Project Title: Cross-boundary Planning for Resilience and Restoration of Endangered Oak Savannah and Coastal Douglas-fir Forest Ecosystems

Agreement: F14AC00552

Lead PI: Peter Arcese, Professor and FRBC Chair in Conservation Biology
Chair of the Board, The Nature Trust of British Columbia
Steering Committee Member, Coastal Douglas Fir Conservation Partnership
Department of Forest and Conservation Sciences, UBC
2424 Main Mall, Vancouver, BC
Telephone: 604-822-1886
Email: peter.arcese@ubc.ca

Lead Agencies: The Nature Trust of British Columbia (www.NatureTrust.bc.ca) and Coastal Douglas Fir Conservation Partnership (www.cdfcp.ca)

Date of report: 28 June 2016
Period covered: 1 December 2014 - 28 June 2016

Public Summary: The Georgia Basin region supports a globally unique mix of dry forest and savannah habitats that evolved under historic climates and First Nations land management. These extraordinary areas still provide ecosystem services essential to human health and well-being and are widely recognized for their outstanding beauty, recreational and economic values. However, most of this historic habitat has been converted to human use, and what remains will be lost without further investments in conservation and restoration. The goal of this project was to develop a landscape planning tool to answer the question: can we maximize the biodiversity benefits of conservation investments by prioritizing land parcels and landscapes for acquisition and stewardship? To do so, we provide a web-based prioritization tool and tutorial designed to identify 'optimal solutions' to user-defined problems in the conservation of Coastal Douglas-fir, Garry oak and Arbutus forest, savanna and maritime meadow bird and plant communities of the Georgia Basin. The resulting NPLCC planning tool described extensively in the tutorial represents a state-of-the-art, web-based planning tool designed to facilitate the ability of land managers to maximize returns on conservation investments by prioritizing land parcels and landscapes for acquisition and stewardship based on the distributions of target and non-target plant and bird communities as they exist now and are predicted to occur in 2045 (for Tutorial see http://arcese.forestry.ubc.ca/marxan-tool/).

Executive Summary: Marxan planning tools developed by Ian Ball and Hugh Possingham (http://uq.edu.au/marxan/; University of Queensland, AU) are now used around the world to provide 'near-optimal' solutions to complex problems in land use planning and conservation area design using a 'simulated annealing' algorithm. The NPLCC-funded project described herein

delivers a Marxan-based planning tool that instead employs integer linear programming (ILP) and a web-accessible interface to return optimal solutions to highly complex problems in conservation planning defined by the user. ILP makes it possible to solve computationally-intensive problems in 1-3 minutes that require hours to days to solve via simulated annealing. The NPLCC tool is the also the first Marxan-based tool to offer a web-based, graphical interface. This allows users to explore multiple scenarios relatively rapidly, without downloading spatial data.

The NPLCC tool in designed to solve a very wide range of user-defined conservation problems based on the assessed value, condition and biodiversity features mapped at 1ha resolution on ~3,000,000 land parcels in the Georgia Basin region. The tool also allows users to lock existing reserves into the solution space, or make them available or not for selection. Once the scenarios of interest have been developed, high-resolution (1 ha) outputs can be downloaded and viewed with GIS software. We recommend that the results of multiple scenarios be used as 'portfolios' of candidate parcels to engage stakeholders in conservation planning.

The process of prioritizing land parcels for conservation is likely depend on a very large number of constraints and targets, as discussed in the NPLCC tool tutorial. It may also be complicated by the influence of climate change on plant and animal species distribution to affect the value of existing conservation areas in future. The NPLCC tool therefore include predictive maps of bird and plant communities in the planning area for 2045 based on the current and future predicted distributions of Douglas-fir, Arbutus and Garry oak tree species, provided by Dr. Tong Li Wang (Climate BC/WNA). Overall, the NPLCC tool was designed to address goals outlined briefly below and in detail in the attached tutorial.

Project Purpose and Objectives: This project aimed to: a) synthesize existing regional models of invasive/native species distribution and terrestrial ecosystem mapping, forest age and climate change to deliver GIS tools to prioritize land acquisition and conservation investment throughout the Georgia Basin; and b) extend those tools to facilitate cross-boundary planning with US partners to conserve endangered forest and savannah habitats in BC, WA & OR.

Approach to Planning Tool Design and Development:

1) Collaboration with the Cornell Lab of Ornithology and Center for Natural Lands Management: Land manager feedback from 6 workshops used to display and elicit feedback on the prioritization tool made it clear that larger suites of indicator species were desirable for the development of focal community maps used to prioritize parcels. We therefore formed new collaborations with two organizations which provided plot-based data for plant and bird species presence and absence in the planning region. Collaboration allowed us to access >30,000 presence-absence observations for 73 species of birds, 20 invasive plants of Garry Oak meadow habitats, and 20 iconic Garry Oak plant species indicative of high-quality meadow habitats in the

study region (>1600 sample plots for plants, >3000 for birds). These data were used in state of the art occupancy models to produce predictive species distribution maps using a variety of spatial data on human land use, vegetation cover and forest type and age.

Achieving these goals required us to overcome substantial challenges in finding suitable data sources that were contiguous across the international boundary. The tutorial/user guide describes the covariates used and the data sources for the Canadian and United States portions of the NPLCC study area and provides maps of the bird and plant community layers assembled from these data.

2) Collaboration with Dr. Tong Li Wang (Climate PNW/WNA, University of British Columbia): Because a key project goal was to predict current and future species distributions, we required special expertise in climate mapping and projection. Dr. Wang is the director and originator of ClimateWNA, ClimateBC and ClimateAsia, which use historic climate data and circulation models to provide high-resolution predictions of current and future climate for species mapping and management. Because Dr. Wang focuses on predicting the current and future distributions of tree species, we used those products to predict change in forest composition over time, and mapped plant and bird species distribution based on their affinities to those forest communities (see user guide). Dr. Wang thus provided critical help and advice in species mapping and climate projection for dry Douglas-fir forest and savanna habitats.

3) Acquisition of Cadastral Parcel Layer and Assessed Land Values: Because our approach to prioritization emphasizes cost-effectiveness in land acquisition and management, we required continuous cadastral parcel layers for the study area to include assessed value. This task proved challenging, particularly for Oregon, where Counties maintain a separate databases and charge for their acquisition. Because we did not budget for these costs, Arcese used other research funds to obtain most of the necessary data for OR. In total, we assembled a cadastral property layer with assessed values for > 3,000,000 parcels in the study area (Figure 1).

4) Leveraging External Research Funds: We applied for and won $3,500 in matching funds to engage a PhD candidate at UBC's Biodiversity Research Centre (Elizabeth Kleyhans) as a UBC BRITE Intern to develop and test code for species mapping. We required this help because the computational requirements of our mapping meant that we had to adopt cloud-based computers running Linux. Liz Kleyhans was an outstanding and essential addition to our team. Wendy Wang (undergrad in Computer Science & Statistics, UBC) as a Worklearn intern to develop code for fuzzy map contrasts of distribution maps to assess map similarity. Worklearn added $4,500 in matching funds to the NPLCC effort.

5) Workshops and Elicitation: We organized and delivered 7 day-long workshops to over 70 land managers in Canada and the US to communicate our approach to prioritization and elicit

input on data layers, including representatives of the US BLM, Parks and Forest Services, Washington State Parks, and Fish and Wildlife departments, San Juan County Parks Department, San Juan Land Bank, San Juan Preservation Trust, Klamath Bird Observatory, US and Canadian Partners in Flight and Pacific Joint Venture representatives, the Canadian Wildlife Service, Parks Canada, BC Ministry of Environment, BC Ministry of Forests, Lands and Natural Resources, Capital Regional District (Victoria region), Cowichan Valley Regional District, Nanaimo Regional District, Sunshine Coast Regional District, Island Trust Fund, Galiano Conservancy, Denman Island Conservancy, Piers Island Association, Mayne Island Conservancy, Salt Spring Island Conservancy, Habitat Acquisition Trust, The Nature Trust of British Columbia and many private land managers.

Workshops were held in Victoria, BC (December 2014), Duncan, BC (February 2014), Nanaimo, BC (March 2014), Friday Harbor, WA (April 2015), Delta, BC (September, BC), Sidney, BC (November 2015), and the University of British Columbia (November 2015).

At each workshop we made prioritization tools available to land managers by delivering and providing instruction in the use of a prototype web tool using an intuitive user interface taking advantage of R and Shiny Server. To date, the application has been used in partnership with the Coastal Douglas Fir Conservation Partnership (CDFCP, Canada) to develop strategic conservation plans for the Canadian portion of the Georgia Basin. Beta testing by Municipal, Provincial and Federal land managers resulted in substantive updates to the interface, planning options, and data layers available for prioritization. All updates and options are described in the tutorial/user guide, which also explains the scientific rationale underpinning Marxan-based planning tools. Example prioritizations are explored in the tutorial for the NPLCC study region.

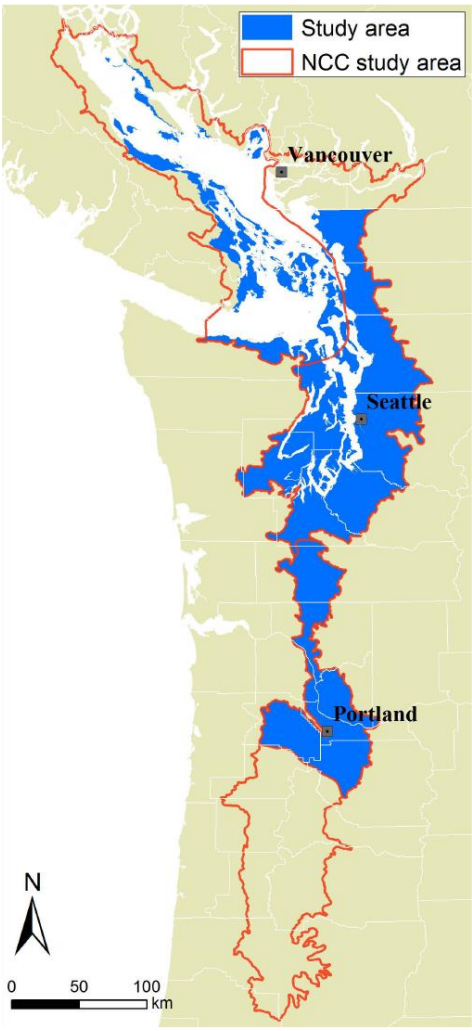

Figure 1. Study area (blue). Outline indicates extent of TNC Ecoregional Plan (2005). Availability of spatial data limited our analysis to the area shown (~3,000,000 parcels with assessed value).

Lessons Learned

1) Data acquisition: It was a substantial challenge to obtain continuous land use and forest cover data for the study region. As a consequence, coverages used in the NPLCC tool may include omissions or errors due to the age of the data available (2006 and 2009 for forest cover data in the US and Canada, respectively).

2) Predicting species response to climate change: We noted much variation in approaches to modeling species distribution under climate change and found that most prior efforts do not include effects of humans on species distribution via land use change. Ignoring the substantial

spatial covariance in more and less human-dominated habitat can undermine the reliability of climate envelope models in particular. We overcame this difficulty by developing climate-based predictions of forest composition now and in 2045 using Dr. Tong Li Wang`s by averaging projections for Douglas-fir, Garry Oak and Arbutus tree species at 1ha resolution. This indicator of forest composition was used a covariate in all species distribution models with all other local and landscape-level indicators of habitat condition. The predicted distribution of bird and plant species communities in future was therefore linked statistically to predicted changes in the occurrence of the Douglas-fir, Garry oak and Arbutus tree species in future (2045, see tutorial). In contrast, because no spatially-explicit predictions for land use change in the Canadian portion of the NPLCC study area, we were unable to contrast the predicted effects of climate vs land use change on species distributions in future. Much work now suggests that birds and plants are more strongly affected by land use than climate in the Georgia Basin region. Thus, the absence of land use predictions for the planning region represents a liability to effective conservation area design.

3) Data layers required to prioritize native biodiversity: Our meetings with dozens of land managers resulted in much feedback and enthusiasm for our planning tool. At the same time, we were often asked about the availability of data layers for additional species, included rare and endangered species, arthropods, amphibians and fish. Unfortunately, many of these species are known from 'presence-only' data which can be biased by human access and therefore not suited to predicting species occurrence in private or remote landscapes without existing surveys. A fuller understanding of species responses to land use type and change may therefore be required to develop reliable predictions of rare species distribution, and additional species maps, such as those for keystone species such as salmonids, and key indicators of ecosystem health such as amphibians, to obtain conservation designs meeting the targets of all users. An outstanding feature of the NPLCC tool is that additional, spatially contiguous data layers can be added to the platform for inclusion in planning processes relatively easily.

Communication and Outreach: A list of project communication and outreach appears above. Additional workshops are planned for November 27- 7 December 2016, including an intensive graduate student seminar at UBC designed to explore a range of scenarios to accommodate 'Critical Habitat' as defined by the Canadian Species At Risk Act. This graduate workshop will also encompass a training workshop at the BC Parks and Protected Areas Research Forum in 5-7 December, University of Victoria, BC. Academic manuscripts in progress include: a) Development and validation of indicator species and community mapping for the Georgia Basin; b) ``Tax-shifting`` policies to promote conservation on private land. Arcese and Rodewald (project collaborator) have been invited to submit a full proposal to the US NSF to developing an internship program and research program on the restoration of Coastal Douglas-fir and Savannah habitats of the Southern Gulf and San Juan Islands, in collaboration with several regional land conservancies (San Juan County Land Bank, Galiano, Denman and Mayne Island Conservancies, and Sallas Forest Partners, Sidney Island, BC). The NPLCC tool tutorial is available on-line and

attached, and will be made available via the web-sites of collaborating conservancies at project completion for the NPLCC region.

NPLCC Tool Tutorial

Reliable use of the NPLCC tool does assume substantial prior exposure among users to the development and application of predictive species maps, indicators of biodiversity, conservation area design, and land prioritization. However, we have also tried to include sufficient introductory and output material in the tutorial that any experienced land manager can explore a very wide range of planning scenarios. Details of the tool, biodiversity feature layers, cost metrics and source data for all of the above are provided in the tutorial. Additional references and web resources are also noted for users wanting more details of technical approaches.

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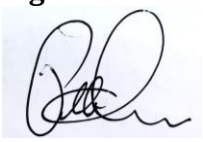

Peter Arcese
Professor and FRBC Chair in Conservation Biology
Department of Forest and Conservation Sciences
Board Chair, The Nature Trust of British Columbia
Chair of the Technical Committee, Coastal Douglas Fir Conservation Partnership
30 June 2016