Tools for Landscape-Level Assessment and Planning

A Guide for the North Pacific Landscape Conservation Cooperative

Ecosystems-Based Management Tools Network, 2014.

Tools for Landscape-Level Assessment and Planning:
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NatureServe, Arlington, VA.

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Edition Date **October 2014**

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This guide, created with the support of the U.S. Fish and Wildlife Service, describes the available tools that can support landscape-level assessment and planning in the face of climate change. A recent comprehensive assessment of the challenges, needs, and opportunities for advancing landscape-scale conservation for the North Pacific Landscape Conservation Cooperative (NPLCC) identified decision support systems and tools as the dominant need (Tillman and Siemann 2012).[1] This guide was developed primarily for natural resource managers, land-use planners, and others working within the NPLCC; however, many of the tools—as well as the lessons learned and helpful hints—will apply beyond that region's boundary.

While some practitioners have the perception that not enough tools exist, or that the "right" tools don't exist, others have difficulty knowing what tools exist. As one participant in the 2012 assessment noted:

> "Finding tools will be useful. I do not have a feel for what types of potential tools there are…"

Similarly, participants in our tools assessment noted that having some way to compare tools would address the challenges they face in identifying which of the numerous available tools would be most applicable for their needs.

For all these reasons, we hope this guide will be a welcome and well-used addition to the resources available to the NPLCC community of practitioners and beyond. We've designed it primarily with the resource manager in mind, but it can be a useful reference for anyone, from an interested layperson to an experienced software engineer.

ABOUT THIS GUIDE

The heart of this Guide is the Matrix of 100 tools, divided into user categories (general public, resource manager, and technical expert) and subject areas. So whether you are a community planner who wants to see the potential cost/benefits of building a sea wall or a forest scientist who wants to work on species connectivity for many species simultaneously, you can quickly look up which tools might be appropriate for you.

All 100 tools are described in detail following the Matrix. Things to note:

- **We use a broad** definition of tools, including anything that facilitated: 1) gathering and distributing relevant data (e.g. regional databases that support queries and downloads); 2) conducting analyses and modeling (e.g. vulnerability assessments); 3) visualizing data and analysis/modeling results (including current and potential future conditions); and, 4) integrating information into planning for conservation, land use, and land management.
- **We place an emphasis** on tools currently in use within the region.
- **We do not include** products that were simply guidelines, frameworks, or processes (but the Appendix does include some that seemed especially useful; for example, see TESSA).
- **We mostly avoid** tools that were geared to one state or province and those that could not be readily utilized throughout the region.
- **We do not include** tools that are more accurately described as services—in other words, those that required extensive and expensive—personalized set-up or customization.
- **We avoid tools** that were no longer maintained as well as most tools still under development. Because tools often become obsolete and new ones frequently emerge, this guide should be updated periodically.

The Background section of this guide lists the Necessary and Desired Attributes of the tools included in the Matrix.

We have selected 11 tools from the Matrix that we describe as a "toolkit" that can support many of the NPLCC's needs. Each of these tools also had widespread interest among NPLCC partners and/or applicability to multiple functions in the Matrix. This guide takes an in-depth look at these 11 Featured Tools, covering what they do best, how they work, their data requirements, key outputs, computer and software requirements, training requirements, and costs. A "snapshot" of each featured tool gives a brief description, examples of use, and an "at-a-glance" table that shows the tools in a matrix format.

We chose four tools to explore further via Case Studies. These are here to provide a more nuanced look at how tools have actually been applied, especially where the application experience yielded important Lessons Learned and Helpful Hints. The case studies from the region will also promote national and international awareness of NPLCC work on landscape-level conservation in the face of climate change.

Finally, the Appendix lists other potentially useful resources that did not qualify as one of our "Matrix tools" but that may assist you with your work—for example, by helping you use the tools more effectively.

ABOUT THE NPLCC

The North Pacific Landscape Conservation Cooperative is one of 22 LCCs established by the Department of Interior. Administratively, it is a self-directed partnership between federal agencies, states, Tribes/First Nations, non-governmental organizations, universities, and other entities to collaboratively define science needs and address broad-scale conservation issues, such as climate change.[2]

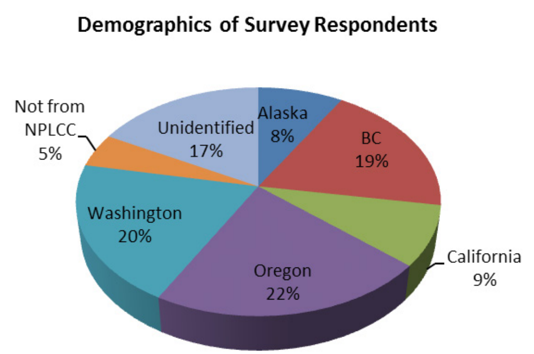
Geographically, the NPLCC extends from northwestern California to south-central Alaska.Throughout this vast north-south gradient, landscapes range from the crests of coastal mountains to the nearshore marine environment. A wealth of natural resources exist within this wide range of latitudes and elevations and the diverse terrestrial, freshwater, and marine habitats. Despite this size and complexity, the region overall is characterized by the Pacific temperate rainforests that occur here and nowhere else.[3]

The most widely valued resources across the NPLCC include forest products, old growth forests, freshwater quality, anadromous fish populations, migratory birds, carbon sequestration capacity, habitat connectivity, and near-shore, coastal, and estuarine habitats. The region's common stressors and potential impacts related to climate change: infrastructure and energy development, invasive species, sea level rise, ocean acidification, shifts in ocean current, changes to food web dynamics, phenological mismatches, and disturbed regimes.[4]

BACKGROUND ON GUIDE DEVELOPMENT

We based a significant amount of our work on understanding the functional needs for tools on a previous study for the NPLCC (Tillman and Siemann 2012). Additional information was captured from other efforts within the NPLCC and from other relevant administrative, ecological, and geographic landscapes on climate-change related tools. Our first step was to review these materials and develop preliminary information on potentially relevant tools to support landscape-level planning in the face of climate change.[5]

We presented the results of our initial research—as well as our ideas for how to conduct the rest of our work—during two webinars that drew broad geographic representation from the NPLCC. The webinars concluded with an online poll to ensure we had an opportunity to hear from everyone about the direction and methodologies we should follow, including the categories of our Matrix. The input was particularly helpful in focusing our research toward spatial, rather than non-spatial, tools.



We surveyed the NPLCC partners about the tools and approaches they have used or have considered using for climate change-related decision making. The survey's respondents described how well current applications are meeting partner needs for current and proposed work and highlighted which science and planning requirements have not been served by existing tools or approaches. The large number of respondents (105) were fairly well distributed throughout the NPLCC.

Our analysis of the survey results included:

- Determining the full range of tools and databases currently being used or considered for climate change-related decision-making; how these tools and data are being used; where they are being used; and how well they are working for the desired purposes.

- Identifying potential topical and geographic gaps in terms of tools

- Identifying potential partners—practitioners currently using tools, tool experts, practitioners interested in initiating tool use—for a Community (or Communities) of Practice for tool use.

- Examining the limitations imposed by funding, data requirements, and time available for training.

The first and last analyses in particular led us to a set of necessary and desirable attributes, which we use to filter the tools included in the Guide:

NECESSARY TOOL ATTRIBUTES

- Addresses key regional needs
- Facilitates landscape-level planning
- Can incorporate climate change considerations with other goals
- Has attainable data requirements
- Has attainable capacity requirements and cost
- Operates at useful temporal and spatial scale(s)
- Provides actionable-level information
- Has been validated
- Has appropriate guidance for use (e.g. manuals, case studies, user groups, training)

DESIRABLE TOOL ATTRIBUTES

- Presents information in visual and interactive formats
- Has been validated in local ecosystems
- Works across ecosystems
- Reflects a dynamic environment
- Already used in NPLCC
- Incorporates uncertainty
- Integrates traditional ecological knowledge and western science

The large volume of tools compelled us to apply the filters as a rapid assessment based primarily on information provided by the tools' websites.

After filtering the full range of tools from the survey based on these necessary attributes, we parsed the tools into the Matrix cells. We also researched other tools that might fulfill unmet needs—both the gaps identified in our survey and those identified by previous researchers. We used the desired attributes as secondary criteria when we found highly duplicative tools. The Ecosystem Based Management (EBM) Tools Network's interactive listserve, with nearly 4,000 participants, was an invaluable resource in identifying tools and approaches to address specialized needs, as was the NPLCC GIS committee and numerous individual experts. These sources helped us augment the Matrix so that all cells include at least one tool that meets our criteria.

Selecting only 11 Featured tools out of the 100 in the Matrix presented many challenges. Not every function and user category could be covered. Focusing only on tools in use in the ecoregion would bypass other important tools. Focusing only on tools for planners and managers would omit important tools serving expert modeling functions. Instead, we presented—and the webinar participants concurred—that a toolkit approach should be used. The selected tools represent key functions, from providing sources of data; through conducting a set of common, core assessments; to serving the decision support needs of planners and managers.

Case studies were selected from the featured tools that have been used in the region and provide key functions of fairly broad interest. We hope these small windows into your colleagues' successes—and challenges—will be enlightening and inspiring.

THE NPLCC TOOL SELECTION MATRIX

Our Matrix consists of columns for the tool functions and three user categories; the cells of the matrix are populated with tools that provide the function and appropriate for the user category. Note that tools appropriate for less technical users are also appropriate for more capable users (e.g., a technical expert will still typically find value in a web-based data portal). Below you will find definitions to help you understand the matrix that follows.

"USER CATEGORY" DEFINITIONS

General public	Tools provide capabilities to view and explore information for less technical users.
Resource Manager/Planner	Tools support a variety of analyses and planning functions by integrating data and providing easy-to-use packaged GIS/database functions
Technical and Science Expert	Tools provide advanced modeling and analytical capabilities that require technical and/or scientific expertise in their proper operation

"FUNCTION CATEGORY" DEFINITIONS

GENERAL DATA ACCESS	Locate and obtain desired data
ECOSYSTEM AND RESOURCE MODELING	
General	Model the distribution of resources and ecosystem processes
Resource distribution	Model the spatial distribution of specific resources
Resource viability analysis	Assess the viability of a resource currently and potentially under different scenarios
Anadromous fish assessment	Assess the viability of anadromous fish populations and or habitat
Resource and landscape connectivity	Assess the locations and condition of habitat connectivity
Ecosystem services provision and valuation	Model the types, location, and value of ecosystem services
Marine processes	Model marine ecosystem processes
Marsh processes	Model marsh processes

Hydrology, erosion, sediment, deposition	Model current and potential change in hydrology and hydrologic processes
Fire regime, vegetation succession	Model current and potential future fire regime and effects on vegetation
Forest modeling	Model forest ecosystem processes and effects of disturbance and management
Invasive species distribution	Model the current and potential future distribution of invasive species
Climate change effects, e.g. vegetation	Model the potential effects on resources and ecosystem processes from climate changes
SCENARIO CHARACTERIZATION	Spatially depict scenarios of current and potential future stressors and conservation/management uses and practices
ASSESSMENT	
Terrestrial climate vulnerability	Assess effects on terrestrial resources and ecosystems from change changes
Aquatic climate vulnerability (including sea level rise)	Assess effects on aquatic resources and ecosystems from climate changes
Invasive species, disease, and pest effects	Assess effects on resources and ecosystems from invasive species, disease, and pests
Management/policy effects	Assess the effects of management or policy actions on resources and ecosystems
Coastal erosion	Model the location and degree of coastal erosion under different scenarios and the effects of erosion on resources and ecosystems
Socioeconomic and value trade-offs/ROI	Assess the socioeconomic outcomes under different scenarios and the social and economic value tradeoffs among different management/policy options
PLANNING/PRIORITIZATION	
Optimization of a conservation network	Model an optimal/efficient network of conservation priority/opportunity areas
Alternatives development and assessment	Develop spatial alternatives for land use, conservation, natural resources management actions and assess effects of alternatives on resources and ecosystems
Freshwater aquatic management planning	Develop management plans for freshwater aquatic resources and ecosystems

The Matrix

FUNCTION	TYPE OF USER: General public	TYPE OF USER: Resource managers and planners	TYPE OF USER: Technical / science experts
GENERAL DATA ACCESS	Google Earth; Google Maps; Western Landscapes Explorer	AKN; NPLCC Conservation Planning Atlas; Hectares BC; NPScape; SARnet	
ECOSYSTEM AND RESOURCE MODELING			
General		Envision	EMDS; NetMap; openModeller
Resource distribution	NatureServe Explorer; Western Landscapes Explorer; CHAT	Diva-GIS; UNEP-WCMC Ocean Data Viewer	Desktop GARP; Maxent; Netmap; Random Forest
Resource viability analysis		Habitat Priority Planner; Miradi; NatureServe Vista	EMDS; HexSim; RAMAS
Anadramous fish assessment	National Fish Habitat Partner Data System; NorWeST Stream Temp; Trout Unlimited's CSI; West Coast Fish Habitat Assessments	NOAA Fisheries Pacific Coastal Salmon Recovery Fund Project and Performance Metrics Database; Regional Aquatic Prioritization and Mapping Tool	NetMap
Resource and landscape connectivity	CHAT	Corridor Designer; UNICOR; Washington Habitat Connectivity HCA Toolkit	Circuitscape; Conefor; CAT; HexSim; LinkageMapper; MulTyLInk
Ecosystem services provision and valuation	ENOW Explorer; NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Puget Sound Coastal Resilience	InVEST; MIMES
Marine processes	BLM Aquatic Priorities Tool; BCMCA; MarineCadastre.gov; West Coast Fish Habitat Assessments	Puget Sound Coastal Resilience	Alaska ShoreZone Coastal Inventory and Mapping Project; MGET; MIMES; RHESSyS
Marsh processes	West Coast Fish Habitat Assessments		SLAMM
Hydrology, erosion, sediment, deposition		StreamStats; USFS Watershed Condition Framework	BASINS; Netmap; OpenNSPECT; RiverTools
Fire regime, vegetation succession	LandFire		FRAMES; MC1+STM
Forest modeling		Forest Planner	FVS; LANDIS-II

FUNCTION	TYPE OF USER: General public	Resource managers and planners	Technical / science experts
Invasive species distribution			Maxent; RandomForest; See5
Climate change effects (e.g., vegetation)	Climate Wizard; Plan2Adapt	CC-VASH; PCIC's Regional Analysis Tool	COAST; MC1+STM; SimCLIM 2013
SCENARIO CHARACTERIZATION		CommunityViz; Envision; NatureServe Vista	EMDS; openModeller; SimCLIM 2013
ASSESSMENT			
Terrestrial climate vulnerability assessment		AHP1.1; CIMPACT-DST; Envision; Habitat Priority Planner; NatureServe Vista; SELES	CCVI; EMDS; HCCVI
Aquatic (marine and freshwater) climate vulnerability assessment (including sea level rise)	NOAA Sea Level Rise and Coastal Flooding Impacts Viewer; SeaSketch; Shellfish Information Viewer	CIMPACT-DST; COAST; Puget Sound Coastal Resilience; Envision; MIDAS; NatureServe Vista; Regional Aquatic Prioritization and Mapping Tool	MIMES; SLAMM
Invasive species, disease, and pest effects	Oregon Juniper Management Tool	Envision; NatureServe Vista	EMDS; RAMAS
Management/policy effects assessment	Western Landscapes Explorer; Oregon Juniper Management Tool	COAST; Envision; Habitat Priority Planner; NatureServe Vista	BVMTool; EMDS; RAMAS
Coastal erosion	C-CAP Land Cover Atlas; Coastal Change Hazards; Coastal County Snapshots; Coastal Resilience Decision-Support Framework; Critical Facilities Flood Exposure Tool; MarineCadastre.gov; NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	Puget Sound Coastal Resilience; DSAS	GENESIS; SimCoast; SLAMM; WEMo
Socioeconomic and value trade-offs/Return on Investment	Practitioner's Toolkit for Marine Conservation Agreements; SeaSketch	COAST; CommunityViz; Envision; Miradi; NatureServe Vista	InVEST; RIOS; SolVES
PLANNING/PRIORITIZATION			
Optimization of a conservation network		NatureServe Vista	Marxan; Marxan with Zones; Zonation
Alternatives development and assessment	SeaSketch	CommunityViz; C-Plan; Envision; NatureServe Vista	EMDS
Freshwater aquatic management planning		NatureServe Vista; Regional Aquatic Prioritization and Mapping Tool; RIBITS	BASINS; Ewater; JGrass; Netmap; OpenNSPECT; RiverTools; USGS water resource applications software

TOOL DESCRIPTIONS

AHP 1.1	This is an ArcScript in Visual Basic for ArcGIS-ArcView software. It performs a criteria weight determination according to the Analytic Hierarchy Process (AHP). AHP1.1 is a tool for the creation of suitability maps (e.g., spatial planning and risk mapping). It is limited to integer rasters and allows up to 20 criteria.
AKN	The Avian Knowledge Network (AKN) provides access to distributed bird observational data and analysis. A collaboration involving many institutions, the AKN is organized in partnerships around nodes, each with a hosting organization, partner institutions, and sponsors.
Alaska ShoreZone Coastal Inventory and Mapping Project	Alaska ShoreZone is a standardized, high resolution mapping system covering the supratidal, intertidal, and some subtidal areas of the Alaskan Coast. Imagery and data are used to support coastal management, facilities citing, emergency planning and response, search and rescue, and for many other purposes.
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources is a multipurpose environmental analysis system designed to help regional, state, and local agencies perform watershed- and water quality-based studies. BASINS has the flexibility to display and integrate a wide range of information (e.g., land use, point source discharges, and water supply withdrawals) at a scale chosen by the user.
BCMCA	The recent British Columbia Marine Conservation Analysis produced several products to inform Canadian Pacific marine planning and management, most notably an atlas, illustrating ecological and human-use areas, and reports on Marxan analyses that identify areas of high value for conservation and human use.
BLM Aquatic Priorities Tool	This tool allows BLM managers to create watershed priorities across or within the North Pacific LCC region, taking into consideration priority fish species, watershed condition (current and future), vulnerability to climate chage and to invasion by non-native species, and the proportion of streams on BLM lands.
BVMTool	BVMtool is a set of R scripts automating marine biological valuation calculations. It facilitates the calculation of a number of valuation questions that are commonly solved when observational data on species densities are available.
CAT	The Connectivity Analysis Tool combines several connectivity analysis and linkage mapping methods in an accessible user interface. The CAT software especially facilitates calculation of 'centrality' metrics. Centrality metrics evaluate paths between all possible pairwise combinations of sites on a landscape to rank the contribution of each site to facilitating ecological flows across the network of sites. Centrality metrics can be applied to landscapes represented as continuous gradients of habitat quality as well as to "patch" and "matrix" classifications.
C-CAP Land Cover Atlas	An online data viewer that provides access to regional land cover and land cover change information developed through NOAA's Coastal Change Analysis Program (C-CAP) to users without GIS expertise. It also summarizes general trends and allows users to query specific types of land cover changes for specific date ranges.
CC-VASH	The Climate Change Vulnerability Assessment for Shorebird Habitat is an Excel-based assessment tool that takes users through a series of worksheets and exercises that enable them to assess the vulnerability of coastal shorebird habitats to climate change, using three categories: 1) Effects of sea-level rise; 2) Effects of other climate-change variables, such as predicted changes in temperature and precipitation; and, 3) Effects of increased frequency and intensity of storms. Once the vulnerability is measured, the assessment outlines explicit strategies and adaptation options, and evaluates each option's chances for success.
CCVI	The NatureServe Climate Change Vulnerability Index can help identify plant and animal species that are particularly vulnerable to the effects of climate change. Using the Index, you apply readily available information about a species' natural history, distribution and landscape circumstances to predict whether it will likely suffer a range contraction and/or population reductions due to climate change. By enabling those responsible for managing lands to assess species' relative vulnerability—as well as the relative importance of factors contributing to such assessments—the Index can help prioritize management strategies for climate change adaptation and develop actions that increase the resilience of species to climate change.

CHAT	The Western Governors' Crucial Habitat Assessment Tool is an online system of maps that displays crucial habitat based on definitions developed by the Western Governors' Wildlife Council. The CHAT provides information across 16 western states, including links to state-level CHATs as they become available.
CIMPACT-DST	The Climate Impact–Decision Support Tool is an integrated platform for climate adaptation planning that works by compiling and synthesizing multiple sources of locally-relevant information—including scientific reports, policies, and spatial information—and filtering it based on simple user inputs. Once customized for a jurisdiction or locale, the tool supplies the latest climate change information and best-practice adaptation strategies along with local policies and guidelines to provide consistent, sector-relevant climate impact summaries and adaptation strategy recommendations.
Circuitscape	Circuitscape is a free software package that borrows algorithms from electronic circuit theory to predict patterns of movement, gene flow, and genetic differentiation among plant and animal populations in heterogeneous landscapes. Circuit theory complements least-cost path approaches because it considers effects of all possible pathways across a landscape simultaneously.
Climate Wizard	This is a user-friendly web program that allows the user to choose a state or country and see both the climate change that has occurred to date and the climate change that is predicted to occur. Map image data can be downloaded in GIS format.
COAST	COAST predicts damages from varying amounts of sea level rise and storms of various intensities and evaluates relative benefits and costs of response strategies. COAST uses locally derived data on vulnerable assets (real estate, economic activity, infrastructure, natural resources, human health, and others) and candidate adaptation actions wherever possible.
Coastal Change Hazards	A USGS tool for exploring of sea level rise, shoreline change, and extreme storms.
Coastal County Snapshots	On this website, users can select a coastal U.S. county and receive a short, printable information page with charts and graphs on one of the following topics: flood exposure, wetland benefits, and ocean-dependent jobs.
Coastal Resilience Decision-Support Framework	The Coastal Resilience Decision-Support Framework supports decisions to reduce the ecological and socioeconomic risks of coastal hazards. Users can visualize future flood risks from sea level rise and storm surge. They can also identify areas and populations at risk and gain a better understanding of ecological, social, and economic impacts from coastal hazards. The Framework provides multiple climate scenarios of projected sea level rise and storm surge conditions, establishes relationships among ecological, social, and economic indicators to provide a comprehenaive platform for local and regional decision making, and proposes solutions for achieving ecosystem protection and community resilience.
CommunityViz	CommunityViz planning software is an extension for ArcGIS Desktop widely used to for development, transportation, conservation, and other land-use planning. It supports scenario planning, 3-D visualization, suitability analysis, impact assessment, growth modeling and other popular techniques. Its many layers of functionality make it useful for a wide range of skill levels and applications.
Conefor	Conefor is a software package that quantifies and prioritizes the importance of various areas to landscape connectivity. It uses Graph Theory and the concept of measuring "habitat reachability" at the landscape scale.
Corridor Designer	Corridor Designer is a suite of ArcGIS tools for designing and evaluating wildlife corridors. It is best suited for designing corridors in a heterogenous landscape at a regional (e.g., 2 km - 500 km long) scale. The designers say, "Our goal is to transfer everything we've learned about designing wildlife corridors to the general public to facilitate better conservation, science, and dialogue... We realized that although several groups have used GIS to design wildlife linkages, the necessary conceptual steps and specific GIS methods have not been documented adequately."
C-Plan	C-Plan is a conservation decision support software that links with GIS to map options for achieving explicit conservation targets. It acts as a graphical user interface for Marxan and can generate Marxan datasets from C-Plan datasets. It interfaces with either ESRI ArcView 3 GIS or Zonae Cogito to act as the GIS graphical user interface.

Critical Facilities Flood Exposure Tool	The Critical Facilities Flood Exposure Tool provides an initial assessment of a community's critical facilities and roads that lie within the 1% annual chance flood zone established by the Federal Emergency Management Agency.
Desktop GARP	DesktopGarp is a software package for biodiversity and ecologic research that allows the user to predict and analyze wild species distributions. GARP is a genetic algorithm that creates an ecological niche model for a species that represents the environmental conditions where that species would be able to maintain populations. GARP uses as input a set of point localities where the species is known to occur and a set of geographic layers representing the environmental parameters that might limit the species' ability to survive.
Diva-GIS	DIVA-GIS is a computer program for mapping and geographic data analysis that is particularly useful for mapping and analyzing biodiversity data, such as the distribution of species, or other 'point-distributions'. It can be used to make grid (raster) maps of the distribution of biological diversity, to find areas that have high, low, or complementary levels of diversity, and to map and query climate data. It reads and writes standard data formats such as ESRI shapefiles.
DSAS	The Digital Shoreline Analysis System is computer software for calculating shoreline change. It computes rate-of-change statistics from multiple historic shoreline positions residing in a GIS.
EMDS	The Ecosystem Management Decision Support system (EMDS) is an application framework to help decision-makers with environmental analysis at any geographic scale. It uses fuzzy logic to make objective, scientific assessments of the ecosystem and then uses multiple-criteria decision analysis to subjectively prioritize management scenarios for decision-makers.
ENOW Explorer	This tool allows users to easily interact with Economics: National Ocean Watch (ENOW) data, which describe six economic sectors that depend on the oceans and Great Lakes: living resources, marine construction, marine transportation, offshore mineral resources, ship and boat building, and tourism and recreation. The ENOW Explorer's interface is designed to allow users who are familiar with economic data to interact with and view data and trends. The tool provides the highest level of interaction with ENOW data short of downloading the full data set.
Envision	Envision is a GIS-based tool for scenario-based community and regional integrated planning and environmental assessments. It provides a platform for integrating a variety of spatially explicit model of landscape change processes and production for conducting alternative futures analyses.ENVISION includes a subsystem that allows for the representation of human decision-makers in landscape simulations. These "actors" make management decisions in parallel with landscape change models using a variety of decision models that can reflect actor values and incorporate landscape feedbacks.
Ewater	A web-based toolkit for the distribution of hydrological, ecological and catchement management models, databases and related resources.
Forest Planner	Forest Planner allows all Washington and Oregon land owners and managers the ability to easily map their property, apply and visualize different harvest practices and other management scenarios, and quickly compare those scenarios with outputs that show timber yeilds, and other financial returns, as well as environmental benefits such as carbon storage.
FRAMES	FRAMES, the Fire Research and Management Exchange System, is an online portal for exchanging information and transferring technology among wildland fire researchers, managers, and other stakeholders. The FRAMES Resource Cataloging System is organized into six resource groups: projects, tools (including models), documents, web pages, data, and programs (organizations). They have also begun to catalog recorded webinars, videos, podcasts, etc.
FVS	The Forest Vegetation Simulator is an individual-tree, distance-independent, growth and yield model. It has been calibrated for 20 geographic areas (variants) of the U.S. FVS can simulate a wide range of silvicultural treatments for most major forest tree species, forest types, and stand conditions and it answers questions about how forest vegetation will change in response to natural succession, disturbances, and proposed management actions. Extensions to the base model are available to assess the effects of insects, disease, and fire. A climate-sensitive version known as Climate-FVS is available for western states which changes core growth, mortality, and regeneration estimates to respond to climate change, according a user-selected general circulation model, allowing users to model the effects of management under changing climate conditions.

GENESIS	GENESIS (GENeralized Model for SImulating Shoreline Change) simulates the long-term platform evolution of the beach in response to imposed wave conditions, coastal structures, and other engineering activity (e.g., beach nourishment).
Google Earth	The desktop (free) version of Google Earth allows users to view satellite imagery, maps, terrain, and seafloor topography. There is also an Enterprise version that allows users to synthesize large quantities of geospatial data.
Google Maps	Google Maps offers conventional road maps and satellite views, as well as "Street View" in many locations. It has a route planner function and it can be embeded into other websites wherever directions are needed.
Habitat Priority Planner	This tool helps coastal communities perform critical habitat analyses and set land use and conservation priorities. Users can easily and quickly change and display scenarios "on the fly,"experimenting with different scenarios and rapidly "seeing" the potential impact of their ideas via reports, maps, and data tables.
HCCVI	The Climate Change Vulnerablity Index for Ecosystems and Habitats, (HCCVI) is a framework for a series of measurements to determine how vulnerable a given community or habitat type might be to climate change. The index measures are organized within categories of Exposure, Sensitivity, and Adaptive Capacity. While the overall index score for each community should be useful for setting regional and national priorities, the results of these individual analyses should provide insight into climate change adaptation for local planners and managers.
Hectares BC	Hectares BC is an application that allows users to access and work with British Columbia's natural resource geospatial data without the need for GIS skills. Scientists, researchers, and government staff can use this in carrying out their planning, assessment, reporting, and decision making functions.
HexSim	HexSim is a computer modeling framework for simulating terrestrial wildlife (plant/animal) population dynamics and interactions.The user defines the life cycle (life history events) and other simulation parameters, which may be simple, with few data needs, or highly complex, with correspondingly complex data requirements. HexSim includes data analyses tools, including output maps and an animated simulation viewer. It can be used for population viability analysis, studying the consequences for wildlife of multiple interacting disturbances, assessing which habitat components are most critical for population maintenance, measuring the consequences for wildlife of changes to landscape connectivity, etc.
InVEST	InVEST (Integrated Valuation of Environmental Services and Tradoffs) is a suite of software models used to map and value the goods and services from nature that sustain and fulfill human life.The toolset currently includes sixteen models suited to terrestrial, freshwater, and marine ecosystems. InVEST models are spatially-explicit, using maps as information sources and producing maps as outputs. InVEST returns results in either biophysical terms (e.g., tons of carbon sequestered) or economic terms (e.g., net present value of that sequestered carbon).
JGrass	The Java Geographic Resources Analysis Support System is an open-source GIS. It is primarily dedicated to hydrological and geomorphological analyses and handles both raster and vector data.
LANDFIRE	LANDFIRE provides more than 20 national geospatial layers, databases, and ecological models for the U.S. updated every two years. Products cover disturbance, vegetation, fuel, fire regimes, and topography.
LANDIS-II	LANDIS-II is a program that simulates forest succession, disturbance, climate change, and seed dispersal over large landscapes. It includes a library of ecological processes for the user to choose from, including many designed to track landscape carbon dynamics.
LinkageMapper	Linkage Mapper is a GIS tool designed to support regional wildlife habitat connectivity analyses. It consists of several Python scripts, packaged as an ArcGIS toolbox, that automate mapping of wildlife habitat corridors. Linkage Mapper uses GIS maps of core habitat areas and resistances to identify and map linkages between core areas. Each cell in a resistance map is attributed with a value reflecting the energetic cost, difficulty, or mortality risk of moving across that cell. The tool identifies adjacent (neighboring) core areas and create maps of least-cost corridors between them. It then mosaics the individual corridors to create a single composite corridor map. The result shows the relative value of each grid cell in providing connectivity between core areas.

MarineCadastre.gov	MarineCadastre.gov provides ocean data and offshore planning tools. The project was designed specifically to support renewable energy siting on the U.S. Outer Continental Shelf but it is also being used for other ocean-related planning. Among its offerings are: a spatial data registry, which provides over 140 data layers or map services; a map viewer that allows users to view and interact with the data; and a map gallery that features custom maps that users can view, modify, or enhance with their own map services or GIS layers.
Marxan	Marxan is widely used conservation planning software for selecting new conservation areas and for natural resource management in terrestrial, freshwater, and marine systems.
Marxan with Zones	Marxan with Zones represents a shift away from the basic focus of Marxan on reserve design toward a multiple zone scheme that supports the efficient allocation of resources across a range of different uses. Thus, the Marxan with Zones software can be applied to address more complex problems by considering multiple zones with different targets, planning unit costs, and biodiversity benefits for each zone.
Maxent	Maxent is software based on the maximum entropy approach for species habitat modeling. This software takes as input a set of layers or environmental variables (such as elevation and precipitation), as well as a set of georeferenced occurrence locations for a species, and produces a model of the range of the given species.
MC1+STM link 1 link 2 link 3	MC1 is a dynamic global vegetation model that predicts climate change impacts on vegetation and fire regimes and the associated cycling of nutrients between plants and the soil. One ongoing effort is to link MC1 results to existing state-and-transition models such as VDDT and ST-SIM to make them "climate smart" for resource managers.
MGET	Marine Geospatial Ecology Tools is a geoprocessing toolbox that can help solve a wide variety of marine research, conservation, and spatial planning problems. MGET plugs into ArcGIS and can perform tasks such as: accessing oceanographic data from ArcGIS; identifying ecologically-relevant oceanographic features in remote sensing imagery; building predictive species distribution models; modeling habitat connectivity by simulating hydrodynamic dispersal of larvae; detecting spatio-temporal patterns in fisheries and other time series data.
MIDAS	The Marine Integrated Decision Analysis System is a software tool for predicting the impacts of Marine Management Areas (MMAs) based on ecological, socioeconomic and governance variables, as well as the results of various management actions on MMAs.
MIMES	MIMES is a multi-scale, integrated set of models that assess the value of ecosystem services. The models facilitate quantitative measures of ecosystem service effects on human well-being.
Miradi	Miradi is a user-friendly program that allows conservation practitioners to design, manage, monitor, and learn from their projects. The program guides users through a series of step-by-step interview wizards, based on the Open Standards for the Practice of Conservation. As practitioners go through these steps, Miradi helps them to define their project scope, and design conceptual models and spatial maps of their project site. The software helps teams to prioritize threats, develop objectives and actions, and select monitoring indicators to assess the effectiveness of their strategies. Miradi also supports the development of workplans, budgets, and other tools.
MulTyLink	MulTyLink is an application designed to select connectivity linkages for distinct types of habitats and to optimise the selection of linkages for every type of habitat. The software provides users the flexibility to assign costs, friction values, and habitat-specific barriers as input data. MulTyLink then retrieves a network of linkages which may be visualised as the overall best solution or independently optimal for each habitat type.
National Fish Habitat Partner Data System	The System provides data access and visualization tools for NFHP data products, as well as contributed data from partners
NatureServe Explorer	NatureServe Explorer® is a searchable database providing conservation information on more than 70,000 plants, animals, and habitats of the United States and Canada. It represents 40 years of field work, ecological inventory, and scientific database development by NatureServe and its natural heritage network member staff in North America.

NatureServe Vista	NatureServe Vista® is a decision-support system that helps users integrate conservation with many types of planning such as land/water use and natural resource management, infrastructure and transportation, energy development, and climate change adaptation. Users can characterize their features of interest, integrate expert knowledge, create and evaluate different spatial scenarios to determine where and how their values are supported or threatened, and develop site mitigations or complete new alternatives to best achieve planning objectives. Vista also supports ongoing plan implementation and adaptive management.
NetMap	NetMap contains about 80 tools packaged as ArcMap add-ins. Tool modules include analysis tools, fluvial processes, aquatic habitats, erosion, transportation, and vegetation/fire/climate. The NetMap analyses tools allow you to conduct your own assessments in conjunction with TerrainWorks' "Digital Landscape"— a numerical platform for characterizing watershed environments and processes and human interactions with those environments. The spatial scale of the Digital Landscapes is customizable from parcels and individual stream reaches to entire states.
NOAA Fisheries Pacific Coastal Salmon Recovery Fund Project	The project's main website includes a "Maps & GIS Data" page with two interactive map viewers: one provides access to demographic data compiled for ESA-listed salmonid populations and one that maps and tracks the implementation of recovery actions of ESA-listed Pacific salmon and steelhead. Critical habitat, essential fish habitat, and other GIS layers are also available.
NOAA Fisheries Pacific Coastal Salmon Performance Metrics Database	Has complete metrics on all projects that have recieived Pacific Coastal Salmon Recovery Funds.
NOAA Sea Level Rise and Coastal Flooding Impacts Viewer	This is a visualization tool that displays how potential future sea levels may impact most of the coastal U.S. Users can zoom in on the map, see images of how local landmarks might appear at various levels of rise, view potential marsh migration, overlay social and economic data onto potential sea level rise, examine how tidal flooding will become more frequent with sea level rise, and understand the spatial uncertainty of mapped sea levels.
NorWeST Stream Temp	The NorWeST webpage hosts both stream temperature data and geospatial map outputs from a regional temperature model for the Northwest U.S. (Washington south to northern California and west to most of Wyoming and Montana). The temperature database was compiled from hundreds of biologists and hydrologists working for dozens of resource agencies and contains more than 45,000,000 hourly temperature recordings at more than 15,000 unique stream sites. These temperature data are being used with spatial statistical stream network models to develop an accurate and consistent set of climate scenarios for all streams.
NPLCC Conservation Planning Atlas/ DataBasin	The North Pacific LCC Conservation Planning Atlas (CPA) is a data discovery, visualization, and analytical platform for stakeholders throughout the NPLCC area. Within the NPLCC CPA there are: data and information developed with NPLCC funding, a series of "galleries" with data layers for different topics relevant for the North Pacific geography, and mapping tools to visualize and overlay the various layers within the CPA. The CPA also provides tools for collaboration. People focused around a particular geography or conservation issue can develop "groups" that can upload and share data, set permissions on datasets, and collaboratively visualize map products.
NPScape	NPScape is a landscape dynamics monitoring project that provides landscape-level data, tools, and evaluations for natural resource management, planning, and interpretation. NPScape metrics fall into seven major categories: human population, housing, roads, land cover, vegetation pattern, climate, and protection status. The target audience spans the range from GIS specialists who will benefit from the geospatial products, to natural resource specialists who will be interested in the landscape metrics presented in a local and regional context, to park superintendents and other land managers who can incorporate the maps and graphics into reports.
openModeller	openModeller is a cross-platform environment to carry out ecological niche modeling experiments. It is comprised of a single framework written in C++ allowing multipe interfaces on top of it, such as command line programs, Desktop interface, Web interface and Web Service interface. The framework includes facilities for sampling points, creating, testing, evaluating and projecting models into different environmental scenarios, reading species occurrence and environmental data in different formats. More than 10 algorithms are available as plugins, including GARP and Maxent. The same functionality can be used by Python programs through a built-in SWIG binding on top of the C++ API.

OpenNSPECT	OpenNSPECT is the open-source version of the Nonpoint Source Pollution and Erosion Comparison Tool; it is used to investigate potential water quality impacts from development, other land uses, and climate change. When applied to coastal and noncoastal areas alike, OpenNSPECT simulates erosion, pollution, and their accumulation from overland flow.
Oregon Juniper Management Tool	This tool allows land managers to review a suite of juniper-related spatial data layers such as juniper canopy, sage grouse habitat, hydrology, and public ownership, in an interactive web map viewer, and then build personalized scenarios for juniper removal by defining specific objectives such as how many acres of juniper to remove or whether or not to prioritize removal in sage grouse habitat.
PCIC's Regional Analysis Tool	The Pacific Climate Impacts Consortium's Regional Analysis Tool generates maps, plots and data describing projected future climate conditions for the Pacific and Yukon Region. It uses an ensemble of more than 15 Global Climate Model (GCM) and SRES emissions scenario combinations provided by the Intergovernmental Panel on Climate Change. The Regional Analysis Tool is similar to PCIC's Plan2Adapt tool, but with a more complex user interface and greater number of configurable options, the Regional Analysis Tool is designed to serve the needs of those involved in climate modelling and impact studies.
Plan2Adapt	Plan2Adapt is an easy-to-use web interface to explore projected future climate conditions for selected regions in British Columbia. Outputs include maps, charts, and tables.
Practitioners Toolkit for Marine Conservation Agreements	The Practitioner's Toolkit for Marine Conservation Agreements helps organizations determine: what marine conservation agreements are, when these agreements can be used to abate threats to oceans and coasts, and how to develop and implement a marine conservation agreement project.
Puget Sound Coastal Resilience	Coastal Resilience is a suite of tools for comparing risk, restoration, and resilience scenarios in an easy-to-use map interface.The tools are designed to support decisions that reduce the ecological and socio-economic risks of coastal hazards.
RAMAS	RAMAS is a suite of proprietary software tools for analysis of spatial data and population data. RAMAS GIS specializes in patch and habitat dynamics, spatial metapopulation models, ecological risk assement. RAMAS Metapop is an interactive program that allows you to build models for species that live in multiple patches. It incorporates the spatial aspects of metapopulation dynamics, such as the configuration of the populations, dispersal and recolonization among patches and similarity of environmental patterns experienced by the populations. The program can be used to predict extinction risks and explore management options such as reserve design, translocations and reintroductions, and to assess human impact on fragmented populations.
Random Forest R-Project link Random Forest on wikipedia	The Random Forest model is typically applied via the R-Project interface and is used to for predictive models of species' extent. The model is/are an ensemble learning method for classification (and regression) that operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes output by individual trees. The algorithm for inducing a random forest was developed by Leo Breiman and Adele Cutler, and "Random Forests" is their trademark.
Regional Aquatic Prioritization and Mapping Tool	This is an aquatic priorities decision support system for Oregon, Washington, and Idaho for use mainly by USFWS. Other users' use of the tool is more restricted. Designed to answer the question: "Given a set of constraints, which sub-basins should I focus on to maximize conservation objectives for specified fish species."
RIBITS	RIBITS (the Regulatory In lieu fee and Bank Information Tracking System) was developed to provide better information on mitigation and conservation banking and in-lieu fee programs across the country. RIBITS allows users to access information on the types and numbers of mitigation and conservation bank and in-lieu fee program sites, associated documents, mitigation credit availability, service areas, as well information on national and local policies and procedures that affect mitigation and conservation bank and in-lieu fee program development and operation.

RIOS	RIOS is a software tool that supports the design of cost-effective investments in watershed services. It combines biophysical, social, and economic data to help users identify the best locations for protection and restoration activities in order to maximize the ecological return on investment, within the bounds of what is socially and politically feasible.
RiverTools	RiverTools is a proprietary GIS application for analysis and visualization of digital terrain, watersheds and river networks. One of RiverTools' most powerful features is its ability to rapidly extract drainage network patterns and analyze hydrologic data from very large DEMs (digital elevation models).
SARnet	The Species At Risk Network for the South Coast of BC is a data hub and networking tool designed to: facilitate an improved understanding of what information is available on priority species and ecological communities at risk in BC's South Coast region; provide information on new inventorying and monitoring standards; initiate networking between those involved in various activities relating to at-risk species and ecological communities; provide a mechanism for gap analyses; and identify where future efforts could be best directed on species at risk conservation.
SeaSketch	SeaSketch is a platform for collaborative ocean GeoDesign. Using SeaSketch, anyone with a web browser and Internet connection may design management plans, including marine protected areas, transportation zones and renewable energy sites. Users can: define a study region, upload map layers from existing web services, define "sketch classes," such as prospective marine protected areas, author sketches, and receive automated feedback on those designs, such as the ecological value or the potential economic impacts of a marine protected area, and share sketches and discuss them with other users in a map-based chat forum.
See5	See5 for Windows Xp/Vista/7/8 (and its Unix counterpart C5.0) are data mining tools for discovering patterns that delineate categories, assembling them into classifiers, and using them to make predictions.See5/C5.0 has been designed to analyze substantial databases containing thousands to millions of records and tens to hundreds of numeric, time, date, or nominal fields.
SELES	The Spatially Explicit Landscape Event Simulator is a tool for constructing and running spatially explicit spatio-temporal landscape models that integrate natural and anthropogenic processes and that track indicators (e.g. age class, habitat supply, timber volumes) over long time-frames and large spatial areas. SELES is useful for land-use planning, sustainable forest management, natural disturbance modelling and habitat modelling.
Shellfish Information Viewer	An online map viewer and tool for viewing and querying shellfish datasets in Washington State.
SimCLIM 2013	SimCLIM is a software package designed to facilitate climate risk and adaptation assessments. Maps, graphs and charts of various aspects of climate change can be generated for sites and spatially for cities, counties, provinces, nations, and the world.
SimCoast	SimCoast is a fuzzy logic rule-based expert system designed to enable users to create and evaluate different policy scenarios for coastal zone management. It aims to combine traditional and advanced specialist knowledge about coastal zones with a set of reasoning and analytical tools.
SLAMM Developer's link NOAA's link	The Sea Level Affecting Marshes Model is a mathematical model that uses digital elevation data and other information to simulate the potential impacts of long-term sea level rise on wetlands and shorelines. SLAMM addresses various wetland scenarios, including inundation, erosion, overwash, saturation, and salinity; computes relative sea level change for time sequences of 5 to 25 years; incorporates areas protected by dikes and other hard structures; incorporates sedimentation and accretion rates and provides options for computing erosion; incorporates standard coastal wetland classes; and provides outputs that can be viewed in a GIS for additional analysis.
SolVES	SolVES is a GIS Application for Assessing, Mapping, and Quantifying the Social Values of Ecosystem Services. SolVES is designed to assess, map, and quantify the perceived social values of ecosystem services, such as aesthetics and recreation. These nonmonetary values, often corresponding to cultural ecosystem services, can be analyzed for various stakeholder groups as distinguished by their attitudes and preferences regarding public uses, such as motorized recreation or logging. SolVES derives a quantitative, 10-point, social-values metric, the Value Index, from a combination of spatial and nonspatial responses to public value and preference surveys and calculates metrics characterizing the underlying environment, such as average distance to water and dominant landcover.

StreamStats	StreamStats is a resource that provides users with access to analytical tools that are useful for water-resources planning and management, as well as for engineering design applications such as for dams and bridges. StreamStats also allows users to easily obtain streamflow statistics, basin characteristics, and other information for streams that the user selects from an interactive map. National (U.S.) coverage is not yet available but Washington, Oregon, and California are fully implemented.
Trout Unlimited's CSI	Trout Unlimited's Conservation Success Index (CSI) is a protocol for assessing and mapping the conservation status of native coldwater fishes using 20 indicator variables that describe such factors as habitat integrity, threats, and population condition. Comparisons of existing status and consideration of future management options can then be made across subwatersheds and species.
UNEP-WCMC Ocean Data Viewer	UNEP-WCMC stands for the United Nations Environment Programme-World Conservation Monitoring Centre. Their Ocean Data Viewer offers a quick look at twenty spatial global datasets such as the distribution of seagrasses, the Pelagic Provinces of the world, and the Global Map of Hurlburt's Index of Biodiversity.
UNICOR	UNICOR (UNIversal CORridor Network Simulator) is a species connectivity and corridor network simulator. UNICOR implements Dijkstra's shortest path algorithm for any number of landscapes and distributions of species. The model's features include a graphical user interface, parallel-processing, kernel path-buffering, connectivity maps, and various formatted outputs ready for graph and patch theory metrics.
USFS Watershed Condition Framework	The Framework is a comprehensive approach for restoring priority watersheds on national forests and grasslands. It includes a methodology for classifying waterhshed condition based on 12 indicator variables (with a technical guide). The results of the planning work are viewable on a map viewer.
USGS water resource applications software	This is a library of software developed by USGS for use in fulfilling its mission and made freely available to others. The categories are: general use, water quality and chemistry, groundwater, statistics & graphics, and surface water.
Washington Habitat Connectivity HCA Toolkit	The HCA toolkit is a GIS tool designed to support regional wildlife habitat connectivity analyses by automating the process of identifying habitat concentration areas (HCAs). HCAs are areas on the landscape between which patterns of connectivity are evaluated. The habitat areas identified by this toolkit may be used as an input for Linkage Mapper.
WEMo	WEMo (the Wave Exposure Model) helps coastal managers, ecologists, and physical hydrologists by estimated wave energy and its effects on ecosystem functions, as well as on developed coastal and inland-water areas. It can be used by non-specialists in hydrodynamics but it does require basic knowledge of GIS. Features include: forecasts and "hindcasts" wind wave energy and the movement of seafloor sediment in enclosed water bodies; provides a foundation for studying or modeling restoration efforts, seafloor and shoreline erosion, and the tolerance limits of habitats; adjusts to wind events that are chronic, extreme, or combined with storm surge.
West Coast Fish Habitat Assessments	This site will become a data portal for information elated to estuary resource protection and restoration efforts along the West Coast.
Western Landscapes Explorer's map tool	Create a map for your area of interest and your selected layers: many to choose from. Critical habitat, earthquake hazards, wetlands, ecosystems, fire potential, WGA Crucial Habitat Score, etc. Publisher of data from the Integrated Landscape Assessment Project (ILAP).
Zonation	Zonation is a conservation planning framework and software. It produces a hierarchical prioritization of the landscape based on the occurrence levels of biodiversity features in sites (cells) by iteratively removing the least valuable remaining cell while accounting for connectivity and generalized complementarity. The output of Zonation can be imported into GIS software to create maps or for further analysis. The computational strategy of Zonation can be characterized as maximal retention of weighted, range size normalized (rarity corrected) richness.

THE CONCEPT BEHIND 'TOOLKIT'

The term "tool" is used to describe a wide variety of resources, processes, analytical approaches, and software that help decision-makers develop potential solutions and gauge their utility.

Tools are suited to different types of users with different skills and may perform functions that are useful at different steps in the planning process. A key to selecting the best tool is to have a well thought-out planning process that identifies the most important steps.

Tools should help the process, not drive it.

However, it is not uncommon to need to adjust a planning process to fit the available data and the tool's functionality.

In this guide, we feature 11 tools from our Matrix, selected so that at least one tool that can be used at each step in many, if not most, planning processes—from initial data collection to analysis and mapping to modeling future conditions. We call this the "toolkit" approach.[i]

FEATURED TOOLS AND A GENERIC PLANNING PROCESS

The following matrix indicates which key planning processes are served by which tools. The planning process is iterative, rather than linear, as this matrix implies.

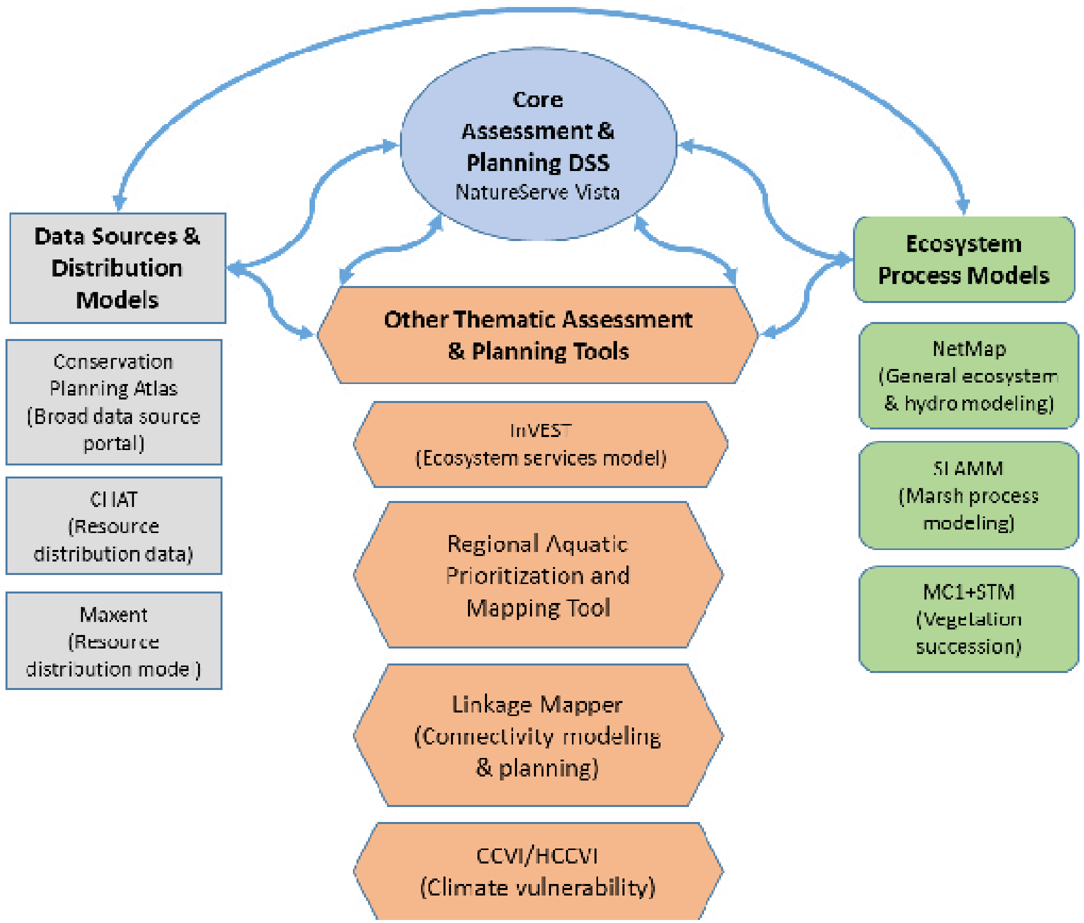
	Data Sourcing/ Modeling Current Condition	Stakeholder Engagement/ Visualization	Assessment/ Analysis	Planning	Modeling Future Condition
NPLCC Conservation Planning Atlas	■	■			
CHAT	■	■			
Maxent	■				■
InVEST	■		■	■	■
Regional Aquatic Prioritization and Mapping Tool	■	■	■	■	■
Linkage Mapper	■		■	■	■
CCVI/HCCVI			■		■
NetMap	■		■		
SLAMM			■		■
MC1+STM			■		■
NatureServe Vista		■	■	■	■

[i] *An extension of this approach is the integrated toolkit, where the output of one tool can be used as input into another, ideally iteratively, to increase overall functionality. An example is the Integrated Land-Sea Planning Toolkit, which integrated three tools from the Matrix in this guide: CommunityViz, NatureServe Vista, and a version of OpenNSPECT.*

TOOLKIT SCHEMATIC

The diagram below places each of the 11 tools into three core categories: 1) Data Sources and Distribution Models, 2) Assessment and Planning, and 3) Ecosystem Process Models. The Data Sources and Distribution Models provide the inputs to the other tools. The Ecosystem Process Models conduct complex modeling to understand how ecosystems are functioning and how they may change in the future.

The Assessment and Planning Tools allow managers to conduct sophisticated (but accessible with training) assessments for particular thematic areas (e.g., wildlife connectivity or ecosystem services) and to develop alternatives. A Core Assessment and Planning DSS (decision-support system) helps integrate information from many of these tools into a central system so that planners and managers can conduct assessments and develop integrated plans. Some tools apply to more than one category; in those instances, we place the tool in the area of its core capability to illustrate this toolkit.



TOOLS AND THE PLANNING PROCESS

The variety of a tool's functions makes it useful at different points in the planning process. The more specialized the tool, the more focused it is on a specific part of that process. Together, our featured tools comprise a "toolkit" that covers the major steps in most planning processes. However, the Matrix contains many more tools that could have been selected to fill similar needs. Furthermore, other tools can be added to fit specific needs not addressed by these 11 tools. Selecting the right tool—or tools—may take careful research. We suggest these as the primary factors to consider:

- *What specific functions must the tool perform?*
- *Do you have the data and capacity to operate the tool?*
- *Does the tool work at the needed geographic and temporal scales?*
- *Is the tool compatible with other tools in your workflow? (That is, can it work the same computing environment with the same input/output data formats?)*
- *If the tool does not fit your project needs, can it be customized? How difficult or expensive would that be? Or can you modify your process to take advantage of the tool?*

FEATURED TOOLS AT A GLANCE

Click on the tool's name to go directly to its 'snapshot' page

	NPLCC CPA	CHAT	Maxent	InVEST	RAPMT	Linkage Mapper
Developer	Conservation Biology Institute	Western Governors' Association	Steven Phillips, Miroslav Dudík, Robert Schapire, and Robert Anderson	Natural Capital Project	Ecotrust and the U.S. Fish & Wildlife Service	Brad McRae and Darren Kavanagh
Purpose	Data discovery and visualization	Understanding important areas for conservation on a regional scale in the western U.S.	Ecological niche / species distribution modeling	Evaluate how human activities and climate change affect terrestrial, freshwater, and marine ecosystem services	Identify watershed priorities at the regional scale (the tool's platform can also be customized for other purposes)	Automated modeling of wildlife connectivity + other options for exploring corridors
Data requirements	None	None	• Georeferenced presence locations • Environmental layers such as temperature, precipitation, elevation, etc. (Presence and environmental layers must both use the same coordinate system, e.g. latitude and longitude)	Variable depending on the model Most models run with globally available datasets and information from peer-reviewed literature Much of these data are included with InVEST Users can also input data more specific to their region	Loaded with data specific to 22 locally endemic and 49 widespread fish species, ESUs, DPSs, and sub-species as well as relative watershed condition, climate change vulnerability, and aquatic invasibility summarized to sub-basins (4th field huc) in OR, WA, and ID. Also includes raw input data, e.g., for vulnerability indices. New data are easily uploaded (e.g., for different species or planning units) using a pre-formatted Excel spreadsheet.	• GIS layers for any factors could affect resistance to movement for the species of interest , e.g., land cover, roads, housing density • Habitat concentration areas for the species of interest; these can be defined by other models or tools, such as Gnarly Landscape Utilities (http://www.circuitscape.org/gnarly-landscape-utilities)
Outputs	Various: this a portal to thousands of curated datasets	• An interactive online map • Geospatial data available for download or via web services	Multiple, including html and a color image indicating probability. Three output formats for model values: raw, cumulative, and logistic (this is the default, an estimate between 0-1 of the probability)	Biophysical and socio-economic metrics	Identification of high-priority planning units based on user-specified parameters and summary statistics specific to global and site specific variables. Outputs can be downloaded as a shapefile.	There are a variety of raster output maps that communicate different aspects of connectivity such as pinch points and important barriers as well as linkages
OS requirements	Windows or MacIntosh	Windows or MacIntosh	Windows or MacIntosh	Any ArcGIS-compatible OS	Client: Any machine with internet or cellular (not ideal for smart phones). Server: Ubuntu 12.04 or later	Any ArcGIS-compatible OS
Software requirements	None per se, but retrieving and using the many spatial datasets will require GIS software	None per se, but retrieving and using the many spatial datasets will require GIS software	Java version 1.4 or later	Variable: e.g., ArcGIS 10 with Spatial Analyst	Client side: current versions of major web browsers Server side: Anisble, Python	AcrGIS 9.3 or 10 with Spatial Analyst, Python 2.5 or 2.6 and NumPy
Training required	None	None	Minimal to run; there is a tutorial on the website. Fully using the models to explore and undersand your data can be more challenging	Basic GIS skills to format data and understand outputs	Depends on intended use and skill of the developer	There is a user guide and a user group
Price	Free	Free	Free	Free	Free and open source	Free

FEATURED TOOLS AT A GLANCE

Click on the tool's name to go directly to its 'snapshot' page

	CCVI/HCCVI	NetMap	SLAMM	MC1 + STM	Vista
Developer	NatureServe	TerrainWorks	Warran Pinnacle Consulting, Inc.	USDA Forest Service, PNW; ESSA, ApexRMS; (Project linking models is led by UDSA http://www.fsl.orst.edu/dgvm/)	Ecotrust and the U.S. Fish & Wildlife Service
Purpose	Assess vulnerability of species and habitats to climate change	Approx. 80 tool modules that address a wide variety of spatial questions in resource management	Predict the potential effects of sea level rise on wetlands	Evaluate how disturbances, management actions and changes in climate could alter vegetation structure and composition	Decision support: Evaluate the impacts of management scenarios on land use and conservation goals
Data requirements	• Past climate data and future climate projections for your area of interest • Life history/ecological information for your species or community of interest	Varies depending on the analysis but the tool comes with numerous data layers for WA, OR, ID, MT, CA, WY, NV, SD, ND, plus areas in Southeast and Southcentral Alaska	Ascii raster files of wetland coverage, elevation, and slope; historic seal level rise rates, tide ranges, 30-day innundation heights, datum correction values, accretion, erosion & sedimentation rates. Ascii raster files of impervious surface & dike coverage optional Uncertainty module can account for missing data	CENTURY Soil Organic Matter Model v.5 (not yet released), MAPSS, historical climate data, future climate data, soils datasets: •ppt.nc •tmin.nc •tmax.nc •tdmean.nc or vpr.nc •elev.nc •soils_scs.nc •bd.nc •CO2 ramp file optional: •tmp.nc •mask file (--mask_file <mask file name>)	• Distribution of conservation elements of interest, e.g. at-risk species, historic buildings • Land cover data • Expert input on the viability requirements and responses to stressors of your conservation elements is highly recommended
Outputs	Scores that reflect the relative vulnerability of individual species/ habitats to climate change, along with an indication of which factors contribute most to vulnerability	NetMap produces many different outputs in the form of comma delimited result files that can be used to reclass ArcGIS grids	Graphical & numerical projections of potential changes in extent and composition of wetland types along with statistics of uncertainty results	Dynamic vegetation models	Rich set of maps (ArcGIS grids), reports, and tabular outputs that can be exported to HTML and MS Excel formats
OS requirements	MacIntosh, Windows, or online	Windows 7	Windows XP or Windows 7	OS X, Amazon Cloud	Windows XP or Windows 7
Software requirements	Excel (not needed for the online version). GIS can be helpful but is not required.	ESRI ArcMap 10.x (Spatial Analyst helpful). Also: "as much Ram as you can muster (at least 4 GB)"	MS Word (and MS Excel optional)	C+ and access to OSU opensource coding site	GIS: ESRI ArcGIS10x with Spatial Analyst Other: Microsoft .Net4 (free)
Training required	Expertise in the life history or ecology of the species/habitat is needed. Some training is useful to ensure calibration and repeatability of assessments	NetMap is primarily an expert tool. It has extensive online technical help documents and custom assistance is available.	GIS expertise to produce raster inputs; basic understanding of model parameters and conceptual model function	Strong programming experience; access by invitation	Basic GIS required to format data for input. Minimal training to run analyses
Price	Free	By subscription	Free	Free	Free

Description

The Conservation Planning Atlas (CPA) is a data-discovery, visualization, and analytical platform developed for anyone working within the North Pacific Landscape Conservation Cooperative. The CPA provides easy access to thousands of curated datasets relevant to the Pacific Northwest, organized into subject-area "galleries" such as coastal and marine resources, freshwater resources, terrestrial resources, anadromous resources, and climate change. These data resources can provide much of the input data to other tools in the toolkit. Mapping tools allow users to overlay and visualize various layers. Much of the data inventory on the CPA is integrated with ScienceBase, a USGS-funded data management system. While data are not necessarily actively stored in the CPA or on ScienceBase —where they could become out of date—the CPA leads you to sites where you can download the most current data. The CPA also provides tools for collaboration: users who are focused on a particular geography or topic can develop a "group" that can upload and share data, set permissions on datasets, and visualize map products together.

Examples of use

As of this guide's publication date, the CPA had only been launched for a few months, but there are several anticipated uses:

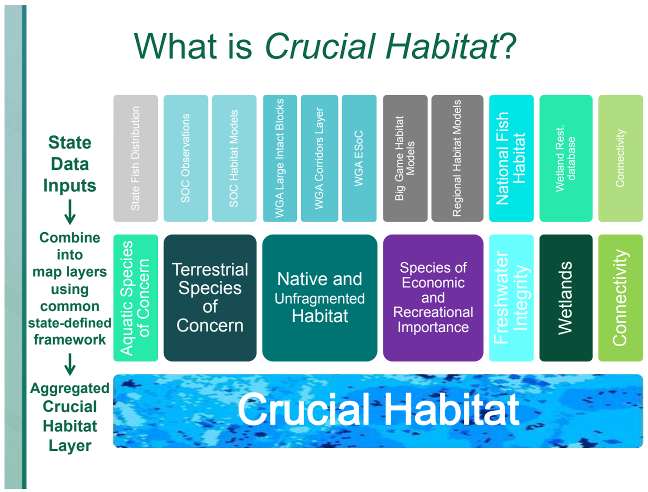
- The Cascadia Partner Forum will use the CPA as a resource for partners share and visualize geospatial data.
- The USFWS Willamette Valley Conservation Study Area is using the CPA as a way to review datasets and provide comments on modeling efforts.
- The CPA will include an interactive climate change assessment tool for protected areas that will allow users to click on a protected area and explore how climate change might affect the area based upon geospatial climate change data.

OUR TAKE

The Conservation Planning Atlas is a big step toward achieving the vision of integration of information on natural resources, conservation, and climate change among agencies and organizations throughout the North Pacific landscape.

Description

Created by state wildlife agencies across the West, the Western Governors' Crucial Habitat Assessment Tool (CHAT) is a non-regulatory online system of maps that displays "crucial habitat." Crucial habitat was defined using a common framework and a suite of priority datasets. Each state had the flexibility to choose what data to include in their compilation of crucial habitat data while still staying within the common definitions set by the Wildlife Council. The states then stitched together their maps into an interactive mapping tool.

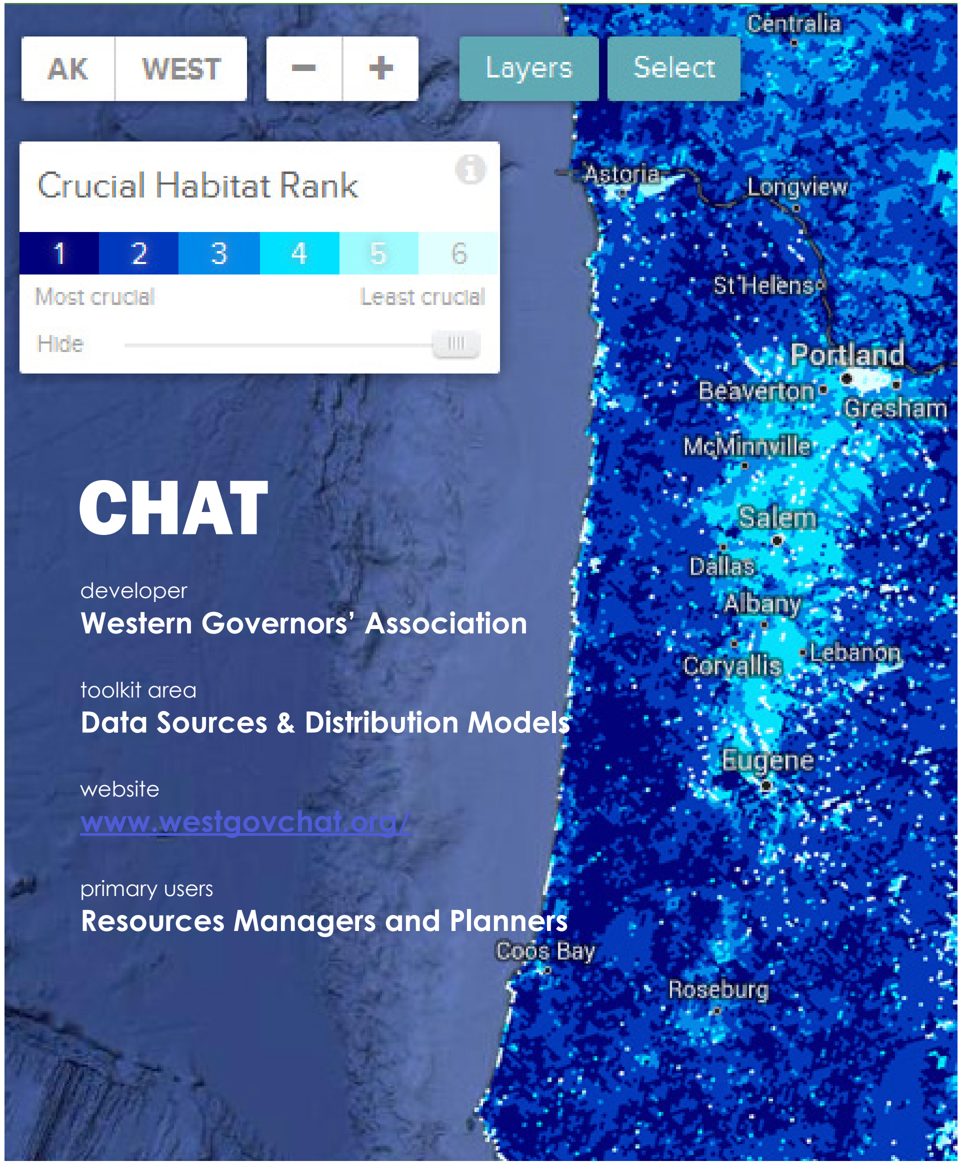


The CHAT is the product of a coordinated effort among state agencies working under the guidance of the Western Governors' Wildlife Council to define crucial fish and wildlife habitat more consistently across state lines. It is especially useful for understanding priorities at inter-state and regional scales. Its coarse resolution (the finest scale is 1 to 5,000) will not meet site-specific planning needs, but its level of coverage and consistency make it appropriate for the early stages of planning, landscape-level analyses, and any efforts to identify important areas for conservation on a regional scale.

Individual state CHATs, as well as the West-wide roll-up, are available. Most geospatial data are available for download or can be obtained via web services.

OUR TAKE

The Western Governors' Association CHAT allows users to quickly understand, on a broad conceptual and spatial scale, where the most and least important areas for species and habitats are likely to be throughout the West.



Examples of use

- Mapping sites for renewable energy development in Arizona
- Building wildlife crossings along a highway in southern Utah

MAXENT

developer
Steven Phillips, Miroslav Dudik, Robert Schapire, and Robert P. Anderson

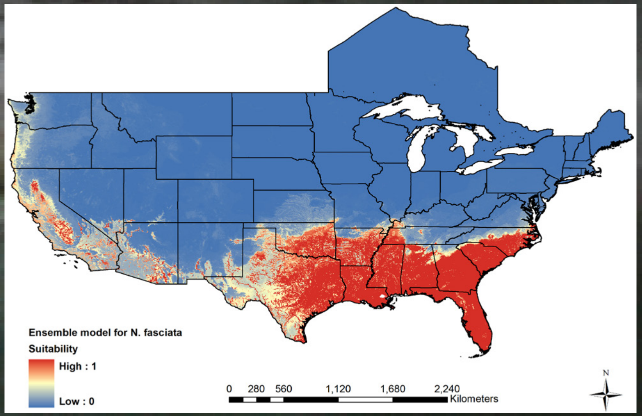
toolkit area
Data Sources & Distribution Models

website
www.cs.princeton.edu/~schapire/maxent/

primary users
Technical/Science Experts

Description

Maxent is a widely popular software package for modeling species distributions. Its users input georeferenced presence locations as well as environmental layers such as temperature, precipitation, and elevation across an area of interest to produce a model of the range of the species. The software is free for research and educational activities and the website offers background papers on the Maxent approach, a tutorial, and a discussion group.



Maxent and two other algorithms' output were combined to create this model of the risk of a species of watersnake (*Nerodia fasciata*) native to the eastern United States, invading into the West. Note the areas of high habitat suitability predicted along the coast of California and Oregon.

Examples of use

• [Estimating the distribution of rare plant species]() in the National Petroleum Reserve, Alaska—a remote area with little existing data and a high potential for land-use conflict

• [Examining terrestrial and]() aquatic invasive species response to climate change in Alaska

• Identifying regions suitable for coral reef growth...

...[under climate change scenarios to inform transplant decisions]()

... and [in deep seas off the U.S. West Coast to identify habitat protected in bottom trawl closure areas and unprotected outside those areas]()

• Developing a [model-based design]() for sampling and monitoring rare plants in Alberta

• Estimating [wildfire probabilities]() at high resolutions in the western U.S.

OUR TAKE

The diversity evident in even this short list of "Examples of Use" says it all: Maxent is the most widely used method of species distribution (or ecological niche) modeling. A growing body of literature over the past eight years has criticized Maxent, as well as clarified and vigorously defended it, and overall has contributed to our understanding of how to make good Maxent models. Methodological issues remain an active area of research.

Description

InVEST is a family of tools that map and model ecosystem services and their variation under different management and climate scenarios. It enables decision-makers to assess tradeoffs among management choices and identify areas where investment in natural capital can enhance human well-being and biodiversity conservation. It can be applied in terrestrial, freshwater, and marine ecosystems worldwide at various spatial scales.

InVEST models are based on production functions that define how an ecosystem's structure and function affect the flows and values of environmental services. Outputs include a variety of metrics, including biophysical (e.g., area of property protected by coastal habitats from erosion and flooding), economic (e.g., value of property protected by coastal habitats), and social (e.g., number and demographic of people protected). These metrics resonate with diverse stakeholders and can be tailored to inform climate adaptation planning.

Tofino, Vancouver Island, British Columbia, once a timber and fishing town, now a fast-growing tourist center where residents have strong opinions about the rapid pace of development.

Examples of use

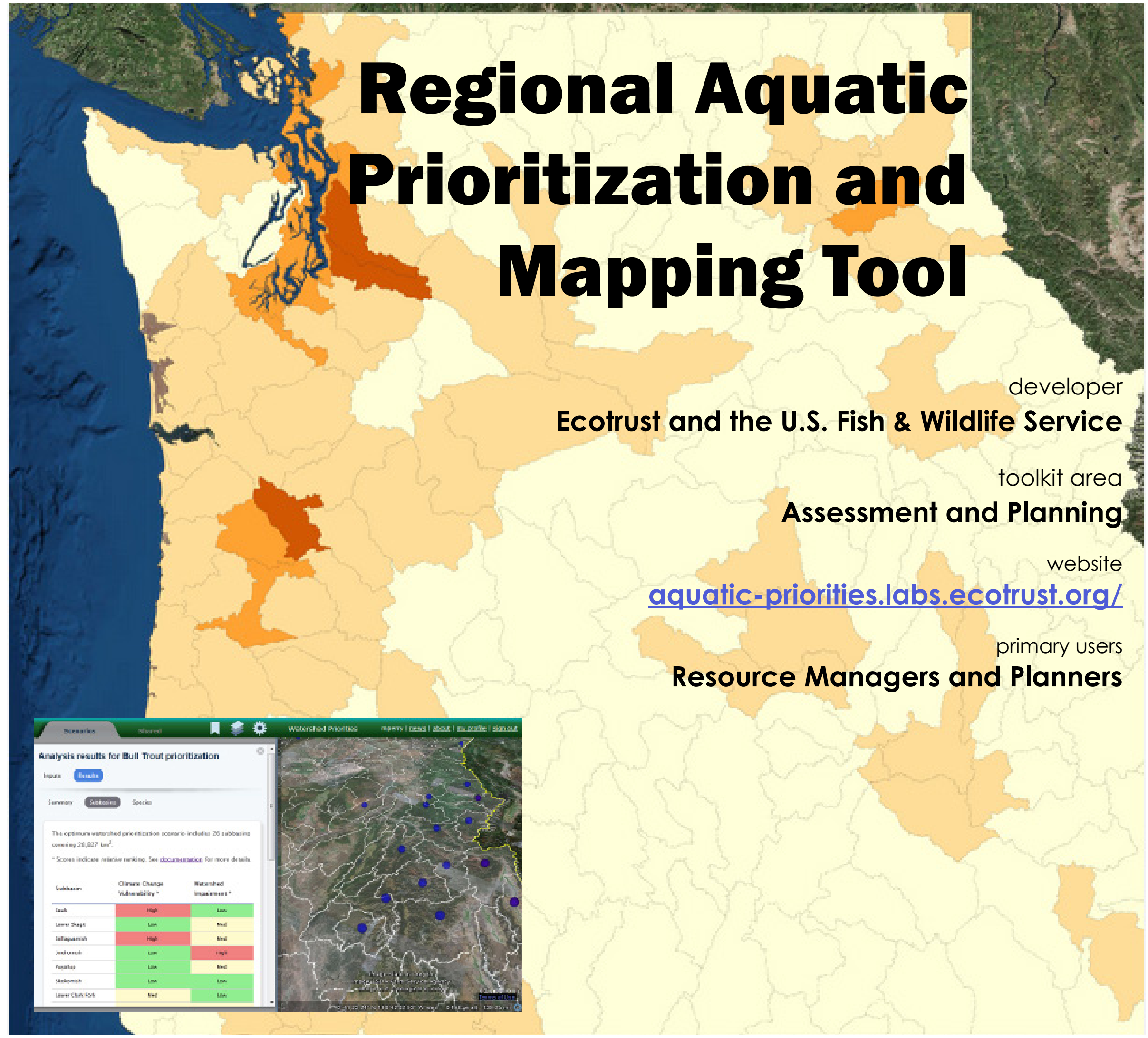
- Mapping and analyzing environmental services across realistic zoning scenarios on the west coast of Vancouver Island, British Columbia so that government, local communities, First Nations, and business interests can compare the tradeoffs involved

- Expanding coastal climate change adaptation plans throughout California to take into account "natural capital" and the effects of coastal adaptation strategies on ecosystem services

- Mapping ecosystem services and values and managing the balance between military training activities and safeguarding natural resources in the diverse ecosystems found on three military bases in Washington, Virginia, and Georgia

OUR TAKE

Ecosystems provide many key services to humans such as food production, air and water purification, and recreational opportunities. InVEST is a set of models that help map and value ecosystem services so they can be included in decision making processes. It also allows planners to assess tradeoffs associated with alternative management options.



Regional Aquatic Prioritization and Mapping Tool

developer
Ecotrust and the U.S. Fish & Wildlife Service

toolkit area
Assessment and Planning

website
aquatic-priorities.labs.ecotrust.org/

primary users
Resource Managers and Planners

Description

The Regional Aquatic Prioritization and Mapping Tool combines GIS datasets, a Marxan decision-support model, and a user-friendly interface to help managers in Oregon, Washington, and Idaho prioritize watersheds in terms of the conservation and restoration of freshwater habitats to support fisheries resources. Data are included on widespread fish species, such as salmon and steelhead trout, and on rare or locally restricted species. Users can evaluate a wide array of watershed priorities depending on which fish species are of concern, and can also take into consideration three parameters for setting regional priorities: climate change vulnerability, the presence of aquatic invasive species, and watershed condition.

The tool was created using Spatial Prioritization and Data Visualization Framework, a web-based system built on Madrona that allows for rapid deployment of custom decision-support applications for a wide variety of prioritization efforts. The underlying framework has also been used to support two other tools in our Matrix: the BLM Aquatic Priorities Tool and the Oregon Juniper Management Tool.

In addition, a general-purpose version of the framework was also developed for the NPLCC to help visualize the various data available at different scales with the region (see http://nplcc.labs.ecotrust.org/news/about/). The codebase for each of these tools is freely available.

Examples of use

• USFWS uses the Regional Aquatic Prioritization and Mapping Tool to prioritize sub-basins to focus conservation and restoration of freshwater habitats, thus ensuring the long-term sustainability of the region's aquatic and fisheries resources. Priority sub-basins can be seen online at http://aquatic-priorities.labs.ecotrust.org/

• In addition to the tools mentioned above, the underlying Spatial Prioritization and Data Visualization Framework is being adapted for use in identifying priority areas for expansion of the National Refuge System administered by USFWS. Contact Mike Mertens for more information: mike@ecotrust.org.

OUR TAKE

The Regional Aquatic Prioritization and Mapping Tool is built on a flexible framework that can be adapted for many purposes.

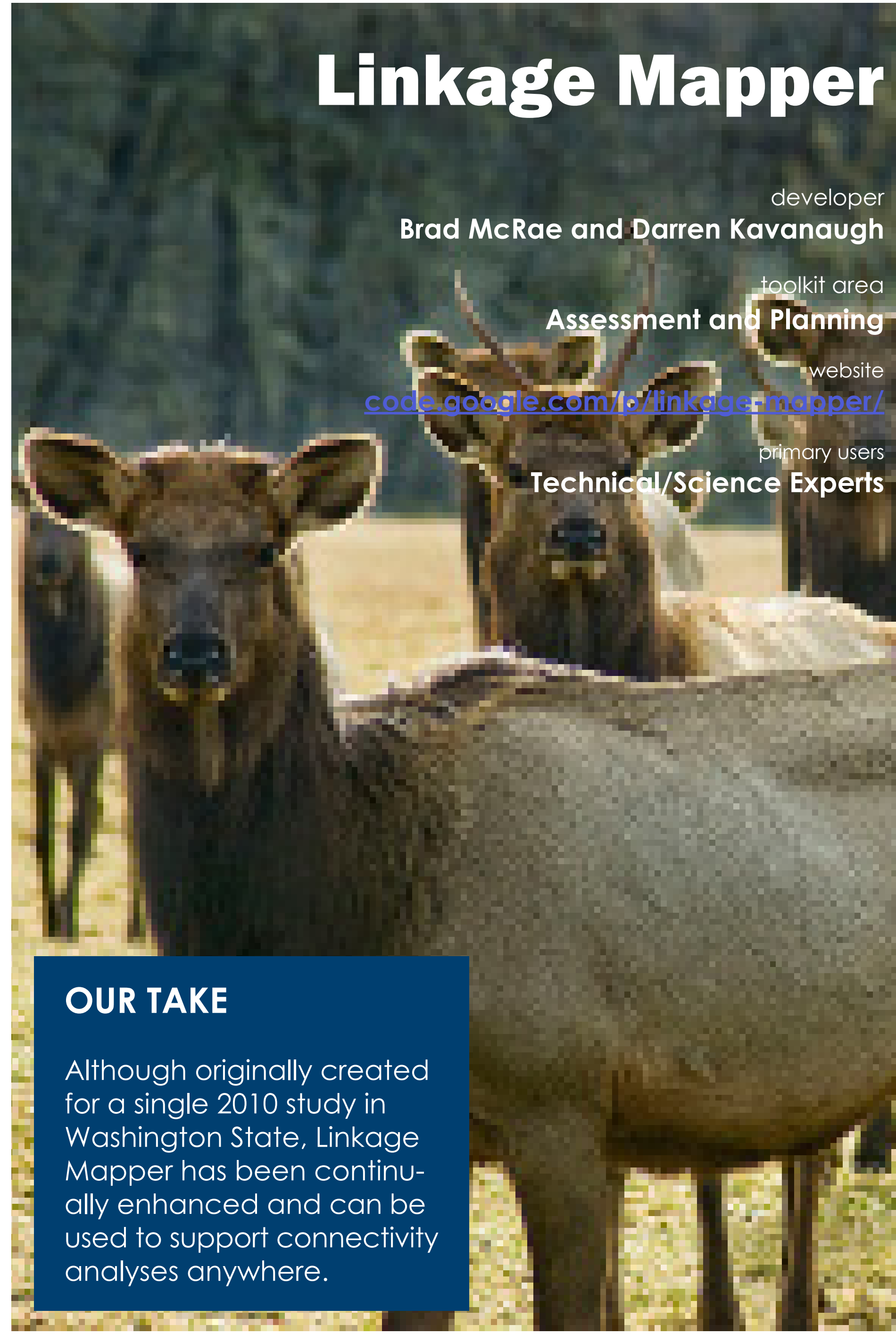
Linkage Mapper

developer
Brad McRae and Darren Kavanaugh

toolkit area
Assessment and Planning

website
code.google.com/p/linkage-mapper/

primary users
Technical/Science Experts



Description

Linkage Mapper automates wildlife habitat corridor mapping using maps of core habitat areas and resistance values. Resistance values are determined by species-specific landscape models as well as by landscape characteristics such as vegetation, land use, and roads. (Both core area and resistance layers can be created using separate tools such as Gnarly Landscape Utilities.) The tool creates maps of “least-cost” corridors between nearby core habitat areas and then produces a single composite corridor map showing the relative value of individual map grid cells in providing connectivity between core areas. The user then has the option to explore vulnerability, restoration opportunities, and corridor importance by mapping pinch points, barriers, and corridor centrality using additional tools in the Linkage Mapper toolkit. Climate Linkage Mapper, for example, identifies corridors that could facilitate species range shifts. It does so by mapping corridors that follow the gentlest climatic gradients between core areas differing in temperature.

Linkage Mapper is a series of Python scripts, packaged as an ArcGIS toolbox. It is in ongoing development, with new modules and enhancements released periodically and an active User Group.

Examples of use

- Assessing wildlife habitat connectivity statewide in Washington
- Identifying opportunities for connectivity restoration
- Assessing barriers, pinchpoints, and corridor centrality in the Columbia Plateau Ecoregion
- Assessing climate connectivity for Washington State and in the Columbia Plateau Ecoregion
- Metapopulation connectivity for Mexican Wolf recovery
- Understanding connectivity and barriers (“landscape permeability”) for mammals along the Romanian/Serbian border
- Identifying Carbon stock corridors to mitigate climate change and promote biodiversity in the tropics

OUR TAKE

Although originally created for a single 2010 study in Washington State, Linkage Mapper has been continually enhanced and can be used to support connectivity analyses anywhere.

Description

The Climate Change Vulnerability Index (CCVI) assesses the relative vulnerability of plant and animal species to the effects of climate change using readily available information about climate projections and species' natural history, distributions and landscape circumstances. This Index helps group taxa by their relative risk to climate change and helps users identify adaptation options that could benefit multiple species. It uses a scoring system that integrates a species' predicted exposure to climate change within an assessment area and three sets of factors associated with climate change sensitivity, each supported by published studies: 1) indirect exposure to climate change, 2) species-specific factors relating to sensitivity and adaptive capacity, and 3) documented response to climate change.

The Habitat Climate Change Vulnerability Index (HCCVI) is a framework for a series of measurements that determine how vulnerable a given community or habitat type might be to climate change over a 50-year span. Similar to the CCVI, the HCCVI measures are organized within categories of exposure, sensitivity, and adaptive capacity.

Examples of use

- Assessing 46 focal species in the Willamette Valley, Oregon
- Assessing wetland species of West Eugene, Oregon
- Assessing more than 150 rare plants of California
- Assessing federally Endangered, Threatened, and Candidate, and Forest Service/BLM Sensitive plants in Washington State. Contact: John Gamon, Program Manager, Washington Natural Heritage Program, at john.gamon@dnr.wa.gov
- Piloting the HCCVI in the Mojave and Sonoran Deserts: report and appendix

CCVI and HCCVI

developer
NatureServe

toolkit area
Assessment and Planning

websites
CCVI and HCCVI

primary users
Technical/Science Experts

Washington Natural Heritage Program and U.S. Fish and Wildlife Service volunteers monitor *Eriogonum codium*, one of the plants assessed by John Gamon's team. It is only known from a single basalt ridge above the Columbia River. Nonetheless, its CCVI score is Not Vulnerable / Presumed Stable.

OUR TAKE

These vulnerability indices provide a platform to assess the relative susceptibility of species and natural communities. They draw upon local experts to derive assessments that are locally and regionally relevant.

NetMap

developer
TerrainWorks

toolkit area
Ecosystem Process Models

website
www.terrainworks.com/get-tools

primary users
Technical/Science Experts

The sediment-laden Mad River enters the Pacific in Humboldt County, California.

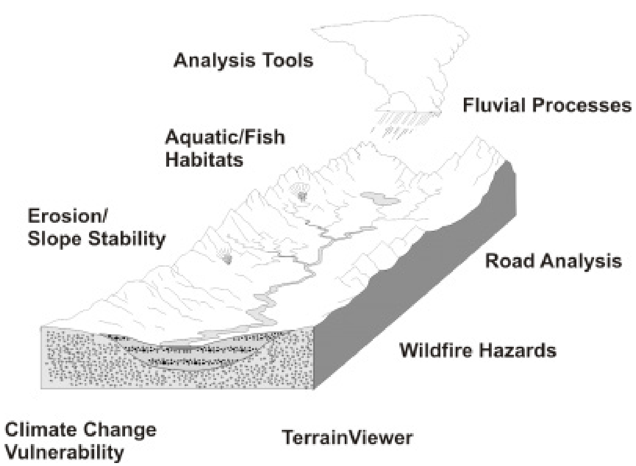
Description

The NetMap analyses tools allow you to conduct your own assessments using TerrainWorks' "Digital Landscape"— a numerical platform for characterizing watershed environments and processes and human interactions with those environments. The spatial scale of the Digital Landscapes is customizable from parcels and individual stream reaches to entire states. NetMap contains about 80 tools packaged as ArcMap add-ins. Tool modules include analysis tools, fluvial processes, aquatic habitats, erosion, transportation, and vegetation/fire/climate. NetMap can address a wide variety of questions in resource management, risk assessment, conservation, and planning.

Examples of use

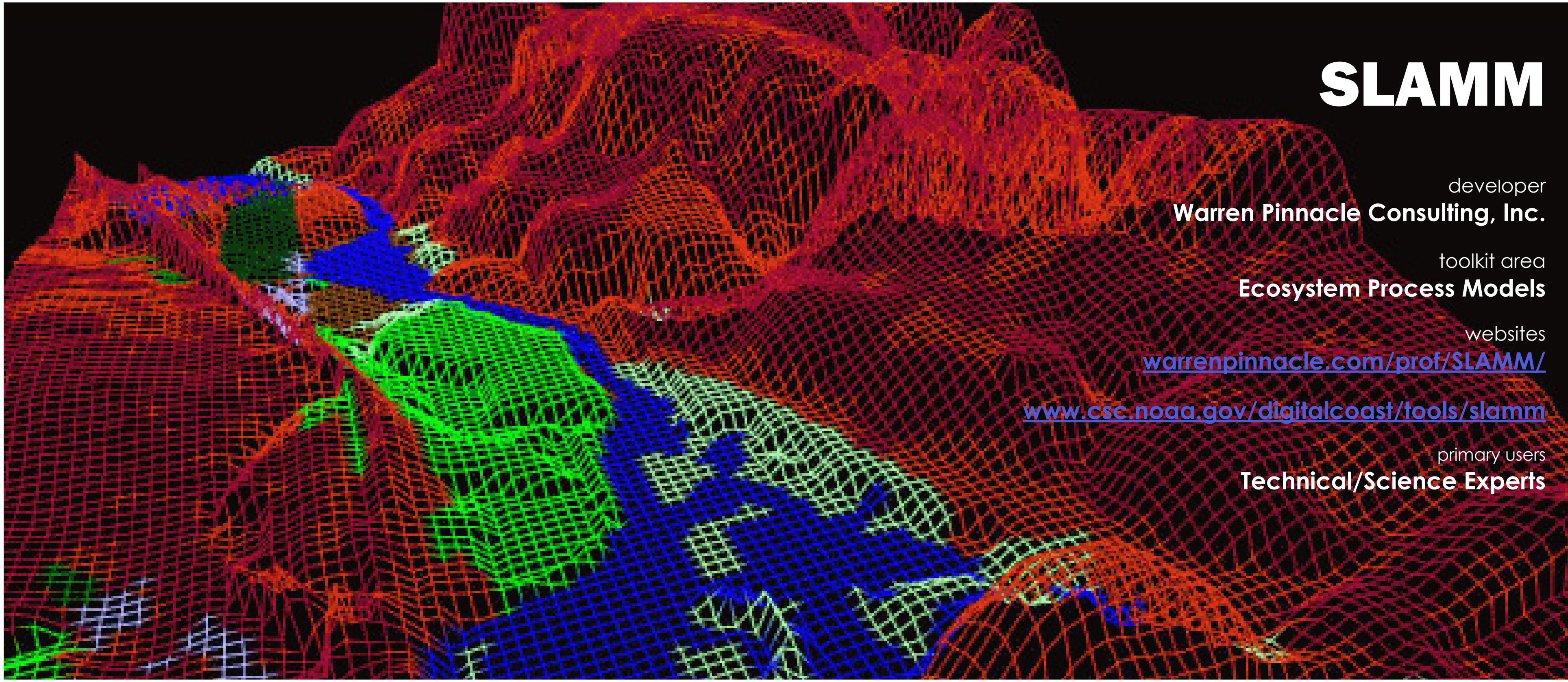
- Designing site-specific riparian management and timber harvests, and analyzing roads in the 17 national forests in U.S. Forest Service Region 6 (WA and OR)
- Contributing to a basin-wide sediment budget for the Mad River in northern California
- Creating intrinsic potential models for salmonid fish on the outer Washington Coast: report 1 and report 2
- Demonstrating how predicted wildfire intensity impacts erosion and delivery of fine sediment into streams and, in turn, how these impact fisheries in the Wenatchee watershed, Washington

NetMap Tools Modules



OUR TAKE

NetMap is a "community based" tool set, meaning that all the tools are available to all TerrainWorks subscribers (customization is an additional cost). Use of the common numerical and programming structure referred to as the "Digital Landscape" allows tools that are built for one area to be used in another. The use of uniform tools can serve to increase communication and collaboration among agencies and stakeholders.



SLAMM

developer
Warren Pinnacle Consulting, Inc.

toolkit area
Ecosystem Process Models

websites
warrenpinnacle.com/prof/SLAMM/

www.csc.noaa.gov/digitalcoast/tools/slamm

primary users
Technical/Science Experts

Description

SLAMM simulates wetland conversion and shoreline modification resulting from long-term sea level rise. It identifies potential changes in both extent and composition of wetland types, and accounts for inundation, subsidence, soil saturation, erosion, accretion, and barrier island overwash. The model uses a complex decision tree incorporating geometric and qualitative relationships to represent wetland changes and provides numerical and map-based output.

SLAMM also integrates a stochastic uncertainty analysis module to provide best/worst case scenarios. It also generates likelihood and confidence statistics accounting for uncertainty in future sea level rise, future erosion rates, and feedbacks between marsh vertical-accretion rates and sea level rise.

Examples of use

- Modelling Pacific Northwest sea-level rise (data are available via another featured tool, the NPLCC Conservation Planning Atlas)

- Incorporating uncertainty into studies of how to provide nature a "right-of-way" as sea level rises along the Lower Columbia River Estuary, Willapa Bay, and North Puget Sound: Study 1 and Study 2

- Assessing the vulnerability of Alaska's coastal habitats to accelerating sea level rise using Cook Inlet as a case study

- Supporting land acquisition and planning for more than 100 U.S. National Wildlife Refuges

OUR TAKE

SLAMM assesses the changes to both the extent and composition of wetland types due to long-term sea level rise—changes from inundation, erosion, overwash, saturation, and accretion.

MC1 + STM

developers
MC1 USDA Forest Service, PNW
VDDT ESSA
ST-Sim ApexRMS

toolkit area
Ecosystem Process Models

primary users
Technical/Science Experts

websites
MC1 www.fsl.orst.edu/dgvm/

VDDT essa.com/

ST-Sim www.apexrms.com/

Linking Project
www.fs.fed.us/wwetac/projects/kerns4.html

and

http://databasin.org/groups/64b28a3d1e584374ac0541802eb733be

Description

The Vegetation Dynamics Development Tool (VDDT) and ST-Sim both allow users to examine how various disturbances (e.g., wildfire, insect outbreaks) and management actions could lead to changes in vegetation structure and composition across a landscape over time. VDDT is Windows-based, relatively user-friendly, and has been used extensively. However, neither of these state-and-transition models incorporate climate change.[i]

MC1 is a dynamic global vegetation model that predicts climate change impacts on vegetation and fire regimes and the associated cycling of nutrients between plants and the soil.

One current effort is to link results from MC1 to existing state-and-transition models, thus making VDDT and ST-Sim models "climate smart" for resource managers.

[i] Most vegetation models that do incorporate climate change are of limited use to land managers because they require high levels of expertise to run and produce outputs that are too coarse spatially to be easily related to most management units.

Examples of use

• Modifying the existing vegetation models for the Deschutes-Freemont-Winema National Forest in eastern Oregon using MC1 simulation results (simulated for 2071-2100 at 800 m resolution)

The linked-model approach is relatively new; see the following for a full description:

Halofsky, J.S., Halofsky, J.E., Burscu, T., and M.A. Hemstrom. 2014. Dry forest resilience varies under simulated climate-management scenarios in a central Oregon, USA landscape. Ecological Applications. In press.

Halofsky, J.E., Hemstrom, M.A., Conklin, D., Halofsky, J.S., Kerns, R., and D. Bachelet. 2013. Assessing potential climate change effects on vegetation using a linked model approach. Ecological Modeling. 266: 131-143

OUR TAKE

Changes in climate can affect plant growth, alter the risk and severity of wildfires, and cause shifts in vegetation. Thus, climate-informed state-and-transition models will improve our understanding of how vegetation is likely to change under varying land management decisions.

NatureServe Vista®

developer
NatureServe

toolkit area
Core Assessment and Planning Decision Support System

website
www.natureserve.org/conservation-tools/natureserve-vista

primary users
Resource Managers and Planners

Description

NatureServe Vista is a spatial decision-support system built as an extension to ArcGIS. It is primarily designed for conducting cumulative effects assessment, mitigation planning, and conservation planning.
It can help integrate conservation with other planning objectives such as land use, transportation, energy, and natural resources management. It enables users to create, analyze, implement, and monitor land use and resource management scenarios that achieve conservation goals.

Assessments and planning can be conducted throughout a region or individual sites and Vista is specifically designed to support ongoing dynamic assessment, planning, and adaptive management

Vista can integrate considerations of climate change in several ways: 1) climate change effects can be integrated into scenarios to understand how they affect conservation elements; 2) the influence of development activities on future potential distributions/refugia of conservation elements can be assessed; and 3) climate adaptation scenarios can be created and used to evaluate management actions. Readily interoperable with a variety of other tools, Vista combines with Marxan to support development of optimized conservation solutions and with N-SPECT (or other hydrologic models) to support integrated land-water-sea assessment and planning.

Examples of use

- Conducting integrated land-sea planning and evaluating the effects of sea level rise

- Refuge Vulnerability Assessment and Alternatives approach and guides

- Used in a toolkit to evaluate the effects of climate change and invasive species southern Oregon/northern Nevada

- Assessing impacts of and potential adaptation and mitigation actions for climate change effects and potential renewable energy development on ecosystems and species in the Central and Mojave Basin

OUR TAKE

NatureServe Vista helps integrate conservation with other land uses, as well as with transportation, energy, and natural resources assessment. Vista uses a spatial-ly- explicit cumulative impacts approach to help users identify the potential effects of climate change on ecosystems and develop and assess alternative management scenarios.

Case study: InVEST

Valuation of Ecosystem Services to Inform Planning on Joint Base Lewis-McChord in western Washington

Starting a prescribed burn to control Scotch broom on Joint Base Lewis-McChord Scotch broom impedes movement (making areas unusable for training activities), increases the fuel load and the chance of catastrophic fire, and chokes out native plant and animal species.

PROJECT LEAD
Shan Ma, economist, Natural Capital Project

PARTNERS
Natural Capital Project, Department of Defense

KEY DATA INPUTS
- Land cover: Joint Base Lewis-McChord
- Training areas and activities: Joint Base Lewis-McChord
- Occupied and potential habitat for candidate species: Joint Base Lewis-McChord
- Stressors for species habitat: partly based on previous consulting with Joint Base Lewis-McChord ecologists conducted by ENVIRON
- Timber harvest and sales records: Joint Base Lewis-McChord
- Aboveground carbon biomass for various vegetation classes: National Biomass and Carbon Dataset and relevant literature
- Natural resource management practices, concerns, and goals: group discussion with Joint Base Lewis-McChord personnel from multiple divisions

PRODUCTS GENERATED
- Summary Report
- Journal articles (in review)
- InVEST online training course offered through Stanford University

CONTACT
Shan Ma,
Natural Capital Project
mashan@stanford.edu

Background

Among the many critically important services that healthy ecosystems can provide, "military training" probably wouldn't be among the first to spring to mind. Yet on Joint Base Lewis-McChord just south of Tacoma, Washington, maintaining the native grasslands and oak savannas of the area also protects an open, ideal landscape suitable for Army and Air Force training activities.

Lewis-McChord's native prairies and savannas are remnants of what used to be a vastly more extensive ecosystem that had formed from a combination of well-drained glacial outwash soils and Native American land management practices that involved the frequent use of fire. The remaining patches of prairie-savanna habitat are now home to several species of conservation concern, including the federally listed butterfly, Taylor's checkerspot.

Compatibility between human land use and maintenance of native ecosystems is important for the Department of Defense (DoD) as it transitions from a compliance-based agency toward one more focused on active stewardship of natural resources. In order to become more proactive (rather than reacting to regulatory requirements), DoD and its partner, the Natural Capital Project, are applying an ecosystem service approach with InVEST to study how they can find the best balance—or greatest synergy—between a high training capacity and maintaining critical habitats and the ecosystem services they provide.

Using the tool

InVEST was used to model and map five ecosystem services on the base:

- Infantry training capacity
- Vehicle training capacity
- Provision of habitat (based on sustainability of the native ecosystem)
- Timber production
- Carbon sequestration

For example, for the infantry and vehicle training capacity services, the team quantified the benefits of having realistic training environments under five scenarios driven by variations in budget and training intensity. The calculations were based on factors such as the suitability and connectivity of land cover (including cover of Scotch broom, a highly invasive, non-native shrub that impedes foot and vehicle traffic), frequency of training activities, and whether there were seasonal or annual restrictions on the use of off-road vehicles. Habitat sustainability was quantified using the InVEST Habitat Risk Assessment model and eight potential habitat stressors—seven stressors related to potentially destructive training activities, and one related to the abundance of Scotch broom in the native vegetation.

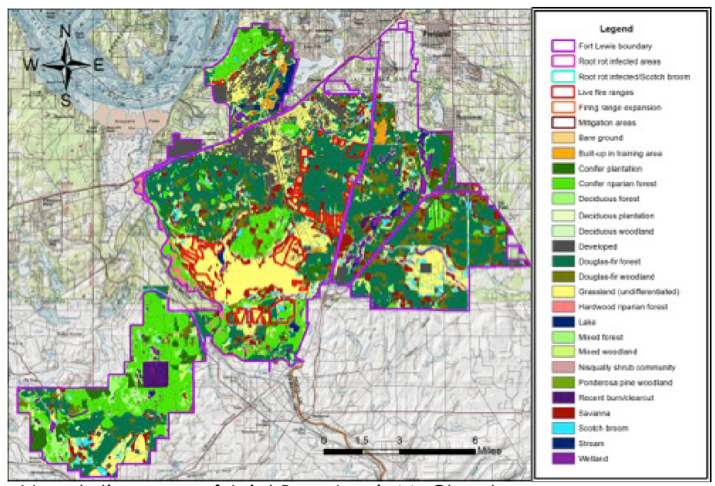
Overall, the approach was a success. It not only proved it was feasible to incorporate ecosystem services into DoD's land use, training, and resource management decisions, but also that the aggregate analysis illustrated potential consequences of training and budgetary variations that could aid installation commanders in justifying requests for modification. In addition, the spatially explicit representations of ecosystem services that were generated could support resource management on the ground. For example, the scenario-based approach showed that a large grassland area on the east side of the base could be providing both more "provision of habitat" and more "training capacity" with an increase in management funds. With its flexibility and adaptability, InVEST can be applied to inform broader decisions for military and other land-based institutions, in assessing environmental impacts, evaluating off-site mitigation options, resolving conflicting land uses within and among agencies, as well as communicating with Congress and the public about ecosystem management objectives.

Lessons learned

- It is important to understand the appropriate use of InVEST. As InVEST is designed to require relatively few data to broaden the range of applicable locations and decision contexts, some simplifying assumptions are made in individual models. It is most useful for comparing tradeoffs of multiple alternatives to guide land use planning and natural resource management. Its outputs are not appropriate to serve as defensible evidence in legal disputes (as the DoD may want). A tradeoff always exists between easiness of modeling process and comprehensiveness of model outcomes.

- The value of ecosystems should be conveyed in measures related to the organization's decision context. Although economic values of ecosystem services are commonly understandable and convenient in supporting decisions, via a cost-benefit analysis for example, non-monetary measures of ecosystem services often play a more vital role in government decision-making. Ecosystem services measured in biophysical units are often adequate or better in aiding land use planning, environmental impact assessment, and resource management prioritization. Calculating economic values from the client's/organization's perspective (e.g., net present value of timber considering the local market price and cost of production) is also important as a reference for decision-makers.

- Successful adaptation of InVEST requires technical capacity within organizations. Creating relevant and realistic scenarios for InVEST can be time-intensive, as is the case for all ecosystem service models. And successful runs of independent models require some site-specific data and GIS expertise at each locale/installation. Because technical capacity and staff time are limited at DoD installations, broader adaptation of the ecosystem service approach and InVEST tools would require additional training of installation personnel or external consultancy.



Vegetation map of Joint Base Lewis-McChord

HELPFUL HINTS

Scenario development is a critical and integrated component of InVEST application. Bringing installation personnel from various divisions (Forestry, Fish and Wildlife, Range Support, and military trainers) helped yield comprehensive and balanced scenarios.

Case study: Linkage Mapper

Promoting the Long-Term Viability of Wildlife Populations by Identifying Priority Habitat 'Linkages' to Conserve and Restore

Background

Providing the connections between functioning ecosystems that allow species to move across a landscape is the most fundamental of all climate change adaptation strategies. The insurance that these "linkages" provide in the face of uncertainty is all the more important where good habitats for wildlife are already fragmented by high levels of development.

The Washington Wildlife Habitat Connectivity Working Group (WHCWG), a collaboration among land and resource management agencies, NGOs, and universities, came together to work on identifying opportunities for conserving habitat linkages throughout Washington State and in the adjacent states of Idaho and Oregon and the province of British Columbia. In the process, they also developed a new tool that automates wildlife habitat corridor mapping: Linkage Mapper. Developing the tool was an enormous upfront investment of time and effort, but—as with building the large number of working relationships required for this project—it was an investment that paid off in the longer term, both for them and for others in the region and beyond.

Using the tool

The team first had to identify important habitat areas for the suite of species they were studying. Once these habitat concentration areas were identified[i], the model was built by assigning species-specific relative resistance values to different landscape features, such as a particular land cover/land use type. In other words for each such landscape feature[ii] and for each species, they estimated the additional resistance to movement imposed by the feature relative to "ideal" habitat: ideal habitat received a "0" resistance value; an absolute barrier to movement received an "infinite" resistance value. The linkage modeling algorithms were then built to create maps of the least-resistance (or least-cost) corridors between two adjacent habitat concentration areas habitat areas and then to produce a single composite corridor map showing the minimum value of all individual normalized corridor layers.

[i] *The Washington Wildlife Habitat Connectivity Working Group (2010) describes how these were identified.*

[ii] *Linkage Mapper can also handle linear landscape features like highways and synthesis information like housing density.*

Lessons learned

• Know Your Base Data…. Including Their Ages

"All spatial data sets, especially those that cover such a broad geographic extent, have errors in them. Acquaint yourself with the base data for areas you are interested in… Comparing the data with other sources of information, such as aerial photography or Google Earth, can give one a good sense of their accuracy at different scales."

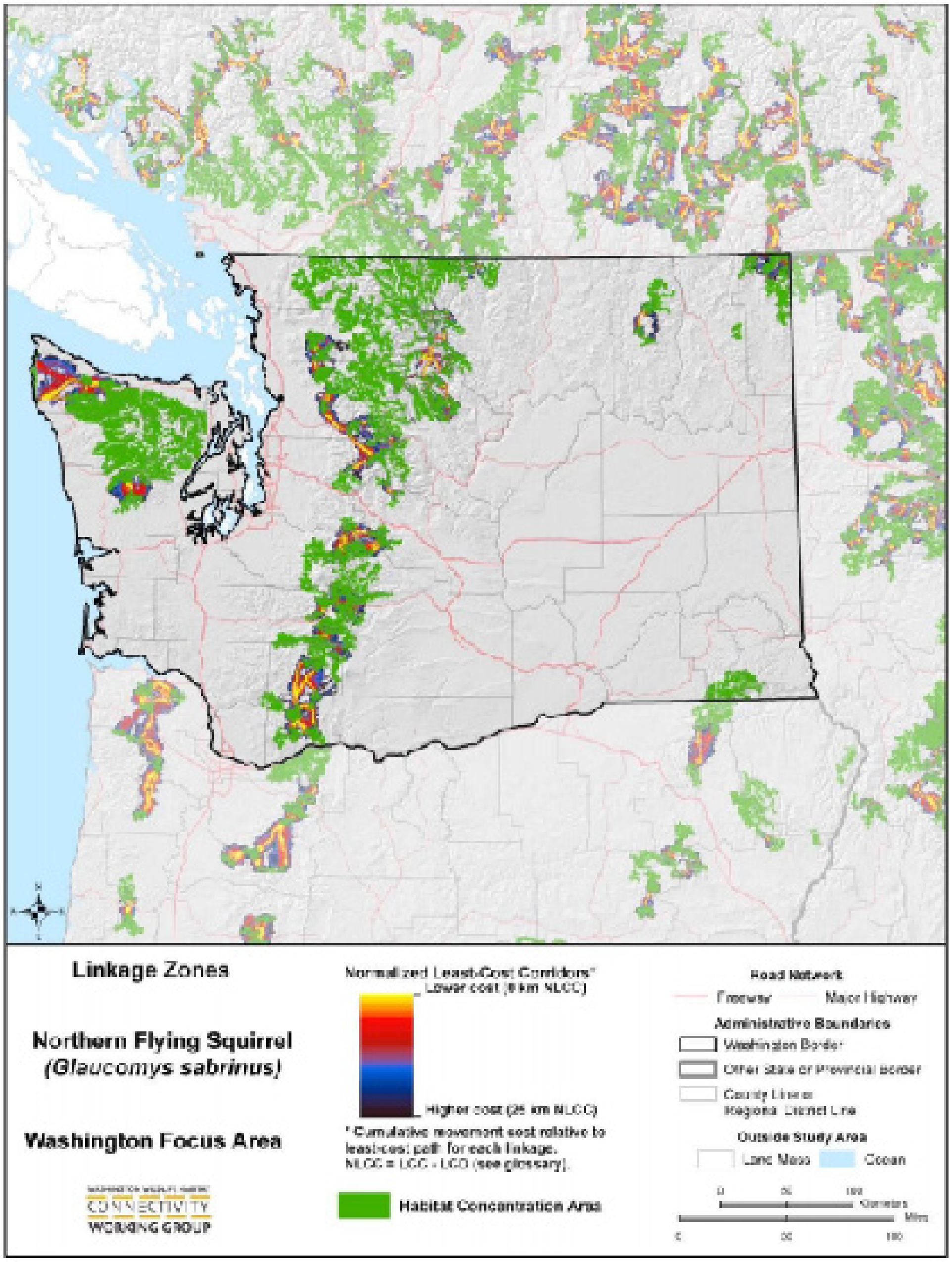
"Our data sources in many cases won't include recent features on the landscape because the data are based on information that can be several years old… For example, GAP and LANDFIRE data are based on satellite imagery acquired between 1999 and 2003. That means if clear-cut logging has created gaps in northern flying squirrel habitat in the last seven years, those gaps won't be reflected in our habitat concentration area maps. Other new features on the landscape, such as wind farms, have also been missed by our models and would need to be considered separately in planning efforts."

• Scale is Always Paramount

"We were surprised by the mapped elk linkage predicted to cross I-90 between Cle Elum and Ellensburg [Washington]. If this was an important movement route, we'd expect higher numbers of elk to be killed on this stretch of road than have been recorded by Washington State Department of Transportation…. A little investigating revealed that an elk fence had been constructed along this segment in the 1970s, presumably because elk were moving through this area and creating hazards for drivers. Features like fences are too detailed to map at statewide scales, but are nonetheless important to consider when developing detailed connectivity conservation plans."

• Have a Plan. Conduct a Pilot. Explicitly Define Your Terms. Calibrate Your Interpretations of Those Definitions. Communicate Redundantly. Be Sure to Communicate Redundantly.

[When conducting any large, collaborative analysis], "we recommend study plan development as a reliable way to save time… The most efficient way to troubleshoot our analysis sequence and overall process was to conduct pilot analyses using a small subset of focal species before initiating the full analysis…. When our best-laid plans proved to be inadequate and needed revision, we sometimes struggled to redirect multiple team members working in parallel on similar tasks. We learned that well-organized decision processes, clearly articulated written guidance, and redundant communication are essential for enabling all team members to respond to inevitable changes in direction. We cannot overstate the importance of clear guidance and explicit definition of key terms as a constructive means for avoiding 'do-overs,' and for minimizing inconsistencies among team members due to differences in interpretation. From our experience, the sooner an explicit and detailed understanding of key terms and concepts can be achieved, the better."



Northern Flying Squirrels are important to the ecology of Pacific Northwest forests. The team assigned riparian and forested areas with >70% canopy cover the lowest resistance values; agriculture, sparsely vegetated, and grass- and shrub-dominated received the highest resistance values for this species.

PROJECT LEAD
Washington Wildlife Habitat
Connectivity Working Group

PARTNERS
U.S. Fish & Wildlife Service; Washington State Department of Fish & Wildlife; The Nature Conservancy; Washington State Department of Natural Resources; Washington State Department of Transportation; Conservation Northwest; Montana State University, U.S. Forest Service; University of Washington

KEY DATA INPUTS
•Land Cover/Land Use: primarily NW GAP for U.S. + Biogeclimatic Subzones/Variant (BCG) + Vegetation Resource Inventory (VRI) + Baseline Thematic Mapping for BC
•Elevation: assembled from USGS 1 arc second, 30 m National Elevation Dataset in U.S. and from 25 m Terrain Resource Information Management layer in BC
•Slope: derived from elevation data
•Housing Density: U.S. Census raster data compiled using EPA methods for U.S. Derived from Statistics Canada for BC
•Roads: drom WA Dept. Natural Resources transportation data and TIGER/Line Roads Census in U.S. From Digital Road Atlas in BC
•Forest Structure: developed from LANDFIRE Existing degetation Cover and Height layers + National Land Cover Database for U.S. Developed from VRI + Earth Observation Sustainable Development + BGC
•Species Distribution Data: various

PRODUCTS GENERATED
•Statewide Analysis Report including maps depicting areas of suitable habitat and the best remaining linkages connecting them
•Modeling methods and GIS tools

REFERENCE
Washington Wildlife Habitat Connectivity Working Group (WHCWG). 2010. Washington Connected Landscapes Project: Statewide Analysis. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA.[iii]

CONTACTS
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Cynthia Wilkerson, Washington Department of Fish and Wildlife
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[iii] A subsequent study by the WHCWG in the Columbia Plateau ecoregion in many ways represented a refinement of tools, including the concepts of network centrality and pinch point and barrier identification, as well as the application of higher resolution data. See: http://waconnected.org/columbia-plateau-ecoregion/ or contact Kelly McAllister, mcallke@wsdot.wa.gov.

Case study: NetMap

Attempting to Identify Stream Reaches with the Best 'Intrinsic Potential' for Salmonid Habitat on the Outer Washington Coast

Background

The basic idea behind intrinsic potential (IP) modeling is that what matters most to fish species are the enduring features of their aquatic habitats such as the underlying geology and the channel gradient. If these persistent features, rather than more transient ones (such as tree canopy cover), largely determine whether or not a particular habitat is suitable, then habitat suitability for most salmon species can be easily mapped from a combination of well-documented habitat preferences and widely-available geomorphic data layers. These "most suitable" areas could then be used to prioritize the limited resources available for salmon habitat restoration.

That's the theory.

Under a contract with the Wild Salmon Center, Keven Bennett and Miranda Wecker of the Olympic Natural Resources Center (ORNC) set out to develop IP models for several species of anadromous fish runs in selected outer coastal rivers of Washington State.

Using the tool

NetMap software is designed to provide a set of standard or default values for the key habitat features used for IP Modeling. These model "settings" are based on supporting scientific publications. In the case of the salmonid species of interest in this project (Chinook, Coho, and Steelhead), the ONRC team chose to use the default values provided by NetMap without modification although local conditions likely differed from the standard (and use by salmonids likely differed from the standard as well). A crucial first step in the application of IP Modeling is the definition of the area within which salmon habitat occurs. ONRC staff carried out the analysis to determine where stream reaches were impassable to salmonids (such as those upstream of large waterfalls) or where the channel width was too small for use (a parameter that addresses seasonal low flow).

Lessons learned

In a second phase of this project, the team convened a workshop to review their work. Here are some things they learned:

• In general, IP models are blunt tools for finding good habitats for species

Reliable, ground-truthed knowledge of stream reaches cannot be replaced with model calculations. Standard parameter settings did not produce results that reflected the known local conditions. Modifications must be made to generate more useful results. However, model runs could be useful as a first step in identifying key stream reaches.

• A major strength of NetMap was that the designers formulated it to use widely available datasets and run on a standard GIS platform

Improvements in the model may someday allow for the production of meaningful guidance on habitat priorities at little cost and with little need for computer programming skills. Such simplicity—if linked with reliable output—would likely assure that public agencies, tribes, and stakeholders would make use of this tool. However, overall the output of the default models used in this first iteration were of "questionable value." In many cases, the most important habitat was not identified by the model. In some cases, habitat with a lesser value was described as important. A clear need emerged to tailor the models to differentiate between spawning and rearing habitat suitability, something not attempted in the first iteration.

• There was wide agreement that models like these may prove useful in helping direct ranking of restoration priorities, but a great deal of refinement would be necessary

It is likely that more meaningful results would be generated if specific models were tailored to specific runs, specific life cycle components (e.g., spawning), and specific geographic subregions of the coastal area (North Coast vs. South Coast).

PROJECT LEADS

Keven Bennett (GIS Programmer Analyst)
Miranda Wecker (Director of Marine Programs)
Richard Osborne (Resource Forum Facilitator)
University of Washington's Olympic Natural Resources Center

PARTNERS

Washington Coast Sustainable Salmon Partnership, Wild Salmon Center, NOAA

KEY DATA INPUTS

•The Standard Netmap Model includes elevation data, stream gradient data, hydrological morphology data, stream width data; channel complexity data, and stream reach data.
•Calculations were executed to evaluate potential habits suitability for each salmon species-specific IP model.
•(Mean annual flow data weres available, but not used as a key parameter)
•Species habitat preferences came from the literature

PRODUCTS GENERATED

•NetMap models for Chinook, Coho, and Steelhead at the HUC8 level within the study area and for Chum for the Bear River Basin
•164 finer scale (HUC12) maps illustrating high, moderate, and low intrinsic potential stream reaches for each of these four species
•A webpage to allow access to map products and facilitate technical review of the project output

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Response to NetMap Case Study

By Dr. Lee Benda
(Sept 2014)

I agree with the findings of the case study, regarding the value of using NetMap's IP modeling interface ("useful as a first step in identifying key stream reaches) and its limitations as identified by the analysts.

It is important to note that the default IP parameter values (as used) represent habitat conditions in the central Oregon Coast Range (Burnett et al. 2008, Clarke et al. 2008), and not those occurring in the outer Washington Coast. Predicting habitat conditions without locally derived IP preference curves could be problematic, as the authors indicate. In other regions where IP models have been applied, local adjustments were made (such as in Southern California [Agrawal et al. 2005] and in Alaska [Bidlack et al. 2014]).

Another aspect of IP modeling is the spatial scale at which it is applied. In general, IP modeling provides a first cut at watershed to landscape scale screening of salmon habitat potential. For example, which valley segments (103 m) or watersheds (102-103 km^2) contain environments (gradient, confinement and flow) that would support more productive habitats? No doubt, expecting accuracy at the reach scale (tens to a couple of hundred meters) is pushing the IP technology beyond where it was meant to go, particularly given that the IP model (as the default in NetMap) does not contain other attributes known to be important for salmon spawning and rearing, including gravel supply, substrate size, large wood, and floodplain off-channels. Importantly, the NetMap IP interface does support the inclusion of other attributes, including those listed in the sentence above; one would need to estimate the preference curves for these within the interface (not done in the Washington Coast). I agree with the analysts that an IP model that distinguishes between spawning and rearing is no doubt a good idea as well.

There are also other ways to improve the outcomes of IP modeling that could be used in areas such as the outer Washington Coast. For example, NetMap is going to be used in NOAA's coho delisting strategy in the Oregon Coast Range. It is acknowledged, even in that landscape, that the IP model in its simplicity does not address other key habitat forming elements. Hence, to define high quality coho habitats in that project using NetMap tools, an iterative approach will be made. First, the default IP model will be run as a screen. Then three other habitat forming elements will be added using NetMap parameters: 1) gravel supply (using NetMap's erosion predictions, converted to sediment yield, as represented in the channel), 2) large wood supply (using NetMap's watershed scale wood model and LEMMA/GNN data), and 3) floodplains (using NetMap's flexible floodplain mapping tool). Thus, locations which have the highest IP can be overlain with locations with adequate gravel supply, wood supply and floodplains (potential for side channel formation). This approach can be used in the context of protection or restoration.

In sum, it should be noted that the IP modeling in the Washington Coast was a minimalist effort, as acknowledged by the authors, and other approaches, as outlined above, could contribute to greater modeling accuracy. No matter which approach is taken in an IP analysis, there is no substitute for field analysis and validation, and location specific calibration.

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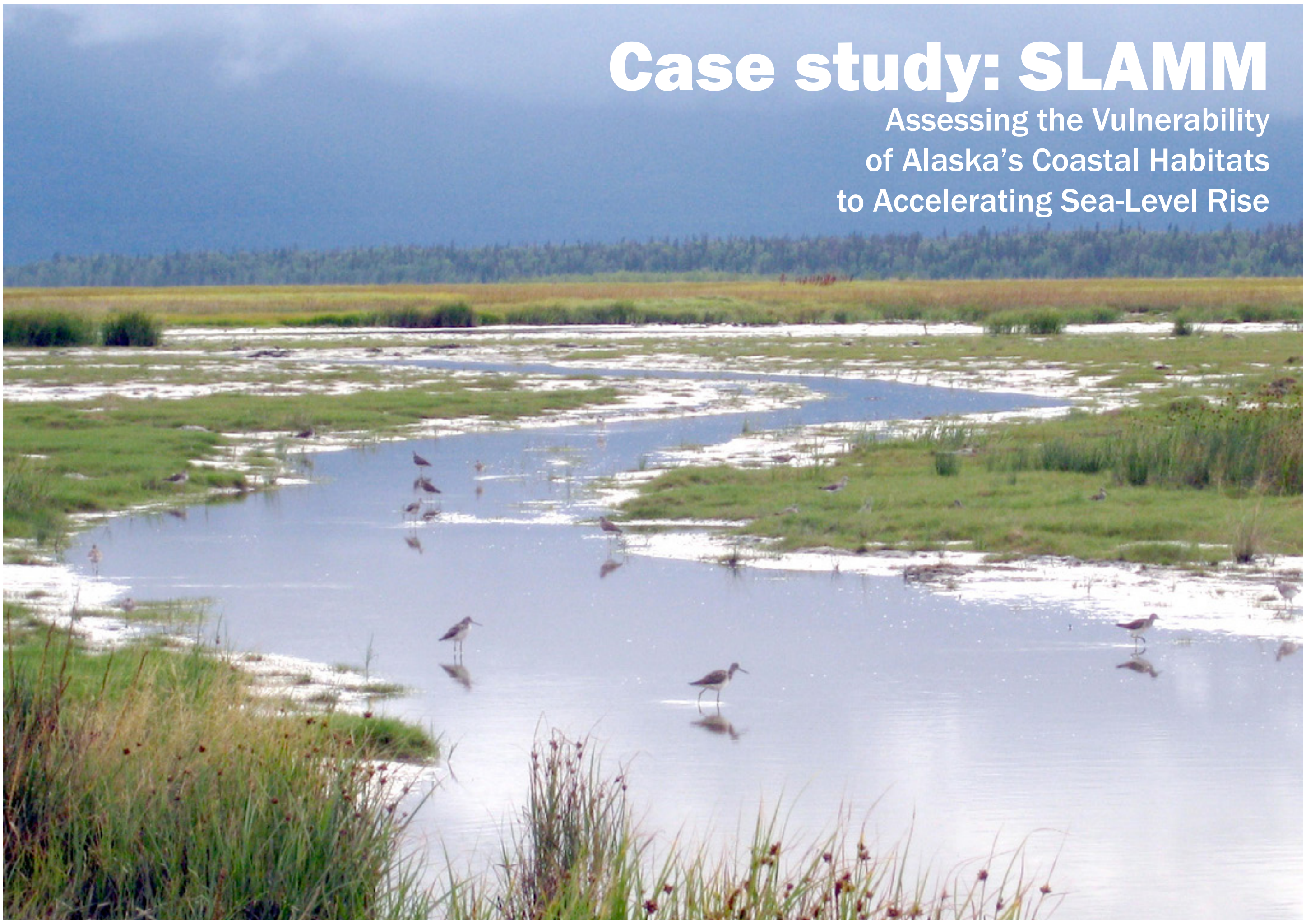

Case study: SLAMM

Assessing the Vulnerability of Alaska's Coastal Habitats to Accelerating Sea-Level Rise

A seaside network of freshwater marshes, sloughs, and ponds comprises the Chickaloon Flats, one of the SLAMM study sites.

Background

This is a case study of a case study. When Patty Glick and her colleagues began to investigate the potential impacts of sea-level rise on the coastal habitats of Cook Inlet, Alaska, they knew that the SLAMM model had never been applied to any of Alaska's shorelines. What's more, they knew that Alaska posed unique and daunting challenges for sea-level rise modeling: significant limitations in data existed, particularly with regard to high resolution elevation data, which are critical for this type of modeling. Regional uplift information and tidal measurements were also lacking or of poor quality. For these reasons, they considered their study a "pilot," useful more for the lessons learned about conducting this kind of modeling in Alaska than for the actual predictions of sea-level rise at the study locations.

Nonetheless, their study was successful, pointing to an unexpectedly low vulnerability of wetland habitats to sea-level rise due to the land uplift and high tidal ranges the region experiences. (Correspondingly, the study points out that sea-level rise studies are needed in low-tidal-range, low-uplift regions of Alaska where wetlands could be significantly more vulnerable.) The "pilot" aspect of this study was also successful in underscoring the need to fill key data gaps and in outlining important lessons learned for the benefit of future researchers.

Using the Tool

It was immediately apparent that SLAMM could not be applied to a large part of Cook Inlet due to severe data limitations (in some areas the best elevation data were based on 100-foot contour intervals and predated the 1964 Alaska earthquake which raised land levels as much as 50 feet). As such, the study areas were limited to four sites in the Kenai region and two in the Anchorage region. In those areas, SLAMM version 6 was run using scenarios for global sea-level rise of 0.40, 1, 1.5, and 2 meters by 2100.

Lessons learned

• Highly dynamic geomorphic responses may not be accurately captured by the SLAMM model

Very rapidly eroding coastal zones or highly spatially variable erosion and sedimentation rates may warrant use of other models or other assessment techniques that are better able to capture dynamic geomorphic responses than SLAMM.

• It is important to ground-truth for localized factors

"Even where adequate input variables for the SLAMM model are available, it is possible that some discrete localized factors (such as the existence of dikes or other infrastructure) are not effectively captured in the land cover data or other relevant data sources. Accordingly, it is important to supplement modeling efforts such as this with expert knowledge of the study regions. For example, within the Anchorage study area, the Potter Marsh input site was estimated as having a reduced tide range (7 meters) due to the effects of culverts on water access. After model results initially suggested saline intrusion, a site visit confirmed that a lower tide range is present at this site due to the railroad embankment between Rabbit and Potter creeks that restricts tides and storm surges."

HELPFUL HINT

"No matter how sophisticated or 'realistic' a model might be, one of the primary factors determining the usefulness of the results is the quality of the data inputs. SLAMM is no exception."

• SLAMM "maximizes" realism

"The SLAMM model... provides a highly accessible tool to assess how rising seas may impact coastal habitats. As with all models, SLAMM is not a crystal ball. It is not intended to forecast what will happen to the region's habitats in the future; rather, it is a tool to offer a picture of possible outcomes under a range of scenarios. To do this, SLAMM integrates potential future scenarios of global sea-level rise with data inputs such as area-specific NOAA tidal data, detailed wetland information from the Fish and Wildlife Service National Wetlands Inventory, regional light-imaging detection and ranging (LiDAR) data, and USGS digital elevation maps to project potential habitat changes. One of the benefits of the SLAMM model is that it integrates multiple processes and datasets in an attempt to maximize realism." In other words, where data are available, SLAMM can provide an accurate projection of impacts by incorporating many factors at relatively fine scales.

PROJECT LEADS

Patty Glick
Senior Global Warming Specialist
National Wildlife Federation

Jonathan Clough
Environmental/Computer Consultant

Brad Nunley
GIS Specialist
Warren Pinnacle Consulting, Inc.

KEY DATA INPUTS

- Elevation: LiDAR ideally but these data are limited in AK
- Vertical Data: NOAA VDATUM is not available in AK so data were derived from NOAA gages (Tidal Datums) or the National Geodetic Survey
- Land Cover: National Wetlands Inventory covers were converted from Cowardin into SLAMM categories
- Land Movement/Uplift: Largely from Dr. J. Freymueller, University of Alaska Fairbanks.
- Accretion: various sources
- Tide Ranges: NOAA gages and/or NOAA tide tables

PRODUCTS GENERATED

- Summary Report
- White Paper on Data Requirements and Data Inventory for the SLAMM Analyses
- SLAMM Analyses of Kenai Peninsula and Anchorage, Alaska

REFERENCE

Glick, P., J. Clough, and B. Nunley. 2010. Assessing the Vulnerability of Alaska's Coastal Habitats to Accelerating Sea-level Rise Using the SLAMM Model: A Case Study for Cook Inlet. The National Wildlife Federation, Reston, VA.

CONTACT

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Final thoughts

The past few years have seen a sea change in the world of tools for resource management. As this guide demonstrates, there is now a large—at times bewilderingly large—number of tools available to support resource management and planning. (We hope this guide has made it a little less bewildering.) Furthermore, as more resource managers have become familiar with geospatial technology, and as tools have become more user-friendly, there has been a large increase in the use of tools at all levels of technical capabilities. This is true for government agencies, non-profit organizations, and the private sector: tools have long since ceased to be under the exclusive control of the technical experts. This is a critically important development because, as resource management becomes more integrated and complex (especially within the context of climate change), it is imperative that planners and managers use tools directly rather than relying on GIS and modeling experts. Broader tool adoption will allow planners and managers to apply sophisticated modeling capabilities to better understand what is and may happen to their resources and develop plans and management actions that combine this understanding with their local knowledge.

However, there will remain challenges to appropriate tool use and understanding of tool limitations. A recurrent theme seen in the case studies presented above is the fact that while this guide is focused on landscape-scale applications, most practitioners are locally focused in their decision-making. They may have difficulty manipulating tools to accurately reflect localized conditions, primarily from a lack of precise data but also from modeling limitations. It is important to distinguish landscape-scale work that focuses on general trends and patterns as a context for local decisions, versus attempting to precisely replicate local observations in models.

As "tools people," we think this explosion of interest in, and use of, tools for resource management is great news. However, this increased interest has also led to increased support for building new, sometimes duplicative tools. Investments in tools would be much better aimed at the refinement and sustainability of a shared toolkit of existing tools that have a proven track record of success.

We recognize that there are many exceptions, but in a number of cases the tool you need—or something quite close to it—may already exist. Investing in customizing or expanding an existing tool will likely be much more cost- and time-effective than building "from scratch"(and keep in mind that many a project has been delayed or even derailed by waiting for that perfect tool to be built). Improving an existing tool may benefit other users of that tool more than would the creation of a totally custom application. Additionally, maintaining tools and keeping them up to date with scientific and technical innovations can be prohibitively expensive. The more that we, as a community of tool-users, can coalesce around improving and supporting a smaller number of well-tested tools, the greater the chance that those tools will be sustained.

Finally, and most importantly, we want to emphasize that you have a great asset available to you in your colleagues; that is, in other tool users. If you don't find an appropriate tool in this guide, we highly recommend speaking with others engaged in similar work. On the other hand, if a tool looks ideal for your work but you don't have the expertise or capacity to use it in-house, contact the tool developer or those who have successfully employed the tool to see if they have suggestions for collaborations or technical assistance. Many tool developers provide support for their tools; in some cases, there may be university students or researchers, or accomplished tool users in agencies or non-governmental organizations that can operate the tool for you. As we found when developing this guide, the NPLCC has a large and growing community of helpful and generous experts with whom to share ideas and approaches. The Ecosystem-Based Management Tools Network (EBM Tools) represents a key resource and access to tool developers and expert users globally at ebmtools.org.

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IMAGE CREDITS

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ABOUT US

The Ecosystem-Based Management Tools Network (EBM Tools Network, www.ebmtools.org), coordinated by NatureServe, is one of the premier sources of information about coastal and marine planning and management tools in the United States and internationally. Coastal and marine planning and management tools help practitioners incorporate scientific and socioeconomic information into decision making. The mission of the Network is to promote healthy coastal and marine ecosystems and communities through the use of tools that help incorporate ecosystem considerations into management.

The Network is more than 5,000 members strong and includes people from federal, state, and local governments and international bodies; universities and research institutes; conservation groups; philanthropic foundations; and independent consultancies and for-profit tool providers. It provides tools-related information through trainings, webinars, live chats, workshops, focused meetings, conference presentation, and symposia, listserves, newsletters, databases, and toolkits.

This guide was funded through a grant from the North Pacific Landscape Conservation Cooperative. It was developed and written by: Patrick Crist, Director of Conservation Planning at NatureServe; Sarah D. Carr, Director of the EBM Tools Network; Kat Maybury, Program Manager at NatureServe; and Jon Hak, GIS Analyst at NatureServe.

ACKNOWLEDGMENTS

We extend our most sincere thanks to the experts who helped us prepare and review our featured tool snapshots and case studies. In particular, we'd like to thank:

Robert P. Anderson, City University of New York
Kevin Andras, TerrainWorks
Dominique Bachelet, Conservation Biology Institute
Lee Benda, TerrainWorks
Keven Bennett, University of Washington's Olympic Natural Resources Center
Carlee Brown, Western Governors' Association
Tosha Comendant, Conservation Biology Institute
Pat Comer, NatureServe
John Gamon, Washington Natural Heritage Program
Patty Glick, National Wildlife Federation
Sonia A. Hall, SAH Ecologia, LLC
Josh Halofsky, Conservation Biology Institute
Suzanne Langridge, The Natural Capital Project, Stanford University
Shan Ma, The Natural Capital Project, Stanford University
Kelly McAllister, Washington State Department of Transportation
Chris McKinnon, Western Governors' Association
Brad McRae, The Nature Conservancy
Mike Mertens, EcoTrust
Tom Miewald, North Pacific LCC
James Ogsbury, Western Governors' Association
Steven Phillips
Marco Propato, Warren Pinnacle Consulting
Holly Propst, Western Governors' Association
Joe Rassenfoss, WesternGovernors' Association
Robert Schapire, Princeton University
Miranda Wecker, University of Washington's Olympic Natural Resources Center
Cynthia Wilkerson, Washington Department of Fish and Wildlife
Bruce Young, NatureServe

We would also like to sincerely thank the planning and tool experts who provided additional research, as well as insightful and helpful guidance to us as we prepared this guide. In particular, we would like to thank:
Douglas Burn, U.S. Fish and Wildlife Service
Michael Cox, U.S. Environmental Protection Agency
Jill Hardiman, U.S. Geological Survey
Jessica Hitt, EcoAdapt
Jennie Hoffman, Adaptation/Insight
Meghan Kearney, U.S. Fish and Wildlife Service
Mary Mahaffy, U.S. Fish and Wildlife Service
Brad McRae, The Nature Conservancy
Tom Miewald, North Pacific LCC
Sara Vickerman, Defenders of Wildlife

And to all of the participants in the various tool surveys and discussions that provided direction to this guide.

OTHER USEFUL RESOURCES

Alaska Science Catalog	
AOOS Data Portal	The Alaska Ocean Observing System
AquaScape Fish Distribution	
ARIES	ARtificial Intelligence for Ecosystem Services (ARIES) is a suite of applications focused on ecosystems services assessment and valuation in decision-making. Users can quantify environmental assets and the factors influencing their values for specific geographic areas and based on user needs and priorities. For example, ARIES can model flows of sediment, nutrients, and freshwater from land to nearshore ecosystems, allowing it to model change in provision of marine ecosystem services based on changing land use practices.
Assessing the Vulnerability of Species and Ecosystems to Projected Future Climate Change in the Pacific Northwest	
Audubon Christmas Bird Count	Census of birds
Audubon/TNC Coastal Forests and Mountains Ecoregional Assessment	A conservation assessment and resource synthesis for The Coastal Forests and Mountains Ecoregion in the Tongass National Forest and Southeast Alaska
Avian Knowledge Northwest	Bird distribution, changes in bird habitat, climate change impacts to bird species, regions of high conservation priority for birds. Has a map viewer + static maps and model results for download.
Bayesian Analysis for Spatial Siting (BASS)	Focused on energy siting. A lot of their research is focused on the Cascadia subduction zone but also California, Peru, Chile. Also Sumatra. Currently has West Coast habitat maps, Cascadia tectonic maps, bathymetry, core and radiocarbon data available. Developing a decision support tool "that can be applied to siting of renewable energy devices, but also more broadly applied to spatial siting issues. Siting issues in the context of coastal marine and seafloor mapping require decision support systems (DSSs) that address stakeholder-inclusive, spatial multi-objective decision-making under uncertainty."
BC Marine Conservation Analysis	
BC Species and Ecosystems Explorer	
California Coastal Geoportal (version 1.0)	
Climate WNA	Downscaled climate data.
CLIR-Cross Linked Information Resource	

Coalition of Oregon Land Trusts	
Collaborate.org	"Collaborate.org has data from a variety of sources including GIS data, news and social media feeds, data from sensor networks, weather feeds, AIS feeds as well as many others."
Community Mapping Network	Provides public access to data, maps, and imagery to build capacity within communities to collect and manage information on their resources and promote active stewardship.
Connecting Landscapes	While it is geared toward those that are relatively new to connectivity practice, experienced practitioners may also find value in this site to learn about new methods, tools, and resources or to contribute such information to this site; it is designed to be self-populating by the connectivity community of practice.
DataBC Catalog	
Digital Image Service	For British Columbia.
eBird	Bird ranges and abundance.
Ecological Integrity Assessment	
Ecosystem Commons	Not a tool, but rather a social resource. The Ecosystem Commons is a portal to the ecosystem services world, hosting discussions, showcasing projects, and tracking trends. The Commons is managed by the Institute for Natural Resources in collaboration with A Community on Ecosystem Services or ACES, the National Ecosystem Services Partnership or NESP, and many others. This project is made possible by support from the USDA Forest Service, USDA Office of Environmental Markets, U.S. Environmental Protection Agency, and the U.S. Geological Survey.
Forest Analysis and Inventory	
Forest Carbon Estimation	
Habitat Work Schedule: Tracking Salmon Recovery Throughout Washington State	
HSPF	Hydrological Simulation Program - Fortran
Klamath Bird Observatory Decision Support Tools	Has a list of downloadable publications to help private and public land managers manage their lands for birds and other wildlife.
Landscope America	Identify local conservation priorities, plan projects, inspire conservation activities.
Lower Columbia Estuary Partnership	

MaPP	Marine Planning Partnership for the North Pacific Coast
Marine Debris Database	Data on beach clean-up events and types of trash / fishing gear collected.
Migratory Bird Joint Ventures	Focus is on regional parterships to conserve habitat for birds. Funded by Congress through USFWS. Some links to studies, e.g., "State of the Birds 2013" regarding contributions of private landowners to bird/habitat conservation.
Monitoring Resources	
Monitoring Trends in Burn Severity (MTBS)	Fire histories (recent) as indicators of how climate is affecting the extent and severity of wildfires that affect natural and cultural resources. Has U.S. burn severity and burn perimeters of fires since 1984. Can download both maps and imagery data.
Nearshore Fish Atlas of Alaska	
Netica	Software package for solving problems using Bayesian belief netowrks and influence diagrams.
North American Breed-ing Bird Survey, Results and Analysis 1966 - 2012	Bird population trends, abundance, species richness, distribution, habitat data. Three analytical tools available for estimating population changes for species x time interval, estimating species richness, obtaining/compiling data on individual survey routes. 1966 - 2012
North Cascadia Adaptation Partnership	
NWIFC's Nearshore Data Exchange	
NWIFC's Puget Sound Steelhead Intrinsic Potential Habitat Viewer	
OntheMap	OntheMap is a web based tool devleloped by the US Census to assist in web-based mapping of and reporting of where workers are employed and where they live. It also provides companion reports on age, earnings, industry distributions, race, ethnicity, educational attainment, and sex.
Oregon Coastal Atlas	
Oregon Explorer: Natural Resources Digital Library	
Oregon Marine Map	
Oregon Ocean Information: A Resource for Planning in the Territorial Sea	
Oregon Water Resources Data	

Pacific Climate Impacts Consortium	Has statistically downscaled climate scenarios: Canada-wide climate change scenarios at ca. 10 km resolution for 1950-2100 (max and min temperature and precipitation). Seasonal maps: 1972-present maps showing differences between seasonal averages and actual weather conditions (max & min temperature & precipitation). And a software library: Several packages of software for working with climate data in R that solves problems such as converting from degrees C to K, using dates on the Gregorian calendar, etc.
Pacific Coast Joint Venture	
Partners in Flight: Physiographic Areas Plans	PNW regions are: 93-Southern Pacific Rainforests; 89-Columbia Plateau and some others depending on how far east and south you go; they don't cover much of BC or Yukon. AK is covered in 1 statewide plan. Contains lists of priority bird species of concern for each region and general description of conservation needs.
Partners in Flight Species Assessment Database	Conservation status (population numbers, threat, trend, etc.) for 462 bird species.
Point Blue	
PRISM	PRISM is climate models and summaries from the Northwest Alliance for Computation Science and Engineering. The PRISM Climate Group gathers climate observations from a wide range of monitoring networks, applies sophisticated quality control measures, and develops spatial climate datasets to reveal short- and long-term climate patterns. The resulting datasets incorporate a variety of modeling techniques and are available at multiple spatial/temporal resolutions, covering the period from 1895 to the present. Whenever possible, PRISM offers these datasets to the public, either free of charge or for a fee (depending on dataset size/complexity and funding available for the activity).
Puget Sound Nearshore Ecosystem Recovery Project	
Regional Hydro-Ecologic Simulation System	
ScienceBase Catalog	
Site Productivity	Covers British Columbia.
Southeast Alaska Fish Habitat Partnership	Data sharing and partnership for conservation of fish habitat.
TACA	Nitschke and Innes 2007. A tree and climate assessment tool for modelling ecosystem response to climate change.
TESSA	The Toolkit for Ecosystem Service Site-based Assessment (TESSA) is a how-to guide for local non-specialists, describing various relatively accessible methods for rapidly identifying and quantifying a range of ecosystem services that may be important at a site. It also guides the user in evaluating the magnitude of benefits that people obtain from them currently compared with those expected under alternative land-uses. The toolkit recommends use of existing data where appropriate and places emphasis on enabling users to collect new field data at relatively low cost and effort.
The Aquatic and Riparian Effectiveness Monitoring Program	
The Conservation Registry	Captures and shares conservation project information related to: restoration & management such as species reintroduction; invasive species removal; habitat improvement; land acquisitions and conservation easements; and monitoring, policy, education and research activities tied to a location.
The Natural Resource Projects Inventory	The Natural Resource Projects Inventory for California.

TNC Ecoregional Assessments	The Nature Conservancy Ecoregional Priorities. See the plans here
TNC's Conpro	Database of TNC projects with actions and targets (goals), etc.
Tribal Wildlife Information Management System	
U.S. Fish & Wildlife Service IPaC	1) Enter your project area and type and find out whether any threatened and endangered species, designated critical habitat, or other natural resources of concern may be affected by your proposed project. 2) Interact with maps that summarize the distribution of important biological resources, such as wetlands, refuges, critical habitat, GAP land cover, and more. 3) Get a preliminary or official U.S. Fish and Wildlife species list. 4) In limited U.S. locations, receive a list of conservation measures (i.e., best management practices) designed specifically for particular project activity types.
Washington Geospatial Clearinghouse	
Washington State Coastal Atlas	
Washington State Marine Planner	
Washington State Recreation and Conservation Office PRISM	Project Information System
Watershed Explorer	
West Coast Ocean Data Portal	
Wildlife TRACS	Tracks and reports on the effectiveness of projects conducted under the Wildlife & Sport Fish Restoration Program. There is a public TRACS and a non-public version.