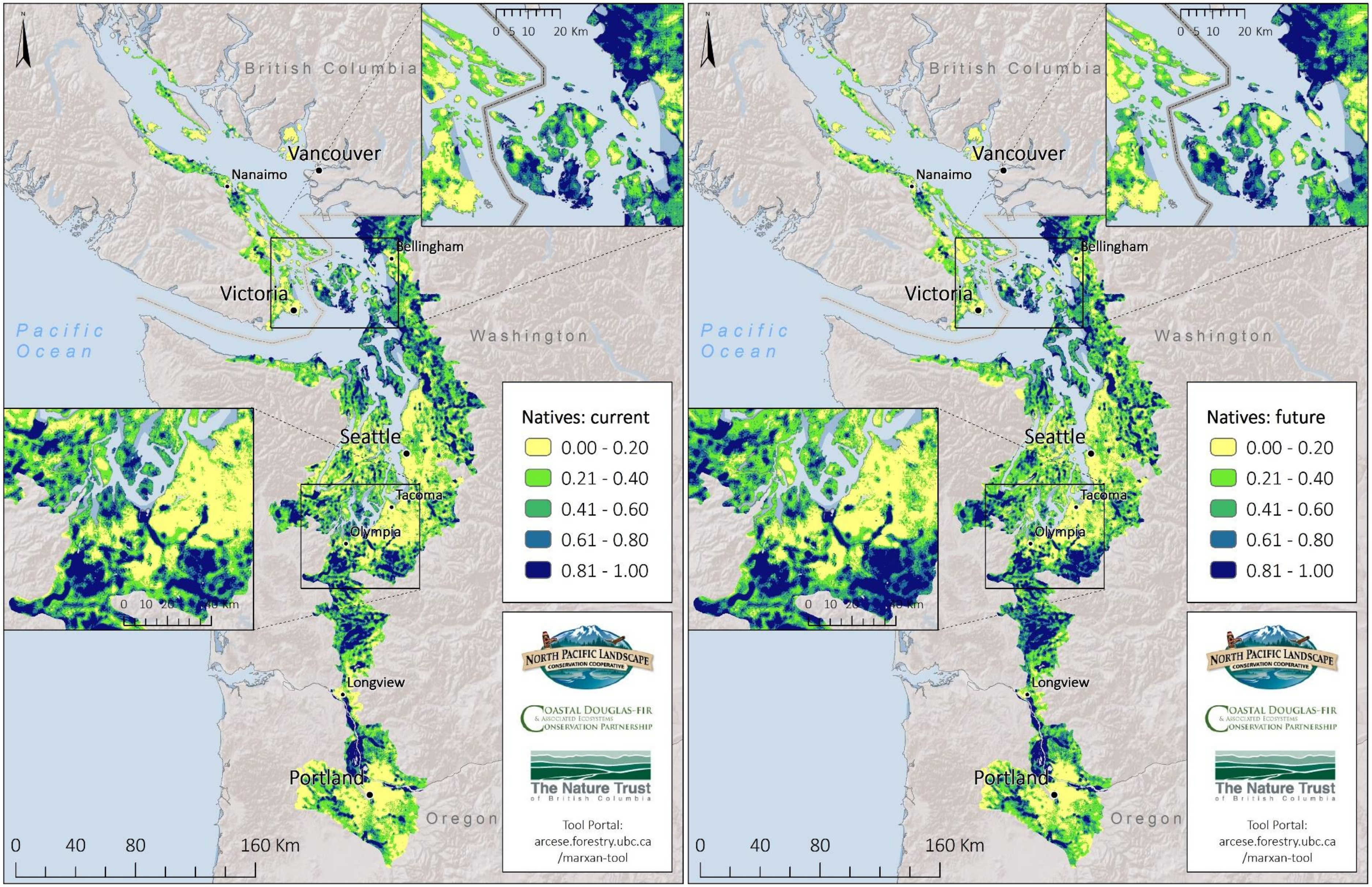




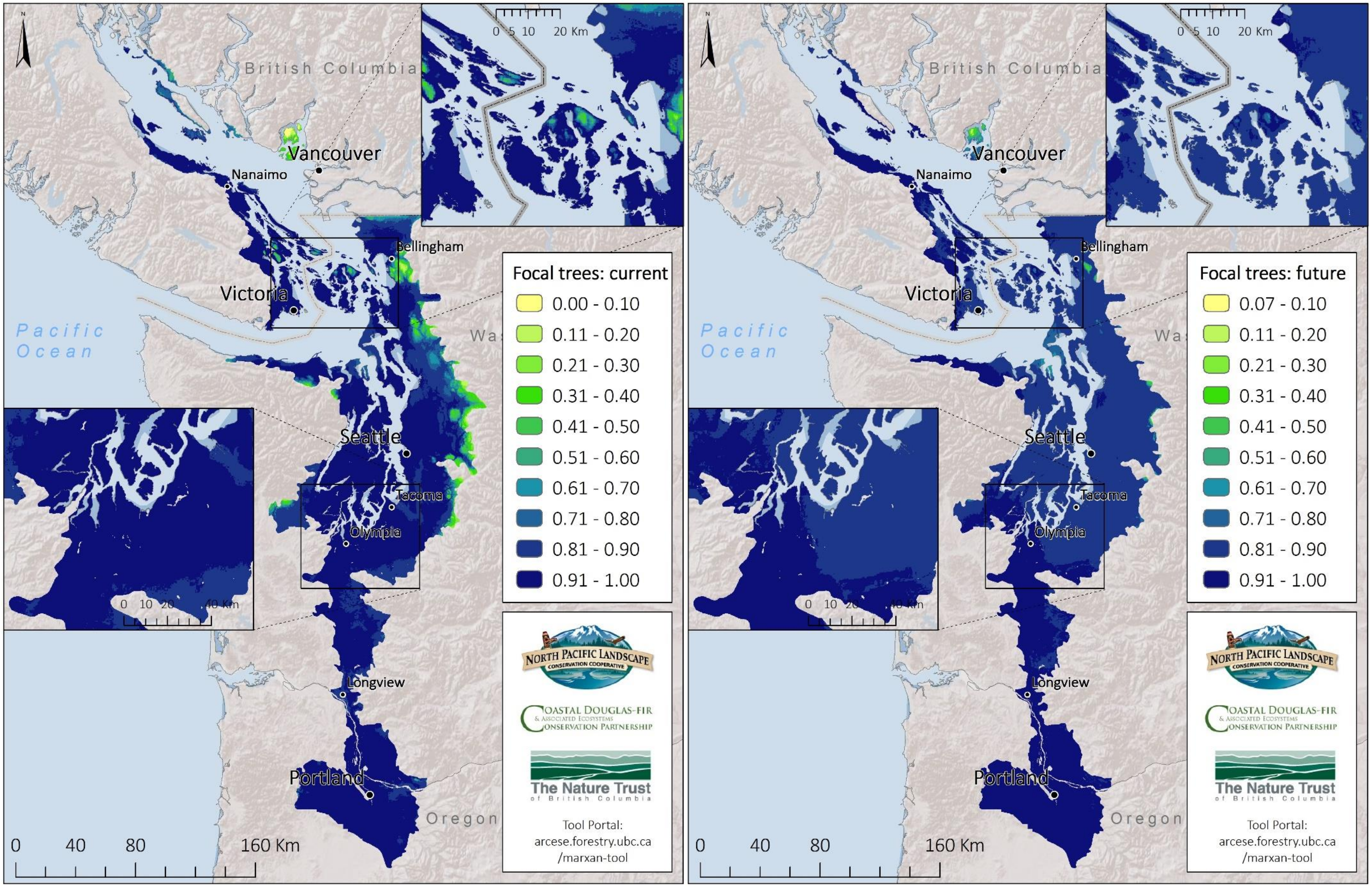
Current and future predicted distribution maps for the human commensal bird community.



Current and future predicted distribution maps for 20 exotic plant species (see Appendix B for species list).



Current and future predicted distribution maps for 20 native savanna plant species (see Appendix B for species list).



Current and future predicted distribution the Douglas-fir - Garry Oak - Arbutus tree community (Courtesy Tong Li Wang; ClimatePNW

Bird species and habitat association scores. Habitat type description can be found in Appendix A. Composite bird communities maps are based on species distribution, weighted habitat association scores >0 (see Appendix A).

Bird	Common name	Herbacous	Shrub	Pole	Young forest	Mature forest	Old forest	Rural	Urban	Woodland	Wetland
BUSH	American bushtit	-1	0.6	-1	-1	-0.8	-0.8	0.6	0.4	0.6	0
CROW	Crow (American + Northern)	-0.18	-0.55	-0.73	-0.45	-0.73	-0.9	0.91	0.82	0.18	-0.55
AMGO	American goldfinch	-0.18	0.64	-0.73	-0.82	-0.82	-0.82	0.45	-0.82	0.45	-0.82
AMRO	American robin	-0.45	0.73	-0.18	0	-0.27	-0.5	0.73	0	0.73	-0.64
ANHU	Anna's hummingbird	0	0.4	-1	-1	-0.6	-0.6	0.6	0.4	0.6	0
BAEA	Bald eagle	-1	-1	-0.91	-0.82	0.18	0.55	-0.36	-1	-0.45	0.2
BTPI	Band-tailed pidgeon	0	0	-1	-1	0.4	0.6	0.2	-0.4	0.6	0.2
BARS	Barn swallow	0	0	-1	-1	-1	-1	0.91	-0.36	-0.45	0.82
BDOW	Barred owl	-0.6	-0.6	-1	-1	0.2	0.4	0.6	0.2	0.8	-0.4
BEKI	Belted kingfisher	-1	-1	-1	-1	-1	-1	-1	-1	-1	1
BEWR	Bewick's wren	-0.91	0.82	-0.55	-0.73	-0.82	-0.82	-0.09	-0.45	0.64	-0.45
BHGR	Black-headed grosbeak	0	0	-1	0	0	0	0.4	-0.2	0.6	0

BRBL	Brewer's blackbird	0.2	0	-1	-1	-1	-1	0.8	-0.2	0.2	-0.6
BRCR	Brown creeper	-1	-1	-0.45	0.09	0.91	0.82	-0.91	-1	0	-1
BHCO	Brown-headed cowbird	0	0.91	-0.45	-0.64	-0.91	-0.91	0.82	-0.2	0.55	0
CAGO	Canada goose	0	-1	-1	-1	-1	-1	1	-0.4	-1	0.8
CEDW	Cedar waxwing	-0.2	0.6	-1	-1	0	0.2	0.6	-0.4	0.6	0.2
CBCH	Chestnut-backed chickadee	-1	-0.36	-0.18	0.18	0.64	0.64	-0.64	-0.55	0.55	-0.91
CHSP	Chipping sparrow	0	0.36	-0.82	-0.91	-1	-1	0.36	-0.91	0.45	-0.91
CORA	Common raven	-0.91	-1	-0.91	-0.27	0.55	0.55	0.18	-0.91	-0.27	-0.73
COHA	Cooper's Hawk	0	0.2	-0.8	-0.6	0	0.2	0.4	-0.2	0.8	0
UDEJ	Dark-eyed junco	-0.09	0.55	0	0.09	-0.09	-0.3	-0.09	-0.64	0.64	-0.91
DOWO	Downy woodpecker	-0.4	0	0	0.2	0.4	0.4	0.2	0	0.8	0.2
ECDO	Eurasian collared dove	-0.8	-1	-1	-1	-1	-1	0.4	0.8	-0.8	-0.8
EUST	European starling	-0.18	-0.36	-0.73	-0.82	-1	-1	1	0.91	-0.18	-0.82
EVGR	Evening grosbeak	-0.4	0	-1	-1	0	0	0	0	0.8	-0.4
FOSP	Fox sparrow	-0.82	0.73	-0.8	-0.78	-0.89	-0.89	-0.7	-0.9	-0.22	-0.8

GCKI	Golden-crowned kinglet	-0.91	-0.64	-0.64	0	0.73	0.82	-0.91	-1	-0.36	-0.91
HAWO	Hairy woodpecker	-1	-1	-0.73	0	0.73	0.82	-1	-1	-0.18	-0.91
HOFI	House finch	-0.64	0.09	-0.6	-0.82	-1	-1	0.91	0.82	0.4	-0.91
HOSP	House sparrow	-0.64	-0.55	-1	-1	-1	-1	0.64	1	-0.82	-1
HOWR	House wren	-0.91	0.27	-0.45	-0.55	-0.55	-0.8	0.27	-0.5	0.9	-0.91
MAWR	MacGillivray's Warbler	-0.82	0.91	-0.45	-0.55	-0.55	-0.5	-0.91	-1	0.09	-0.45
HUVI	Hutton's vireo	-0.2	0.2	0	0	0.4	0.4	0.2	-0.8	0.6	0
AMKE	Kestrel	0.2	0	-1	-1	-1	-1	0.2	-1	0.4	-0.4
MAWR	Marsh wren	-1	0	-1	-1	-1	-1	0	-0.8	-0.8	1
MODO	Mourning dove	0.4	0.2	-1	-0.8	-0.8	-0.8	0.4	-0.2	0.6	0
FLIN	Northern flicker	-0.45	-0.73	-0.73	0.18	0.55	0.36	-0.18	-0.55	0.64	-0.73
NOHA	Northern Harrier	0.4	-0.8	-1	-1	-1	-1	0.2	-0.8	0	0.8
OSFL	Olive-sided flycatcher	-1	-0.64	-0.64	-0.18	0.36	0.27	-0.91	-1	0.18	-0.36
OCWA	Orange-crowned warbler	-0.91	0.91	-0.27	-0.55	-0.45	-0.6	-0.55	-1	0.55	-0.09

OSPR	Osprey	-1	-1	-1	-1	-0.8	-0.8	-0.6	-1	0	0.8
PSFL	Pacific slope flycatcher	-1	-0.64	-0.36	0.36	0.91	0.8	-0.82	-1	0.09	-0.55
PAWR	Pacific wren	-1	-0.45	-0.64	0.09	0.82	0.91	-1	-1	-0.45	-0.73
PISI	Pine siskin	-0.82	-0.64	-0.36	0.09	0.64	0.45	-0.64	-0.91	0.18	-0.64
PIWO	Pileated woodpecker	-1	-1	-1	-0.55	0.91	1	-1	-1	-0.18	-0.91
PUFI	Purple finch	-1	0.18	-0.55	0.09	-0.09	-0.2	-0.18	-0.73	0.45	-0.82
PUMA	Purple martin	-1	-1	-1	-1	-1	-1	-1	-1	-1	1
RECR	Red crossbill	-1	-1	-0.8	-0.4	0.8	0.8	-0.8	-0.8	0.2	-0.2
RBNU	Red-breasted nuthatch	-1	-0.91	-0.36	0.36	0.91	0.82	-0.73	-0.73	0.45	-1
RBSA	Red-breasted sapsucker	-1	0	-0.4	0.2	0.6	0.6	-0.6	-1	0.6	0
RTHA	Red-tailed hawk	0.6	0.2	-1	-1	-0.4	-0.2	0.8	-0.2	0.4	0
RWBL	Red-winged blackbird	-0.91	-0.27	-1	-1	-1	-1	0.36	-1	-0.73	1
RODO	Rock dove	-0.4	-0.8	-1	-1	-1	-1	0.6	1	-0.8	-0.8
RUHU	Rufous humingbird	-0.18	0.91	-0.45	-0.36	-0.18	-0.27	-0.18	-0.55	0.64	-0.36
SAVS	Savanna sparrow	0.55	-0.36	-1	-1	-1	-1	0.82	-0.91	-0.27	-0.73

SOSP	Song sparrow	-0.45	0.91	-0.55	-0.45	-0.45	-0.55	0.18	-0.36	0.18	0.55
SORA	Sora	-0.8	-1	-1	-1	-1	-1	-1	-1	-1	1
SPTO	Spotted towhee	-0.64	1	-0.45	-0.27	-0.45	-0.6	-0.09	-0.36	0.55	-0.55
STJA	Stellar's jay	-0.6	-0.2	-0.8	-0.2	0.6	0.6	0.4	0.2	0.6	0
SWTH	Swainson's thrush	-0.91	0.09	-0.45	-0.09	0.36	0.36	-0.91	-1	0	-0.45
TOWA	Townsend's warbler	-1	-0.73	-0.73	0.09	0.73	0.73	-1	-1	-0.27	-1
TRES	Tree swallow	-0.45	-0.36	-0.91	-0.82	-0.82	-0.9	0.55	-0.82	-0.27	0.91
VATH	Varied thrush	-0.91	-0.91	-0.82	-0.09	0.7	0.8	-1	-1	-0.55	-1
VGSW	Violet-green swallow	-0.36	-0.45	-0.8	-0.73	-0.82	-0.9	0.82	-0.36	0.09	0.82
WAVI	Warbling vireo	-1	0	-0.36	0.18	-0.55	-0.5	-0.55	-1	0.36	-0.45
WETA	Western tanager	-1	-0.73	-0.55	0	0.64	0.55	-0.73	-1	0.18	-0.82
WCSP	White-crowned sparrow	0.09	0.82	-0.82	-0.91	-1	-0.91	0.55	-0.09	0.27	-0.91
WISN	Wilson's snipe	0.2	0	-1	-1	-1	-1	0.2	-1	0.2	0.6
WIWA	Wilson's warbler	-1	0.82	-0.36	-0.36	-0.27	-0.5	-0.73	-1	-0.09	0.2
WODU	Wood duck	-1	-1	-1	-1	-1	-1	-0.8	-1	-0.8	1

YEWA	Yellow warbler	-1	0.55	-0.73	-0.73	-1	-1	-0.64	-1	-0.18	0.55
UYRW	Yellow-rumped warbler	-1	-0.36	0	0.27	0.18	0.1	-0.55	-1	0.09	-0.45

Bird species community scores. Community association scores for each species were calculated by summing a species' rank in each habitat as described in Appendix A. All birds with positive community association scores were considered to be members of a community map. To standardize individual species weights between 0 and 1, we summed positive community association scores across all species and divided by the number of species included. Bird species community scores can be thought of as an index of the probability that none versus all members of the focal community are present, weighted by their reliance on the focal habitat type.

Bird	Common Name	Old Forest (OF)	Savannah (SAV)	Human (HUM)	Shrub (SHR)	Wetland (WET)
BUSH	American bushtit	-0.14	-0.04	0.47	0.6	0
CROW	Crow (American + Northern)	-0.21	-0.11	0.85	-0.55	-0.55
AMGO	American goldfinch	-0.4	0.24	-0.4	0.64	-0.82
AMRO	American robin	-0.14	0.26	0.24	0.73	-0.64
ANHU	Anna's hummingbird	-0.31	0.32	0.47	0.4	0
BAEA	Bald eagle	0.62	-0.78	-0.79	-1	0.2
BTPI	Band-tailed pidgeon	0.23	0.24	-0.2	0	0.2
BARS	Barn swallow	-0.43	-0.18	0.06	0	0.82

BDOW	Barred owl	0.4	-0.04	0.33	-0.6	-0.4
BEKI	Belted kingfisher	0	-1	-1	-1	1
BEWR	Bewick's wren	-0.22	0.06	-0.33	0.82	-0.45
BHGR	Black-headed grosbeak	0.07	0.24	0	0	0
BRBL	Brewer's blackbird	-0.49	0.16	0.13	0	-0.6
BRCR	Brown creeper	0.83	-0.6	-0.97	-1	-1
BHCO	Brown-headed cowbird	-0.53	0.4	0.14	0.91	0
CAGO	Canada goose	-0.29	-0.6	0.07	-1	0.8
CEDW	Cedar waxwing	0.03	0.28	-0.07	0.6	0.2
CBCH	Chestnut-backed chickadee	0.64	-0.25	-0.58	-0.36	-0.91

CHSP	Chipping sparrow	-0.49	0.25	-0.49	0.36	-0.91
CORA	Common raven	0.68	-0.67	-0.55	-1	-0.73
COHA	Cooper's Hawk	0.04	0.36	0	0.2	0
UDEJ	Dark-eyed junco	-0.15	0.33	-0.46	0.55	-0.91
DOWO	Downy woodpecker	0.3	0.16	0.07	0	0.2
ECDO	Eurasian collared dove	-0.06	-0.84	0.67	-1	-0.8
EUST	European starling	-0.33	-0.22	0.94	-0.36	-0.82
EVGR	Evening grosbeak	0.11	0.16	0	0	-0.4
FOSP	Fox sparrow	-0.25	-0.27	-0.83	0.73	-0.8
GCKI	Golden-crowned kinglet	0.74	-0.64	-0.97	-0.64	-0.91

HAWO	Hairy woodpecker	0.82	-0.67	-1	-1	-0.91
HOFI	House finch	-0.27	-0.08	0.85	0.09	-0.91
HOSP	House sparrow	-0.17	-0.69	0.88	-0.55	-1
HOWR	House wren	-0.09	0.05	-0.24	0.27	-0.91
MGWA	MacGillivray's Warbler	-0.12	-0.11	-0.97	0.91	-0.45
HUVI	Hutton's vireo	0.2	0.2	-0.47	0.2	0
AMKE	American Kestrel	-0.49	0.24	-0.6	0	-0.4
MAWR	Marsh wren	-0.14	-0.72	-0.53	0	1
MODO	Mourning dove	-0.47	0.44	0	0.2	0
FLIN	Northern flicker	0.48	-0.07	-0.43	-0.73	-0.73
NOHA	Northern Harrier	-0.43	0	-0.47	-0.8	0.8

OSFL	Olive-sided flycatcher	0.54	-0.46	-0.97	-0.64	-0.36
OCWA	Orange-crowned warbler	-0.13	0.04	-0.85	0.91	-0.09
OSPR	Osprey	0.09	-0.6	-0.87	-1	0.8
PSFL	Pacific slope flycatcher	0.79	-0.49	-0.94	-0.64	-0.55
PAWR	Pacific wren	0.78	-0.67	-1	-0.45	-0.73
PISI	Pine siskin	0.58	-0.38	-0.82	-0.64	-0.64
PIWO	Pileated woodpecker	0.88	-0.67	-1	-1	-0.91
PUFI	Purple finch	0.24	-0.18	-0.55	0.18	-0.82
PUMA	Purple martin	0	-1	-1	-1	1
RECR	Red crossbill	0.8	-0.52	-0.8	-1	-0.2
RBNU	Red-breasted nuthatch	0.83	-0.4	-0.73	-0.91	-1
RBSA	Red-breasted sapsucker	0.59	-0.16	-0.87	0	0

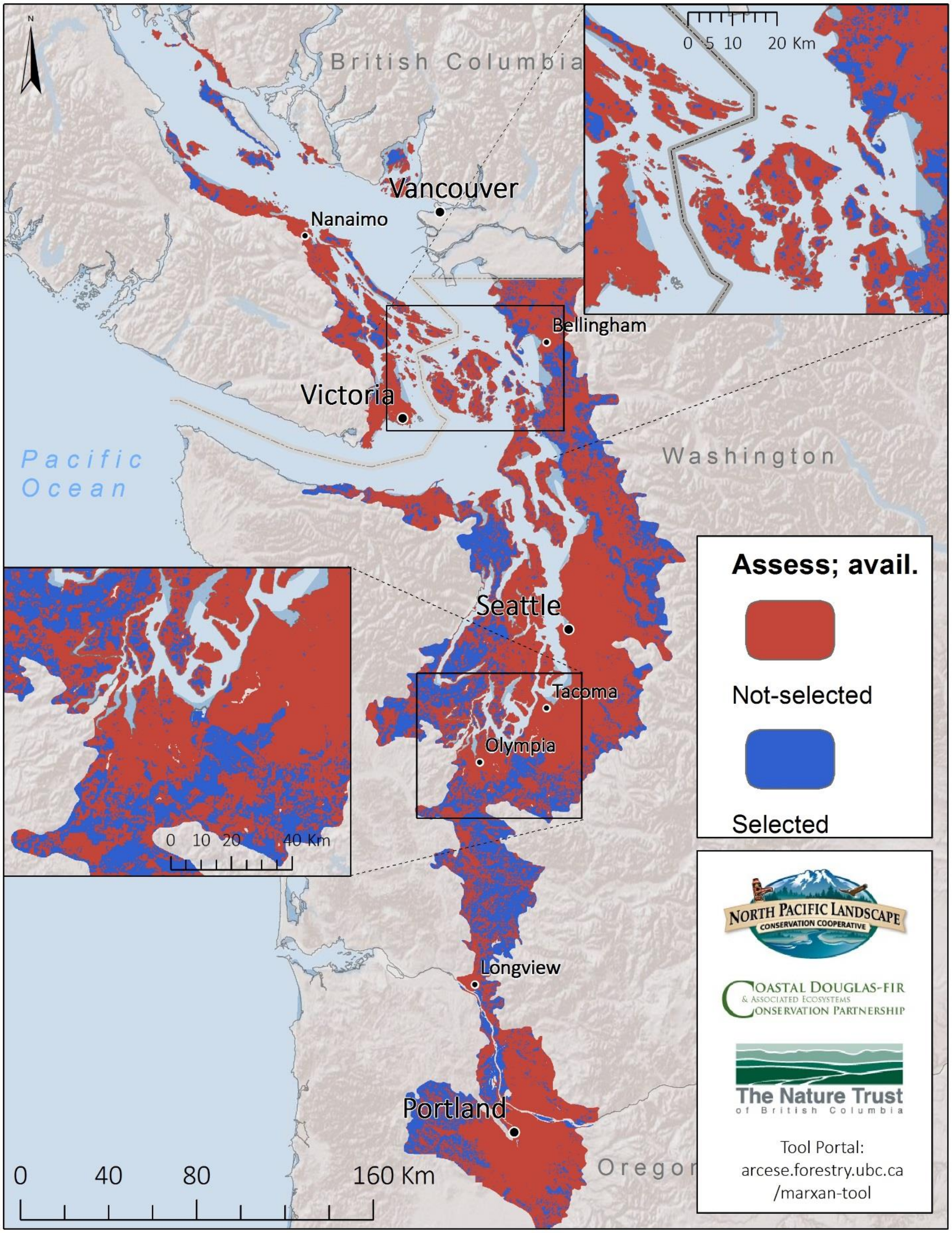
RTHA	Red-tailed hawk	-0.31	0.44	0.13	0.2	0
RWBL	Red-winged blackbird	-0.13	-0.71	-0.55	-0.27	1
RODO	Rock dove	-0.2	-0.64	0.87	-0.8	-0.8
RUHU	Rufous hummingbird	-0.18	0.37	-0.43	0.91	-0.36
SAVS	Savannah sparrow	-0.53	0.04	-0.33	-0.36	-0.73
SOSP	Song sparrow	-0.22	0.07	-0.18	0.91	0.55
SORA	Sora	-0.06	-0.92	-1	-1	1
SPTO	Spotted towhee	-0.18	0.16	-0.27	1	-0.55
STJA	Stellar's jay	0.5	-0.04	0.27	-0.2	0
SWTH	Swainson's thrush	0.43	-0.35	-0.97	0.09	-0.45
TOWA	Townsend's warbler	0.76	-0.65	-1	-0.73	-1
TRES	Tree swallow	-0.19	-0.36	-0.36	-0.36	0.91

VATH	Varied thrush	0.77	-0.77	-1	-0.91	-1
VGSW	Violet-green swallow	-0.2	-0.2	0.03	-0.45	0.82
WAVI	Warbling vireo	0.1	-0.26	-0.85	0	-0.45
WETA	Western tanager	0.68	-0.47	-0.91	-0.73	-0.82
WCSP	White-crowned sparrow	-0.55	0.31	0.12	0.82	-0.91
WISN	Wilson's snipe	-0.49	0.16	-0.6	0	0.6
WIWA	Wilson's warbler	-0.01	-0.27	-0.91	0.82	0.2
WODU	Wood duck	0	-0.92	-0.93	-1	1
YEWA	Yellow warbler	-0.22	-0.36	-0.88	0.55	0.55
UYRW	Yellow-rumped warbler	0.41	-0.44	-0.85	-0.36	-0.45

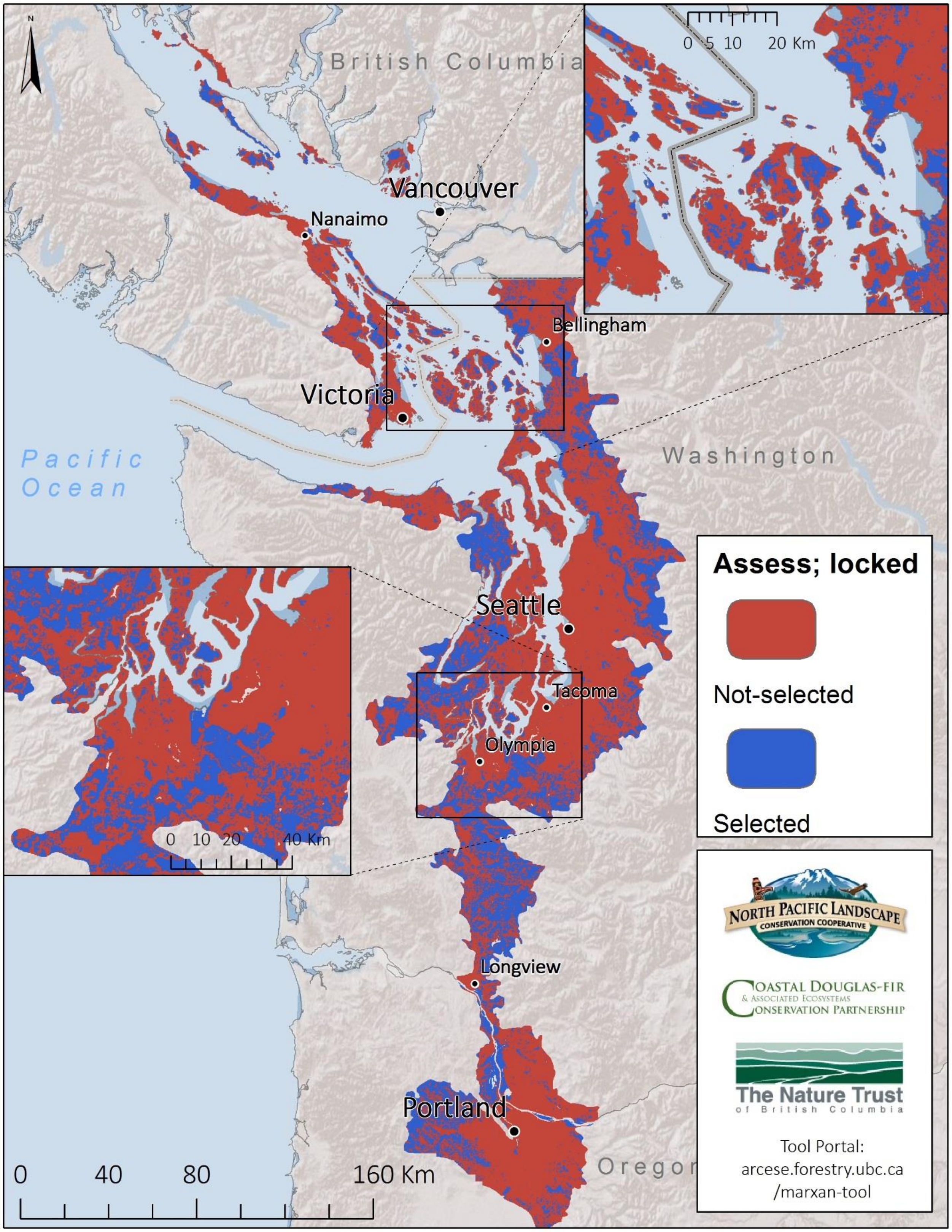
APPENDIX E: EXAMPLE SCENARIO RESULT MAPS

1. Four example output scenarios based on a goal of obtaining 50% of the current OF, SAV, WET & NAT bird and plant communities, predicted to be 66% or more likely to include the indicator community (habitat quality = 66%). Parks where either locked-in (locked) or available for selection (avail). Cost layers used include Assessed Value (Assess) and Human/Management costs (Human).

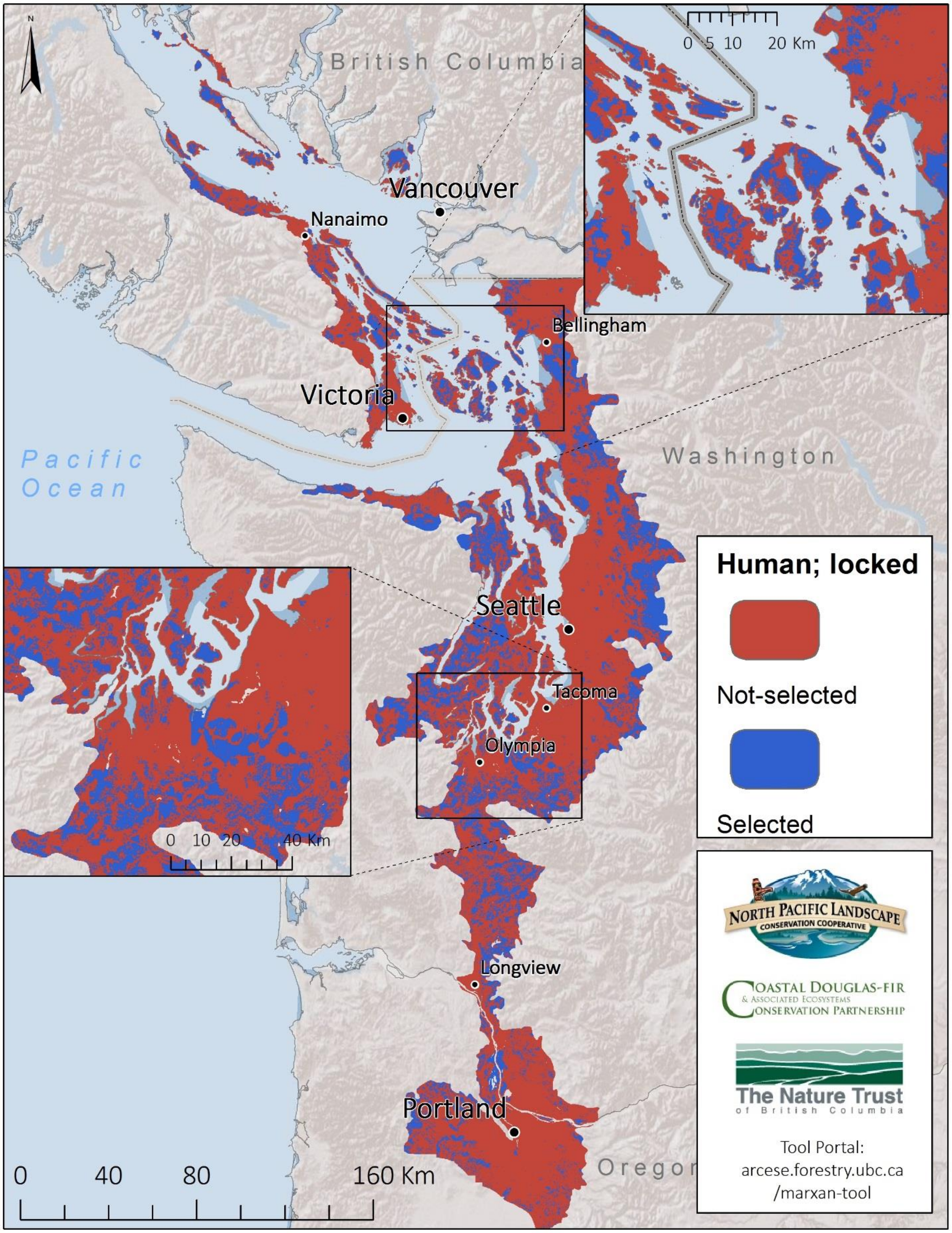
2. Two example scenairos based on conditions outlined above, but using the predicted bird and plant community layers corresponding to the 2045 (see text).



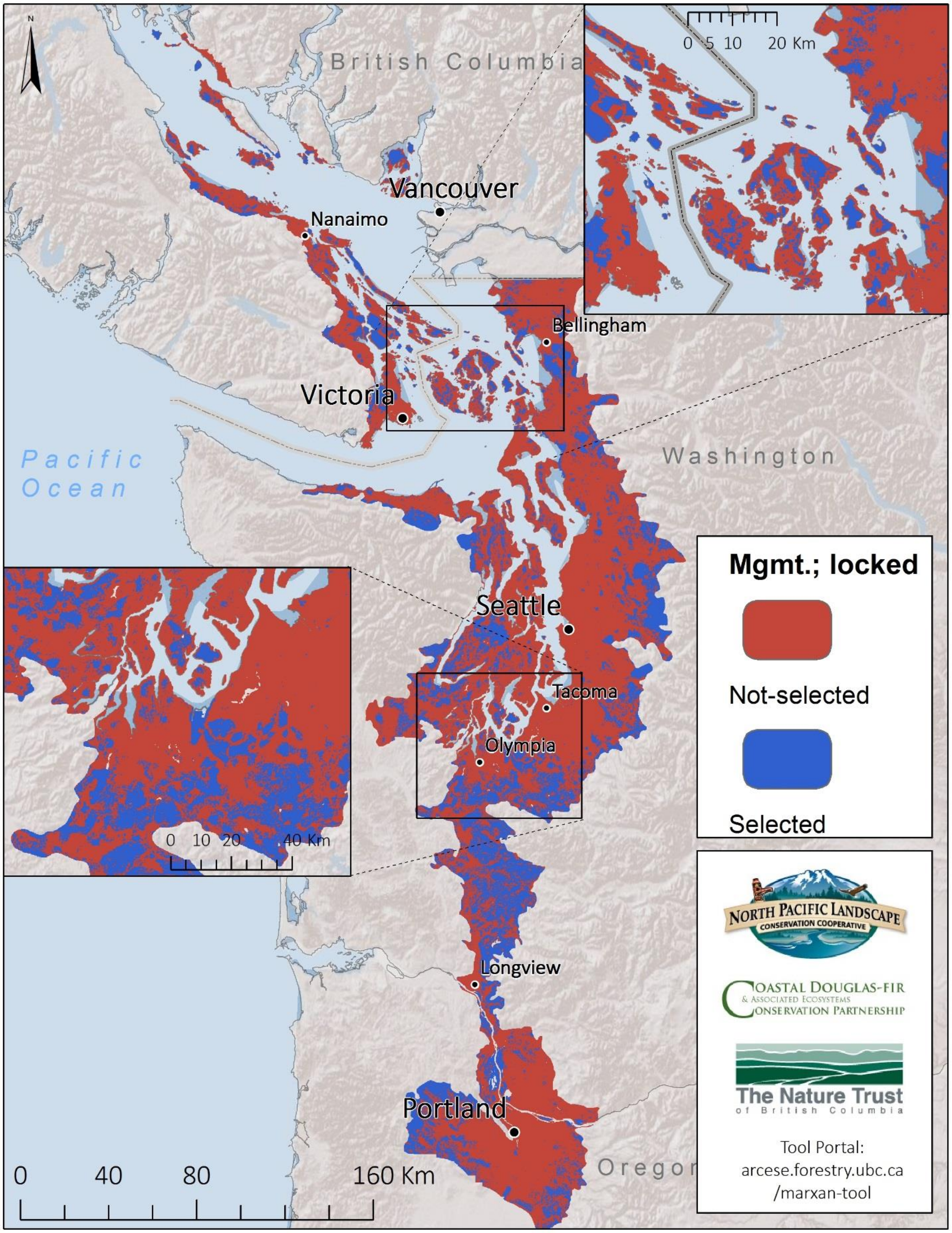
Example scenario output using the NPLCC tool. Old forest, savannah, wetland, and native plant targets were set to 50% each, the time period was set to 'current', the high quality target was set to 66%, the cost metric was assessed value, and protected areas was set to 'available'.



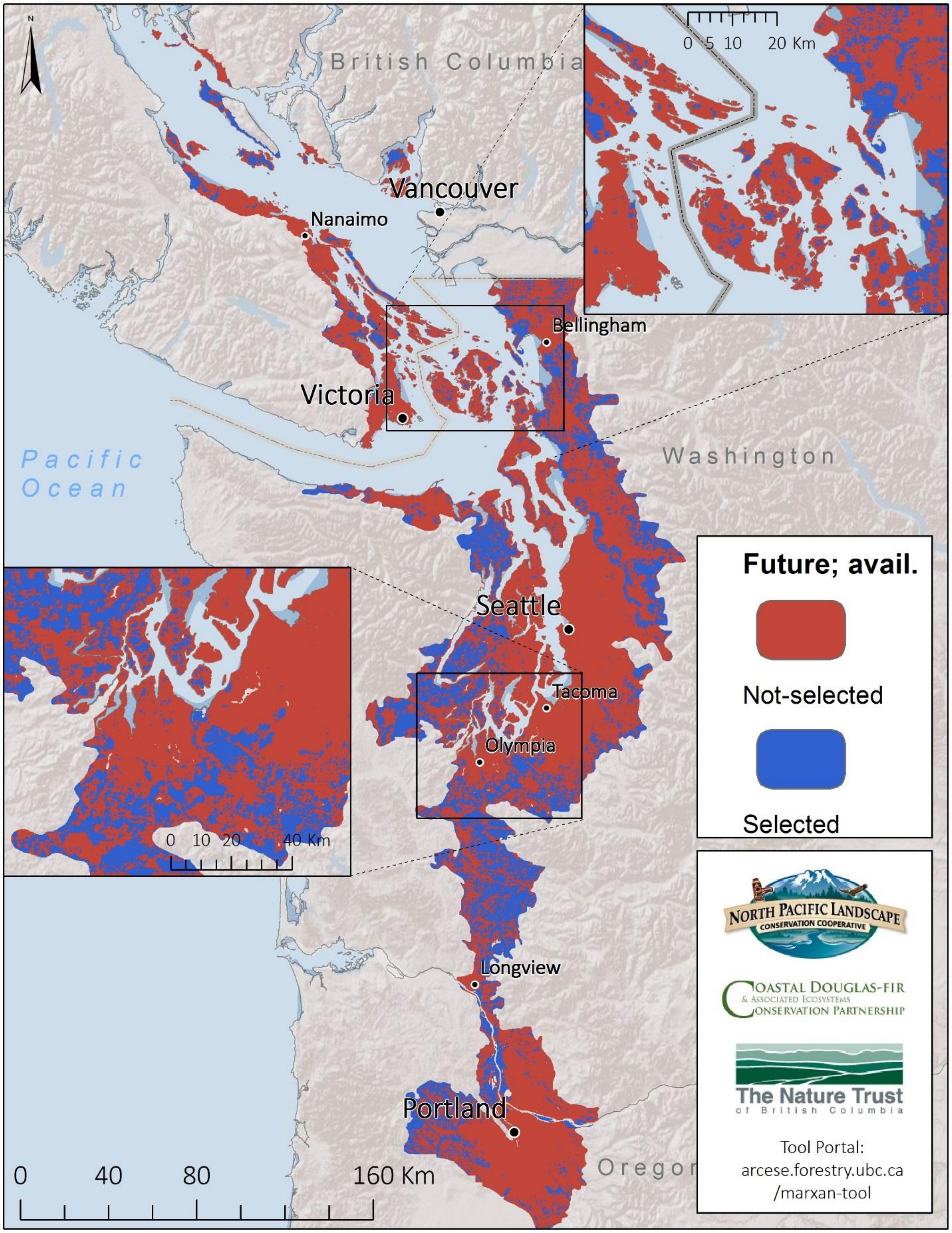
Example scenario output using the NPLCC tool. Old forest, savannah, wetland, and native plant targets were set tuo 50% each, the time period was set to 'current', the high quality target was set to 66%, the cost metric was assessed value, and protected areas was set to 'locked-in'.



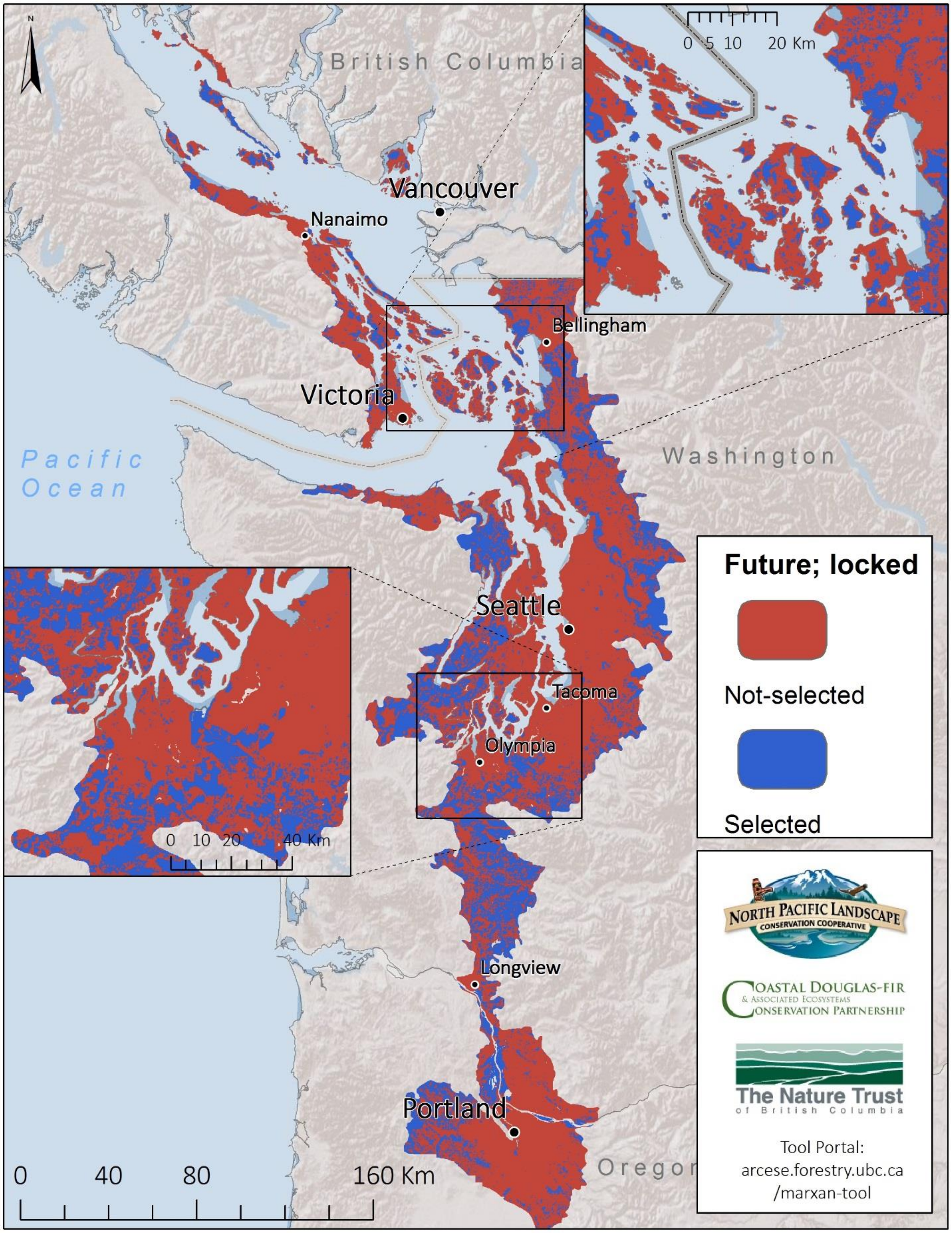
Example scenario output using the NPLCC tool. Old forest, savannah, wetland, and native plant targets were set to 50% each, the time period was set to 'current', the high quality target was set to 66%, the cost metric was 'human', and protected areas was set to 'locked-in'.



Example scenario output using the NPLCC tool. Old forest, savannah, wetland, and native plant targets were set to 50% each, the time period was set to 'current', the high quality target was set to 66%, the cost metric was 'management', and protected areas was set to 'locked'.



Example scenario output using the NPLCC tool. Old forest, savannah, wetland, and native plant targets were set to 50% each, the time period was set to 'rcp45' (future), the high quality target was set to 66%, the cost metric was assessed value, and protected areas was set to 'available'.



Example scenario output using the NPLCC tool. Old forest, savannah, wetland, and native plant targets were set to 50% each, the time period was set to 'rcp45' (future), the high quality target was set to 66%, the cost metric was assessed value, and protected areas was set to 'locked-in'.