Spatial Landscape Conservation Prioritization for Strategic Growth of the National Wildlife Refuge System in the Pacific Northwest

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Abstract:

The National Wildlife Refuge System is developing policy to guide the strategic growth of the Refuge System. Strategic growth factors are stated as Recovery of Threatened and Endangered Species; Achieving Objectives for North American Waterfowl Management Plans; and Conservation of Migratory Birds of Conservation Concern. Spatial prioritization of these factors provides data on how to make the greatest contribution to conservation in a strategic, efficient, and cost-effective manner. The methodology is based on essential steps in Systematic Conservation Planning. A Marxan analysis was performed to identify areas of conservation priority across the Pacific Northwest. This analysis resulted in maps of priority conservation areas which have been compared to current protected areas, and priorities of our conservation partners. The maps and data focus on modeling spatial priorities in order to provide resources and decision support tools to aid in the planning and design of the Refuge System across the Pacific Northwest. The results show how important goal levels can be in finding different solutions and depending on the cost being modeled, solutions can vary across the landscape. Although the solutions may vary, trends can be seen in the high priority areas providing useful information to decision makers. Moving forward models and analysis should incorporate finer scale data and continue to add better quality data as it is produced. Future efforts should seek to evaluate how these models are used and the best potential uses as these analyses continue to develop.

Introduction:

The need for landscape scale prioritization for conservation has become increasingly apparent, with both species ranges and threats (such as climate change, development, and invasive species) extending beyond the boundaries of protected areas. The National Wildlife Refuge System (NWRS or Refuge System) is the world's largest collection of lands and waters specifically designated and managed for fish and wildlife[1]; however these are self-acknowledged "postage stamps" on the landscape indicating a need to manage these areas within the broader landscape. This puts the Refuge System in a unique place where it can lead the way in large landscape conservation planning and implementation.

The Strategic Growth of the Refuge System and Strategic Habitat Conservation at the National Scale should be based upon Systematic Conservation Planning (SCP)[1], Landscape Conservation Design (LCD)[2], and Return-on-Investment (ROI)[3] principles. Over time, the end results will be a system of protected areas that a) are based upon best available science, b) are complimentary to other partners' protected areas, and c) representative of USFWS and NWRS priorities.

With limited resources, the NWRS needs to maximize its efforts through prioritization. By identifying priority conservation targets with quantifiable goals and costs, prioritization can provide information on how to "make the greatest contribution to conservation in a strategic, efficient, and cost-effective manner[2]."

This project was a pilot project for the assessment approach in Region 1. The project will help us answer the questions:

- Where should we focus ecoregional – scale Landscape Conservation Design first?

- Are there geographic regions within the Pacific Northwest where land protection as a means for conservation should be focused?
- What areas will increase our likelihood of receiving funding for land acquisition?
- How do our conservation goals and targets align with our conservation partners?
- How can this project align with the process to select surrogate species for landscapes and associated landscape delineation within Region 1?

The goals for this project were to:

- Identify other past/current efforts focused on landscape conservation prioritization
- Determine how our current Refuges in the Pacific Northwest align with high priority areas determined by Marxan modeling
- Locate high priority conservation areas that most effectively meet the requirements of the draft NWRS Strategic Growth policy
- Identify areas of overlap with priority areas of our conservation partners
- Identify how results change based upon varying “constraints,” such as landscape integrity, climate change, land value, etc.
- Rank high priority conservation areas for potential land protection
- Re-evaluate how we define study area boundaries
- Integrate with the Region 1 Surrogate Species effort

Geographic Scope:

The Pacific Northwest study area includes Washington, Oregon, Idaho, and Omernik level 3 ecoregions that intersect the boundaries and go beyond these states except in Southeast Idaho. The ecoregions intersecting southeast Idaho are large and extend only a small way into Region 1 so in this area the USFWS Bear River Watershed Conservation Area is included in the study area. The geographic scope can be seen in Figure 1. The intersecting ecoregions are included so the prioritization results are not skewed based on the presence of just a portion of an ecoregion in the analysis. Ecoregions are also considered better for conservation planning than geopolitical boundaries[3] since nature does not confine itself to man-made boundaries.

Figure 1

Methods:

The methodology used in this assessment was based upon essential steps in Systematic Conservation Planning (Margules and Pressey, 2000). This "version 1.0" exercise was predominantly in-house, meaning we did not go through an extensive review of conservation goals and objectives with our external partners. However, this assessment could be used as a basis for developing more-robust partner outreach. This project tests a methodology and evaluates associated datasets for regional NWRS planning.

A Marxan model was developed in order to spatially evaluate areas of opportunity for the growth of the Refuge System. Hexagonal planning units 346.41km^2, similar in size to Breeding Bird Survey grids, were used across the study area. All data were preexisting and prepared using ESRI ArcGIS 10.1 (see Appendix Table 1 for descriptions of datasets used).

Targets for the model were based on the Draft Strategic Growth Policy of the Refuge System with target goals evaluated at 10, 30, 50, and 80 percent. Breeding Bird Survey (BBS) abundance and trend data and GAP species models were used to account for Birds of Conservation Concern and waterfowl species (see Appendix Table 2 for list of species); alternative breeding density data was used for sage grouse. National Wetlands Inventory data on freshwater emergent type wetlands were used to further represent waterfowl species. Element occurrence data for threatened and endangered species in Idaho, Oregon, and Washington and critical habitat data were used to represent threatened and endangered species.

In order to evaluate these targets, different constraints or costs were added to the model. Land value was based on the 2012 US Census of Agriculture land and building value per acre. This is coarse county level data, however, when compared to actual sale prices from recent Refuge System purchases the relative values follow the same trend. Landscape integrity was used in order to target landscapes with a minimum amount of human impact; this dataset was created by NatureServe based on landscape condition. Conservation opportunity as an inverse cost layer was created from a combination of datasets: Western Governors' Association Crucial Habitat (only those with the highest rank), The Nature Conservancy portfolio sites, Salmon Strongholds, and important bird areas. This cost was used to determine areas that met Refuge System targets and are within high priority areas of partner organizations. To represent climate change in a cost layer a Climate Stress Index dataset from the USFS was used. The Climate Change Stress Index is based on the degree of change between the recent history (1950-1999) and projected future (2050-2099) of temperature, precipitation, biomass, and vegetation community type shifts. The Climate Stress Index will provide insight into what areas will have the most or least stable habitat "biomes".

In addition to running scenarios with differing costs and goal levels, scenarios were run with different "lock" statuses. With no locks, any planning unit within the study area could be selected for the solutions. Planning units with over 75% public land were locked out from potential solutions since they would not provide opportunities for the growth of the Refuge System. Planning units containing any part of a Refuge were locked in the final models so they would be present in all solutions. With Refuges locked in, the results show if current Refuges were able to meet the target goals under any given cost, or if Marxan had to accept additional costs to include more planning units in the solution to meet the target goals.

The model finds areas that best meet target goals while avoiding the highest cost areas. For each scenario Marxan performed 20 runs with 10 million iterations and had a boundary length modifier of 1.2 based on calibration efforts (see Appendix Table 3A and 3B). The boundary length modifier allowed for connectivity within the solutions and prevented scattered planning units from being selected which would not be useful in Refuge planning. Multiple scenarios were put through the model in order to get the results (see Appendix Table 4 for final scenario details).

Results

Scenarios were run through Marxan resulting in many model outputs. The results were a series of maps (see maps attached). The resulting maps show how varying costs leads to different solutions. There is no single answer in conservation planning and these models are intended to provide decision support materials for planning as well as lessons for how to model prioritization in the future.

For the four cost scenarios, the solutions were summarized to find the highest priority areas when all the costs were taken into consideration. These maps reveal important trends in the solutions.

No Locks

Scenarios with no locks at 10% goals had varying results. With no costs the Klamath area appears most frequently in solutions due to a high overlap of targets. The land value and landscape integrity results have many highly selected areas throughout the study area. With 30% goals large portions of the study area appear in the results.

Public Lands Locked Out

With public lands locked out at 10% goals, there are smaller solution areas. Hot spots occur in part of the Columbia Plateau and in the Klamath region in all the scenarios, except landscape integrity cost. At 30% goals the Columbia Plateau, Puget Sound and the southern part of the Willamette Valley/northern Klamath Mountains are the most frequently selected areas.

Public Lands Locked Out and Refuges Locked In

With goals at 10% only Refuges and a small number of additional planning units show in the solution, meaning Refuges were able to meet 10% goals for each target, while at 30% goals additional places appear that would be beneficial for the Service to work in, in order to further meet the Draft Strategic Growth Policy goals. Solutions for the Climate Stress Index and for the Conservation Opportunities Inverse cost layers yielded very similar results at all goal levels with high selection frequency in the western half of the Columbia Plateau Ecoregion and the northern parts of the Willamette Valley and Coast Range Ecoregion. The Landscape Integrity 10% goal solution mostly contained planning units with Refuges. When the goal level was increased to 30% the Blue Mountains Ecoregion appeared more frequently in the solution. For Land Value, the 10% goal solution mainly occurred in planning units with Refuges; when the goal was increased to 30% the solution frequency increased visibly in the Middle Rockies, Blue Mountains, and Coast Range Ecoregions.

For all scenarios when goals were set at 50%, the priority areas grew larger; in the no lock scenarios the solutions cover nearly the entire study area while in the locked scenarios the solutions cover most of the available area. Since the solutions at 50% cover so much area, they are not useful in determining high priority areas.

Discussion/Conclusion

The maps of the scenarios show how goal levels greatly influence the results. Evaluating goal levels is important. However in this in-house version 1.0 approach all targets were set at the same goal level. Moving forward discussions with experts and partner organizations can help set goal levels that align with the goals of the Refuge System.

As additional and improved data becomes available this model can be updated. This model is not intended to make decisions or to be an answer but rather a tool to assist conservation planners in decision-making by providing additional information.

The results from this model can be used to evaluate acquisition plans to determine what targets the new acquisition will best meet, and which costs exist in that location. This information will give planners an idea of where more effort will be needed and whether it will be economic, gaining partner support, more restoration efforts, or focus on education and outreach, etc. The results can also be compared to current or past projects in order to see where work is being done compared to where the high priority areas are located, the Willamette Valley and the Columbia Plateau are good examples of where there have been projects within the FWS and the model results show these areas as high priorities.

The goals of this project were for the most part accomplished, although the last three goals were not directly addressed in this version 1.0: Rank high priority conservation areas for potential land protection, re-evaluate how we define study boundaries, and integrating with the Region 1 Surrogate Species effort. To rank the high priority areas would require expert opinion and is not a black and white process. In order to thoroughly evaluate study boundaries the model should be run with other study boundaries, such as political or based on watersheds. By running the model with different boundaries the results could be compared and the different boundaries evaluated. The Region's surrogate species effort is still under development so it was unclear how to best incorporate their effort in this stage. However, just as this Version 1.0 effort focused on a suite of species to identify priorities, the Region's subsequent list of surrogate species could similarly be incorporated into the model to inform and evaluate the surrogate species effort and associated landscape-scale conservation.

Examples of additional data that could be added to the model which were not added in this version 1.0 include State Wildlife Action Plan data, added to the conservation opportunity inverse cost layer; sea level rise and other climate change data integrated into the model to supplement the climate stress index cost analysis; and adding surrogate species data as a target in order to expand this tool beyond NWRS specific goals to a more Service-wide approach (see Appendix Table 5 for future scenarios).

Currently the NWRS has two projects working on the national scale to assist in decision support for the Refuge System. One of these is COGS (Constraints and Opportunities for the Growth of the Refuge System). Working with Ecotrust, the COGS group has developed an online tool to perform Marxan with the ability to create different scenarios with self-set goals and costs or opportunities. The COGS tool operates at the national scale. The Marxan model described in this report could be integrated into the tool to connect the different scales of prioritization and show how this approach can be beneficial at the regional scale.

In order to lead the way in large landscape conservation planning and implementation the Refuge System should utilize decision support tools such as the one in this report and others being created by groups like COGS and The Nature Conservancy. Looking ahead as prioritization and spatial modeling continues to develop, then we will know where they can best fit as a decision support resource and how to best further improve these tools.

References:

1. "A Landscape-Scale Approach to Refuge System Planning." Final Report, USFWS 2013.
2. Series: Refuge Management Part 602 National Wildlife Refuge System Planning Chapter 5: Strategic Growth New, Draft
3. Groves, C.R. & The Nature Conservancy. 2003. *Drafting a Conservation Blueprint: A Practitioner's Guide to Planning for Biodiversity.* Island Press
4. Margules and Pressey. 2000. "Systematic Conservation Planning", Nature.

APPENDIX

Table 1: Prioritization Data

Dataset	Source	Description	Use	Constraints
BBS abundance data	USGS BBS Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2010. Version 12.07.2011 USGS Patuxent Wildlife Research Center, Laurel, MD	abundance of bird species. These maps indicate the number of birds seen on BBS routes, grouped into convenient categories of relative abundance. The maps predict the average number of birds of the species that could be seen in about 2.5 hours of birdwatching along roadsides (by very good birders). They are based on mean counts on BBS routes over the interval 2006 - 2010.	Target: birds of conservation concern and waterfowl species abundance	Acknowledgment of the U.S. Geological Survey Patuxent Wildlife Research Center would be appreciated in products derived from these data.

BBS trend data	USGS BBS Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2010. Version 12.07.2011 USGS Patuxent Wildlife Research Center, Laurel, MD	Best guess of population change for the species over its range. Note that these maps are supposed to provide a general view of population change for the long-term. They do not provide much insight into short-term changes within the 1966 - 2010 period. In this analysis, the trend at any point was estimated as a weighted average of trend information from nearby survey routes containing information from the species. Trend on these routes was estimated as a yearly change, using the Link and Sauer (1994) estimating equation procedure. The weights in the average are the standard route-regression weights (Geissler and Sauer 1990, Link and Sauer 1994), and an inverse distance from the point, the allow for decreased influence as distance from the point of interest increased	Target: identify areas where BCC and waterfowl are declining	Acknowledgment of the U.S. Geological Survey Patuxent Wildlife Research Center would be appreciated in products derived from these data.
BRWCA_Boundary_2012	FWS	Bear River Watershed Boundary	part of study area boundary	
CHAT	http://westgovchat.org/data/download	This dataset represents an aggregated measure of crucial habitat for species of interest to the western states' fish and wildlife management agencies. Crucial habitat describes places that are expected to contain the resources necessary for continued health of fish and wildlife populations or important ecological systems expected to provide high value for a diversity of fish and wildlife.	Cost: Comparing crucial habitat from CHAT to results of this model (in conservation opportunity inverse cost).	Users interested in publishing the results of analysis online or in print agree to: (1) credit the Western Governors' Association using the attribution and disclaimer language provided by WGA and (2) not change the map's core display features, including the color scheme and the number of crucial habitat rankings.

Climate Stress Index	USFS	This index reflects a mean across 12 realizations of the index (3 climate models, 2 economic scenarios that affect emissions, and 2 ecological assumptions that affect plant sensitivity to elevated CO2).	Cost layer to represent climate change	The hexagons extend beyond the borders of the US so when they initially view it, it won't look like the map. The attribute to plot is hex_mean_1 (shapefiles have a 10-character limit so Arc truncates) and they can exclude all values where hex_mean_1 = 0 and the map should look the same.
Critical Habitat	FWS	designated critical habitat for T & E Species	Target	
Element Occurance	FWS	Occurance of Threatened and Endangered Species in Oregon, Washington, and Idaho	Target: to compliment the critical habitat data	
fedlandp.shp	ESRI Data	Public land (federally owned land)	To lock out areas that cannot be part of the growth of the Refuge system	
GAP Species Distribution Models	USGS Gap Analysis Program http://gapanalysis.usgs.gov/species/data/download/	GAP distribution models represent the areas where species are predicted to occur based on habitat associations. GAP distribution models are the spatial arrangement of environments suitable for occupation by a species. In other words, a species distribution is created using a deductive model to predict areas suitable for occupation within a species range. 1= known or probable summer occurance 2 = winter and 3 = year-round. Metadata: http://gapanalysis.usgs.gov/wp-content/uploads/2013/09/GAPSpeciesDistributionModelmetadata.pdf	Target: to represent waterfowl and birds of conservation concern not present in the BBS data	U.S. Geological Survey Gap Analysis Program. 2011. National GAP vertebrate species distribution model. http://gapanalysis.usgs.gov/species

Greater Sage Grouse Range-Wide Breeding Densities	Doherty et al, 2010	Breeding Densities of Greater Sage Grouse. Data for maps collected during lek counts.	Target: used 25 and 50% breeding densities in place of BBS abundance data for the Sage Grouse.	
Land Value	USDA (http://www.agcensus.usda.gov/Publications/2012/)	US Agricultural Census 2012.	Cost: Field for land and buildings value (county level) used to determine average land value per hexagon	
Landscape Integrity (li_hmv4_int)	NatureServe http://www.natureserve.org/conservation-tools/data-maps-tools/modeling-landscape-condition-0	raster data of the ecological condition of the landscape. A measure of land cover impacted by human activities.	Cost layer	

National Wetland Inventory	FWS http://www.fws.gov/wetlands/Data/State-Downloads.html	Wetlands	Target: As surrogate for waterfowl species. Used freshwater emergent wetland type as target.	The maps are prepared from the analysis of high altitude imagery. Wetlands are identified based on vegetation, visible hydrology and geography. A margin of error is inherent in the use of imagery; thus, detailed on-the-ground inspection of any particular site may result in revision of the wetland boundaries or classification established through image analysis. The accuracy of image interpretation depends on the quality of the imagery, the experience of the image analysts, the amount and quality of the collateral data and the amount of ground truth verification work conducted. Metadata should be consulted to determine the date of the source imagery used and any mapping problems.
Omernik_level3Ecoregions	FWS		boundary for study area	
states.shp	ESRI Data	polygon shapefile of the United States		

Table 2: Bird species in the model

Species					
Allen's Hummingbird	Brant	Dunlin	Loggerhead Shrike	Prairie Falcon	Sooty Grouse
American Bittern	Brewer's Sparrow	Eared Grebe	Long-billed Curlew	Purple Finch	Sprague's Pipit
American Wigeon	Bufflehead	Ferruginous Hawk	Mallard	Red Knot	Swainson's Hawk
Baird's Sparrow	Burrowing Owl	Flammulated Owl	Marbled Godwit	Redhead	Tricolored Blackbird
Bald Eagle	Cackling Goose	Gadwall	Marbled Murrelet	Red-throated Loon	Upland Sandpiper
Barrow's Goldeneye	California Thrasher	Golden Eagle	McCown's Longspur	Ring-necked Duck	Veery
Bewick's Wren	Calliope Hummingbird	Grasshopper Sparrow	Mountain Plover	Rock Sandpiper	Virginia's Warbler
Black Oystercatcher	Canada Goose	Gray Vireo	Northern Goshawk	Ruddy Duck	Western/Clark's Grebe

Black Rail	Canvasback	Greater White-fronted Goose	Northern Pintail	Ruddy Turnstone	Whimbrel (nb)
Black Rosy-Finch	Caspian Tern	Green-tailed Towhee	Northern Shoveler	Rufous Hummingbird	White-headed Woodpecker
Black Swift	Cassin's Finch	Hooded Merganser	Oak Titmouse	Rufous Hummingbird	Willet
Black-bellied Plover	Cgreater Scaup	Horned Lark	Olive-sided Flycatcher	Sage Grouse	Williamson's Sapsucker
Black-billed Cuckoo	Chestnut-bkd. Chickadee	Juniper Titmouse	Oregon Vesper Sparrow (affinis ssp.)	Sage Sparrow	Willow Flycatcher
Black-chinned Sparrow	Chestnut-col. Longspur	Least Bittern	Pacific Golden-plover	Sage Thrasher	Wood Duck
Black-crn. Night Heron	Cinnamon Teal	Lesser Scaup	Pelagic Cormorant	Sanderling	Wrentit
Blue-winged teal	Common Goldeneye	Lesser Yellowlegs	Peregrine Falcon	Short-billed Dowitcher	Yellow Rail
Brandt's Cormorant	Common Merganser	Lewis's Woodpecker	Pinyon Jay	Snowy Plover	

Table 3A: BLM Calibration

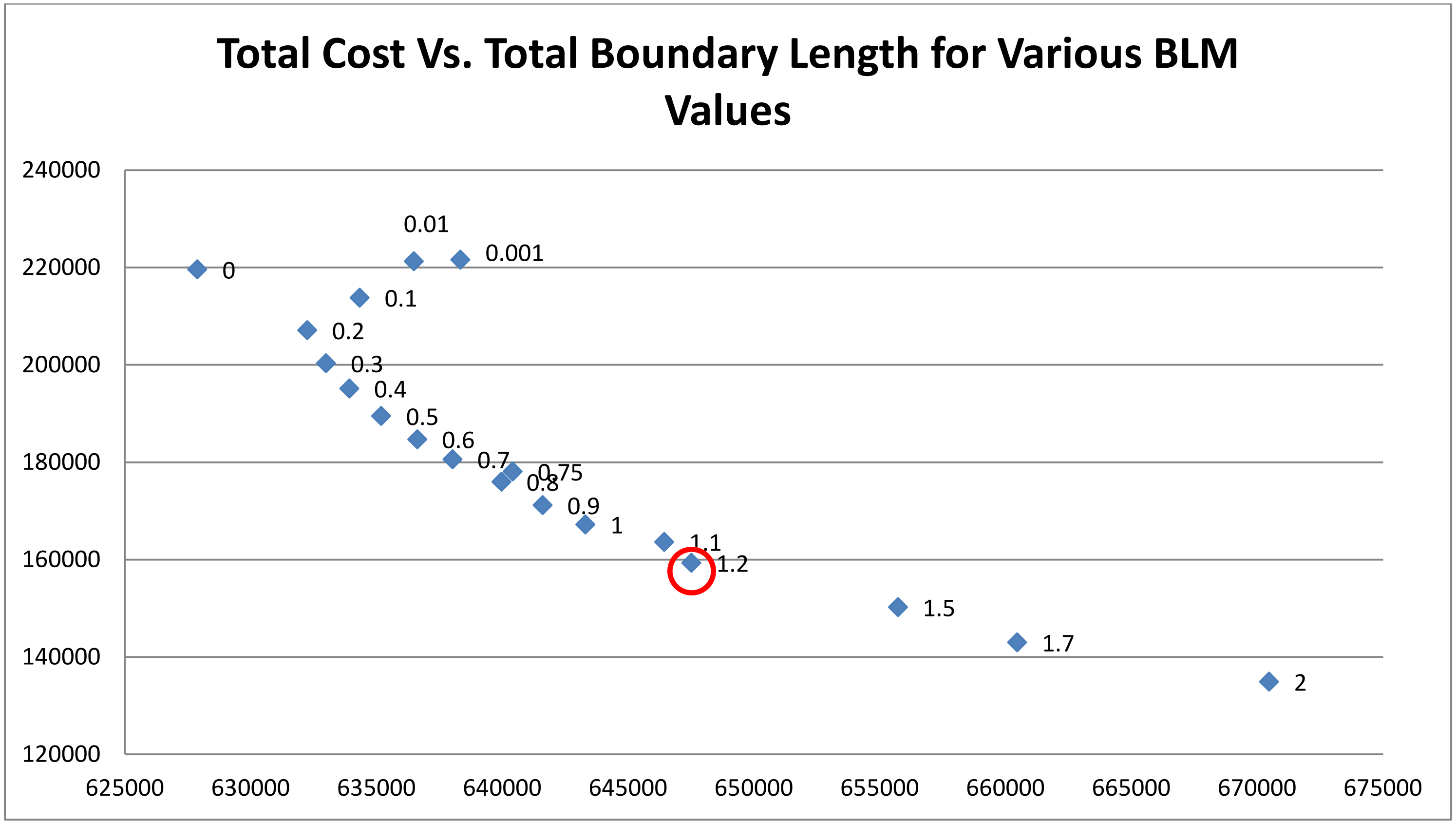


Table 3B: Iteration Calibration:

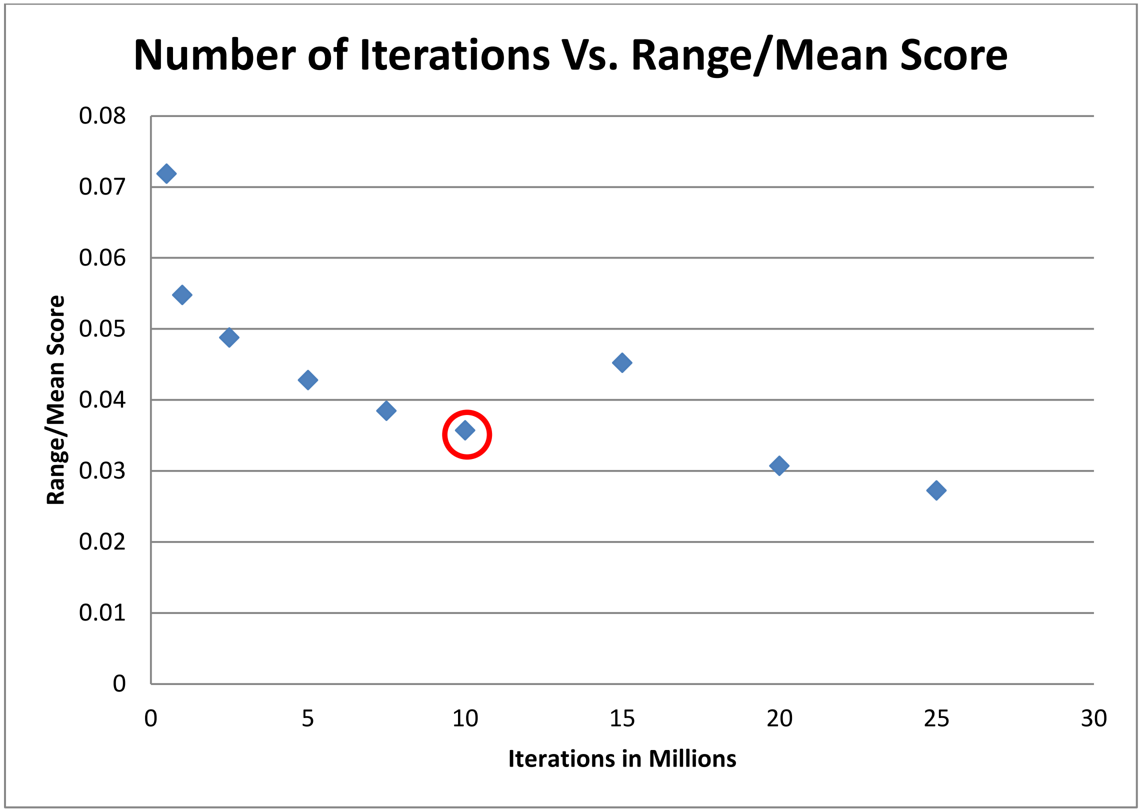


Table 4: Marxan Scenarios

All performed at calibrated values (10 million iterations, BLM 1.2) and 20 runs

Final Runs							
id	**cost**	**Lock-out**	**Lock-in**	**goal Level**	**notes**	**notes_2**	field name of cost
FR0	Equal Area Cost	none	none	10%			Equal_cost
FR01	Equal Area Cost	none	none	30%			Equal_cost
FR02	Equal Area Cost	>=75% public land	none	10%	No targets within locked out planning units.		Equal_cost
FR03	Equal Area Cost	>=75% public land	none	30%	No targets within locked out planning units.		Equal_cost
FR04	Equal Area Cost	>=75% public land	Refuges	10%	No targets within locked out planning units.		Equal_cost
FR05	Equal Area Cost	>=75% public land	Refuges	30%	No targets within locked out planning units.		Equal_cost
FR1	Landscape Integrity	>=75% public land	Refuges	10%			mean_landscape_integrity
FR11	Landscape Integrity	>=75% public land	Refuges	30%			mean_landscape_integrity
FR110	Landscape Integrity	none	none	50%			mean_landscape_integrity
FR111	Landscape Integrity	>=75% public land	none	50%	No targets within locked out planning units.		mean_landscape_integrity

FR112	Landscape Integrity	>=75% public land	Refuges	50%	No targets within locked out planning units.	mean_landscape_integrity
FR12	Landscape Integrity	>=75% public land	Refuges	50%		mean_landscape_integrity
FR13	Landscape Integrity	>=75% public land	Refuges	80%		mean_landscape_integrity
FR14	Landscape Integrity	none	none	10%		mean_landscape_integrity
FR15	Landscape Integrity	>=75% public land	none	10%	No targets within locked out planning units.	mean_landscape_integrity
FR16	Landscape Integrity	>=75% public land	Refuges	10%	No targets within locked out planning units.	mean_landscape_integrity
FR17	Landscape Integrity	none	none	30%		mean_landscape_integrity
FR18	Landscape Integrity	>=75% public land	none	30%	No targets within locked out planning units.	mean_landscape_integrity
FR19	Landscape Integrity	>=75% public land	Refuges	30%	No targets within locked out planning units.	mean_landscape_integrity
FR2	Land Value	>=75% public land	Refuges	10%		Land_Value
FR21	Land Value	>=75% public land	Refuges	30%		Land_Value
FR210	Land Value	none	none	50%		Land_Value
FR211	Land Value	>=75%	none	50%	No targets within locked out planning units.	Land_Value

		public land				
FR212	Land Value	>=75% public land	Refuges	50%	No targets within locked out planning units.	Land_Value
FR22	Land Value	>=75% public land	Refuges	50%		Land_Value
FR23	Land Value	>=75% public land	Refuges	80%		Land_Value
FR24	Land Value	none	none	10%		Land_Value
FR25	Land Value	>=75% public land	none	10%	No targets within locked out planning units.	Land_Value
FR26	Land Value	>=75% public land	Refuges	10%	No targets within locked out planning units.	Land_Value
FR27	Land Value	none	none	30%		Land_Value
FR28	Land Value	>=75% public land	none	30%	No targets within locked out planning units.	Land_Value
FR29	Land Value	>=75% public land	Refuges	30%	No targets within locked out planning units.	Land_Value
FR3	Climate Stress Index	>=75% public land	Refuges	10%		mean_Climate_stress_index
FR31	Climate Stress Index	>=75% public land	Refuges	30%		mean_Climate_stress_index
FR310	Climate Stress Index	none	none	50%		mean_Climate_stress_index

FR311	Climate Stress Index	>=75% public land	none	50%	No targets within locked out planning units.		mean_Climate_stress_index
FR312	Climate Stress Index	>=75% public land	Refuges	50%	No targets within locked out planning units.		mean_Climate_stress_index
FR32	Climate Stress Index	>=75% public land	Refuges	50%			mean_Climate_stress_index
FR33	Climate Stress Index	>=75% public land	Refuges	80%			mean_Climate_stress_index
FR34	Climate Stress Index	none	none	10%			mean_Climate_stress_index
FR34_2	Climate Stress Index	none	none	10%		Took mean_climate_stress_index and divided by the largest value then multplied by 100.	CSI_cost_2
FR35	Climate Stress Index	>=75% public land	none	10%	No targets within locked out planning units.		mean_Climate_stress_index
FR35_2	Climate Stress Index	>=75% public land	none	10%	No targets within locked out planning units.	Took mean_climate_stress_index and divided by the largest value then multplied by 100.	CSI_cost_2
FR36	Climate Stress Index	>=75% public land	Refuges	10%	No targets within locked out planning units.		mean_Climate_stress_index
FR36_2	Climate Stress Index	>=75% public land	Refuges	10%	No targets within locked out planning units.	Took mean_climate_stress_index and divided by the largest value then multplied by 100.	CSI_cost_2
FR37	Climate Stress Index	none	none	30%			mean_Climate_stress_index
FR37_2	Climate Stress Index	none	none	30%		Took mean_climate_stress_index and divided by the largest value then multplied by 100.	CSI_cost_2

FR38	Climate Stress Index	>=75% public land	none	30%	No targets within locked out planning units.		mean_Climate_stress_index
FR38_2	Climate Stress Index	>=75% public land	none	30%	No targets within locked out planning units.	Took mean_climate_stress_index and divided by the largest value then multplied by 100.	CSI_cost_2
FR39	Climate Stress Index	>=75% public land	Refuges	30%	No targets within locked out planning units.		mean_Climate_stress_index
FR39_2	Climate Stress Index	>=75% public land	Refuges	30%	No targets within locked out planning units.	Took mean_climate_stress_index and divided by the largest value then multplied by 100.	CSI_cost_2
FR4	Conservation Opportunity Inverse	>=75% public land	Refuges	10%			Conservation_Opportunity_Inverse_Cost
FR41	Conservation Opportunity Inverse	>=75% public land	Refuges	30%			Conservation_Opportunity_Inverse_Cost
FR410	Conservation Opportunity Inverse	none	none	50%			Conservation_Opportunity_Inverse_Cost
FR411	Conservation Opportunity Inverse	>=75% public land	none	50%	No targets within locked out planning units.		Conservation_Opportunity_Inverse_Cost
FR412	Conservation Opportunity Inverse	>=75% public land	Refuges	50%	No targets within locked out planning units.		Conservation_Opportunity_Inverse_Cost
FR42	Conservation Opportunity Inverse	>=75% public land	Refuges	50%			Conservation_Opportunity_Inverse_Cost
FR43	Conservation Opportunity Inverse	>=75% public land	Refuges	80%			Conservation_Opportunity_Inverse_Cost
FR44	Conservation	none	none	10%			Conservation_Opportunity_I

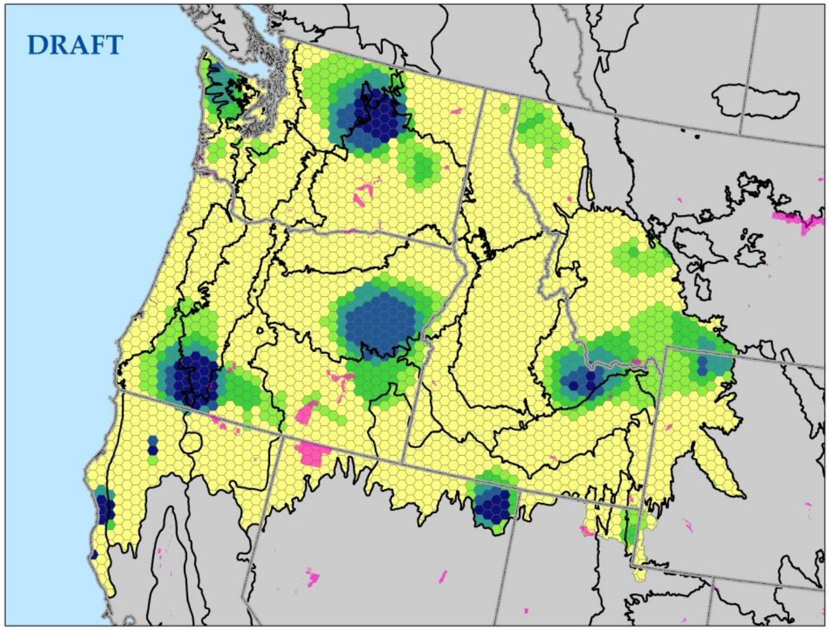
	Opportunity Inverse						nverse_Cost
FR44_2	Conservation Opportunity Inverse	none	none	10%		Took Conservation_opportunity_area divided by largest value, multiplied that by 100 then took the inverse. This made the values larger so they were not all small decimal values.	COI_cost_2
FR45	Conservation Opportunity Inverse	>=75% public land	none	10%	No targets within locked out planning units.		Conservation_Opportunity_Inverse_Cost
FR45_2	Conservation Opportunity Inverse	>=75% public land	none	10%	No targets within locked out planning units.	Took Conservation_opportunity_area divided by largest value, multiplied that by 100 then took the inverse. This made the values larger so they were not all small decimal values.	COI_cost_2
FR46	Conservation Opportunity Inverse	>=75% public land	Refuges	10%	No targets within locked out planning units.		Conservation_Opportunity_Inverse_Cost
FR46_2	Conservation Opportunity Inverse	>=75% public land	Refuges	10%	No targets within locked out planning units.	Took Conservation_opportunity_area divided by largest value, multiplied that by 100 then took the inverse. This made the values larger so they were not all small decimal values.	COI_cost_2
FR47	Conservation Opportunity Inverse	none	none	30%			Conservation_Opportunity_Inverse_Cost
FR47_2	Conservation Opportunity Inverse	none	none	30%		Took Conservation_opportunity_area divided by largest value, multiplied that by 100 then took the inverse. This made the values larger so they were not all small decimal values.	COI_cost_2
FR48	Conservation Opportunity Inverse	>=75% public land	none	30%	No targets within locked out planning units.		Conservation_Opportunity_Inverse_Cost

FR48_2	Conservation Opportunity Inverse	>=75% public land	none	30%	No targets within locked out planning units.	Took Conservation_opportunity_area divided by largest value, multiplied that by 100 then took the inverse. This made the values larger so they were not all small decimal values.	COI_cost_2
FR49	Conservation Opportunity Inverse	>=75% public land	Refuges	30%	No targets within locked out planning units.		Conservation_Opportunity_Inverse_Cost
FR49_2	Conservation Opportunity Inverse	>=75% public land	Refuges	30%	No targets within locked out planning units.	Took Conservation_opportunity_area divided by largest value, multiplied that by 100 then took the inverse. This made the values larger so they were not all small decimal values.	COI_cost_2

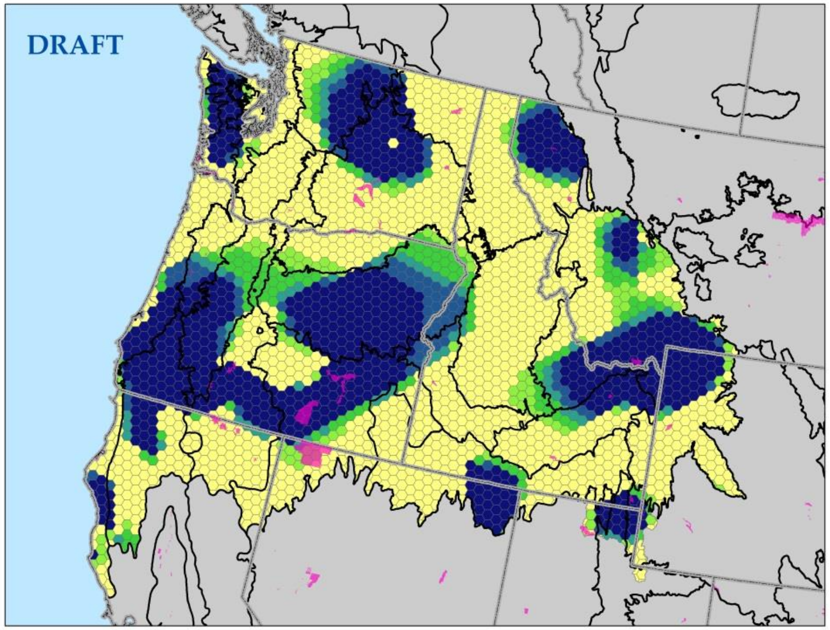
Table 5: Future Scenarios

Scenario Cost	Planning units	How to	Data needed	Concerns	Data Projection
Cost: use all cost layers	hexagons	Remove the current targets (T&E, Mig Birds, Waterfowl/Wetlands) and replace with surrogate species data. Set target goals, create new dictionary file. And new PU vs SP file.	Distribution of surrogate species	If the same species is selected for more than one ecoregion then need to determine if want the determined goal to be achieved across the landscape or within each ecoregion -- May have to include distribution (or other data) for each ecoregion as individual targets within the model.	USA_Contiguous_Albers_Equal_Area_Conic
Cost: other climate	hexagons	Create new PU files with new climate change data	Climate change velocity data,	Not one climate change model will provide all the information needed to get a full picture of how targets might be affected.	USA_Contiguous_Albers_Equal_Area_Conic

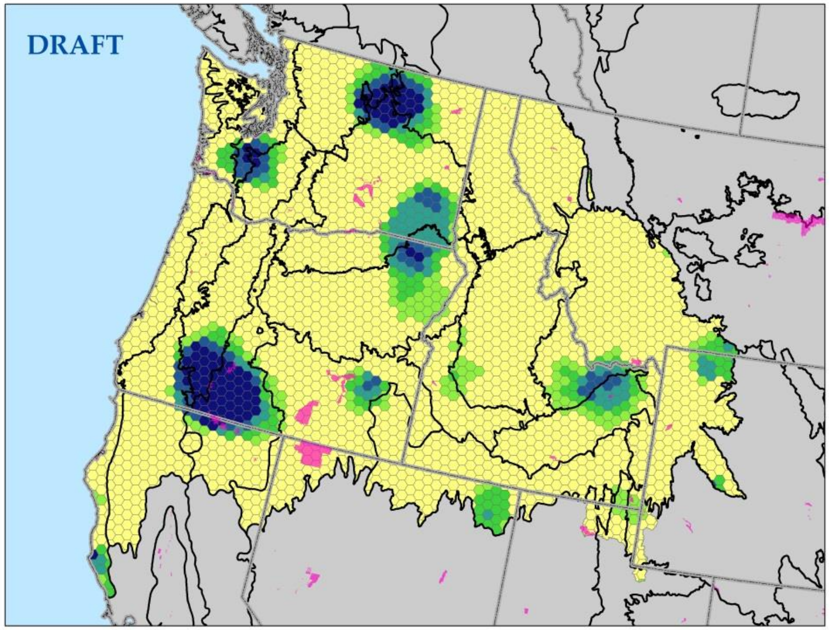
change scenarios			other climate change data		
Cost: Connectivity for species	hexagons	Create an inverse cost layer so planning units with the best connectivity have the lowest cost. Create new PU file.	Connectivity data for each species	How to combine connectivity for each species into one dataset. Finding connectivity data for each species is also unlikely	USA_Contiguous_Albers_Equal_Area_Conic
Cost: All cost layers	HUC watersheds	Would need to run all the python scripts to re-add data to new planning units. And create all new marxan input files.	HUC Watershed data	Watershed planning units work best with aquatic targets. However some of the targets are aquatic or will at least rely on waterways.	USA_Contiguous_Albers_Equal_Area_Conic
Cost: All cost layers	Counties (or other smaller political unit)	Would need to run all the python scripts to re-add data to new planning units. And create all new marxan input files.	County or census data	The purpose of this is to compare to the hexagon planning units and to the watershed units to determine what planning units work best for the FWS' prioritization purposes.	USA_Contiguous_Albers_Equal_Area_Conic
Cost: All cost layers	hexagons	Get professional opinion to set more specific goal levels for each target. Create new spec input file for marxan with new goal levels.	Expert opinion on targets and ideal goals	Expert opinion may vary.	USA_Contiguous_Albers_Equal_Area_Conic



Conservation Opportunity Inverse Cost: 10% Goals, No Locks



Conservation Opportunity Inverse Cost: 30% Goals, No Locks



Climate Stress Index Cost: 10% Goals, No Locks

Boundaries

FWS Refuge

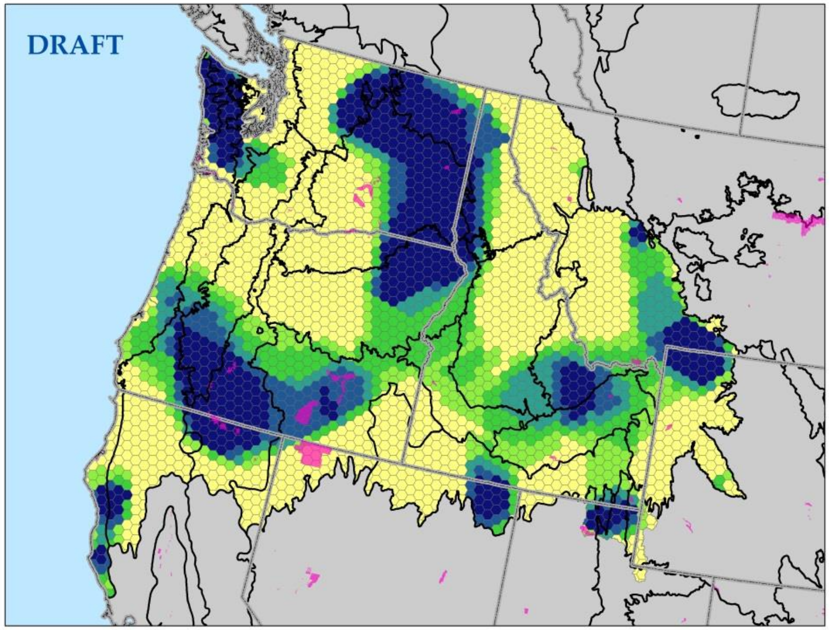
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Climate Stress Index Cost: 30% Goals, No Locks

Boundaries

FWS Refuge

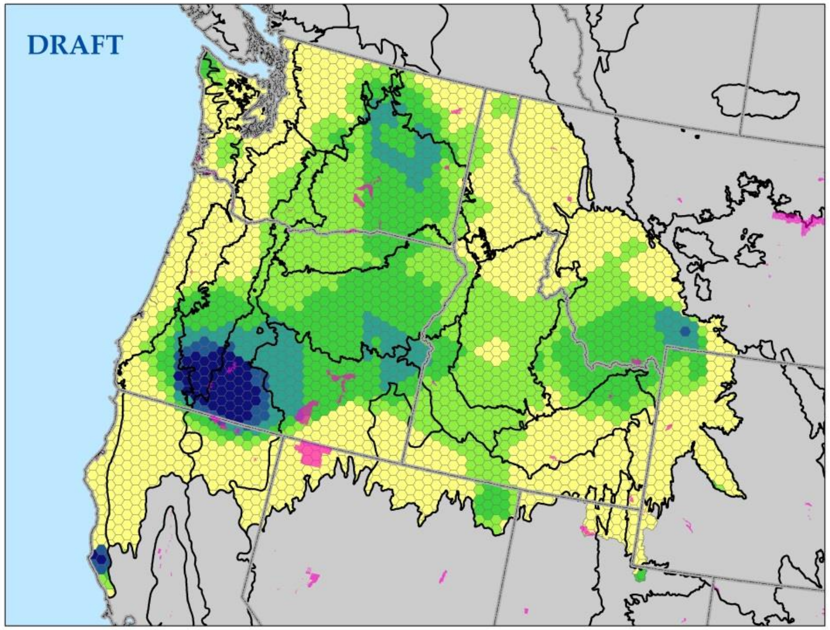
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Equal Cost: 10% Goals, No Locks

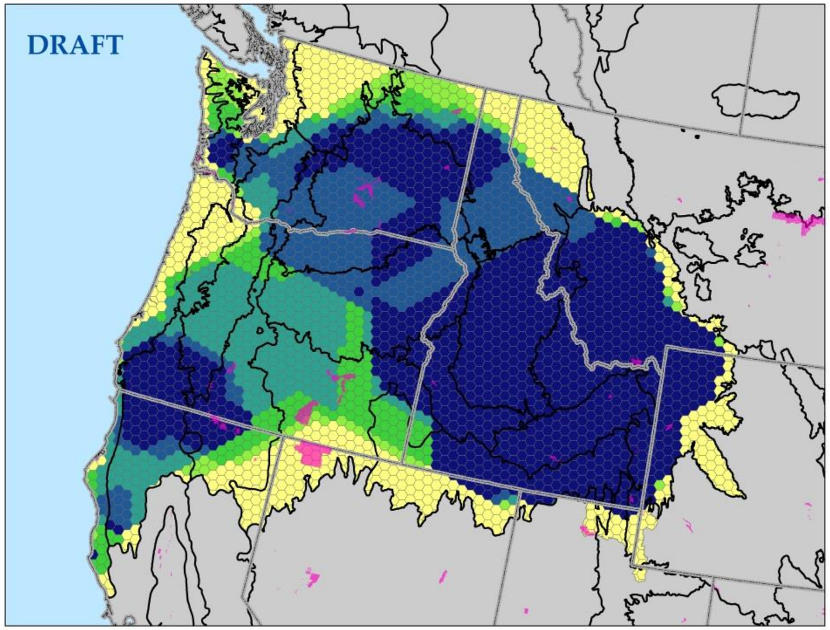
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Equal Cost: 30% Goals, No Locks

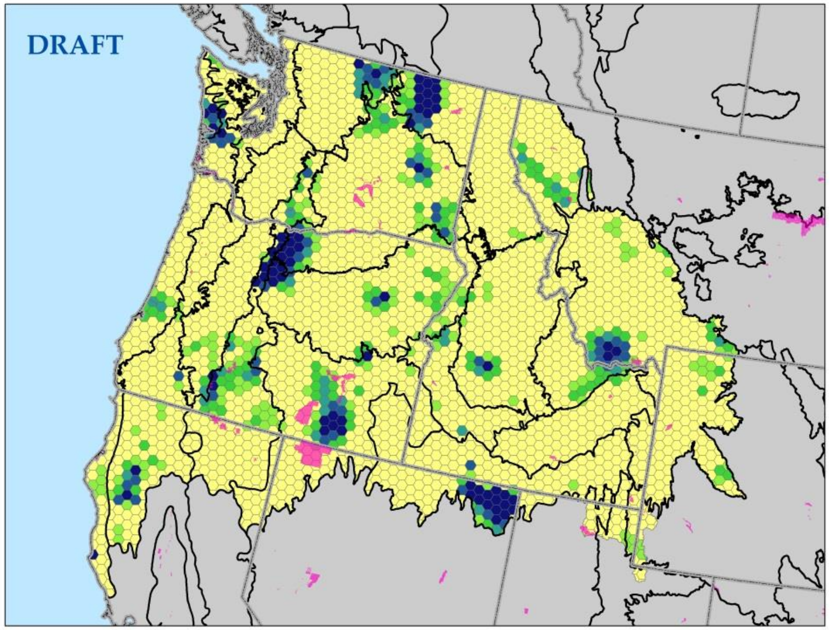
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Land Value Cost: 10% Goals, No Locks

Boundaries

FWS Refuge

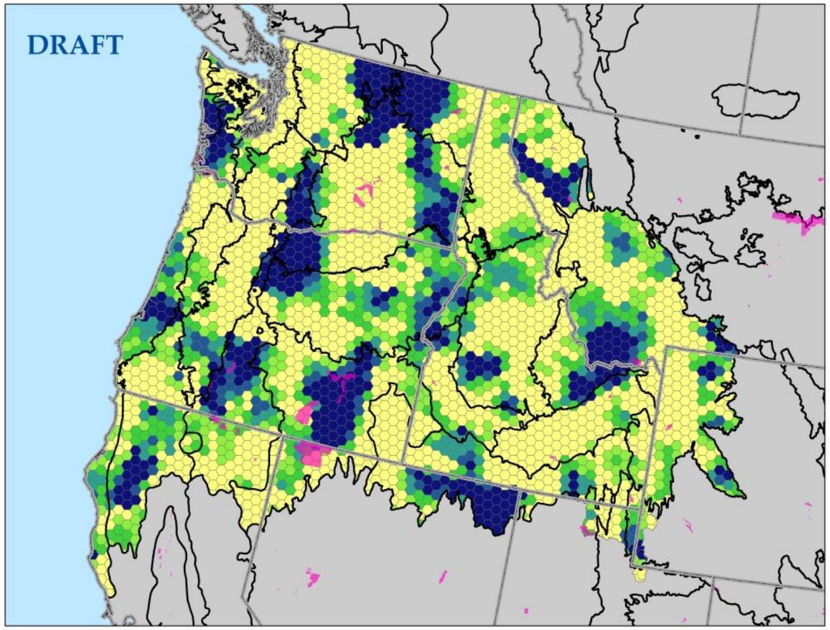
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Land Value Cost: 30% Goals, No Locks

Boundaries

FWS Refuge

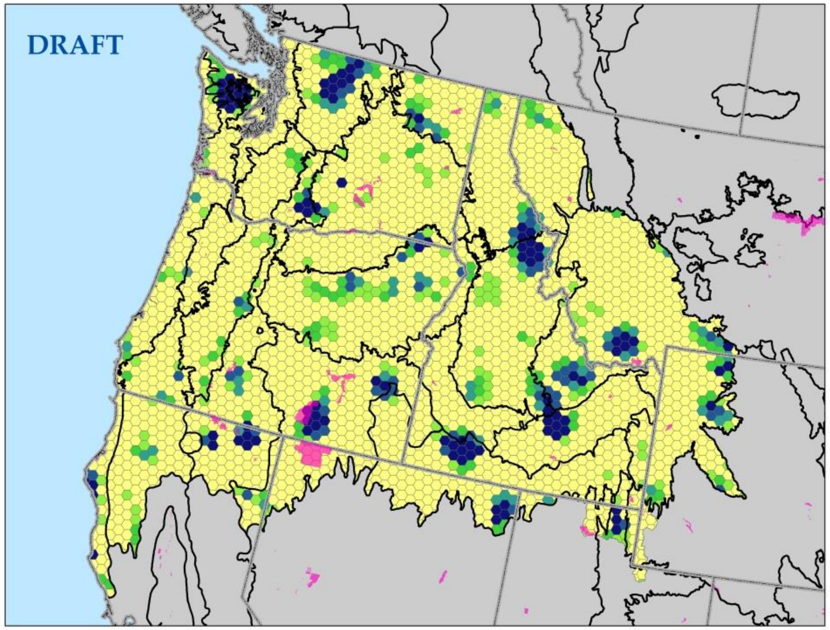
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



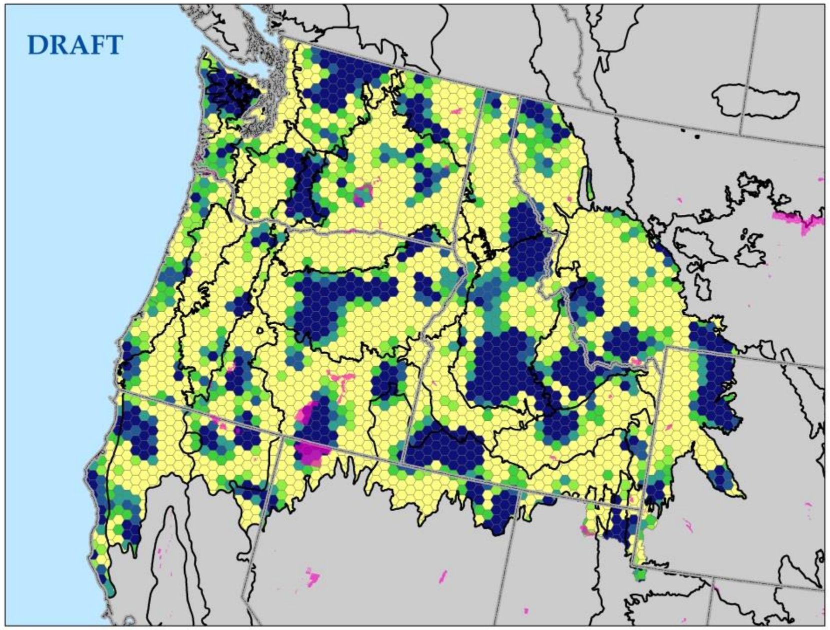
Landscape Integrity Cost: 10% Goals, No Locks

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



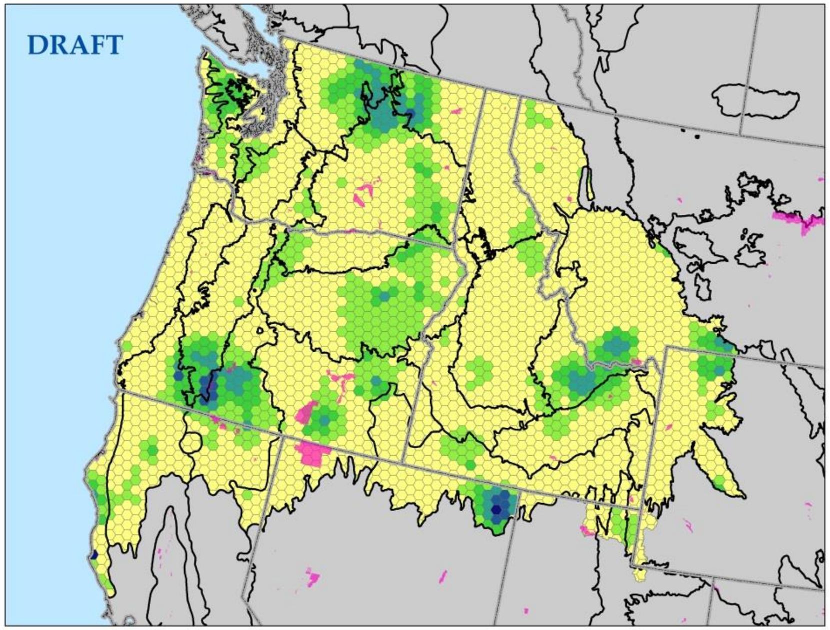
Landscape Integrity Cost: 30% Goals, No Locks

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



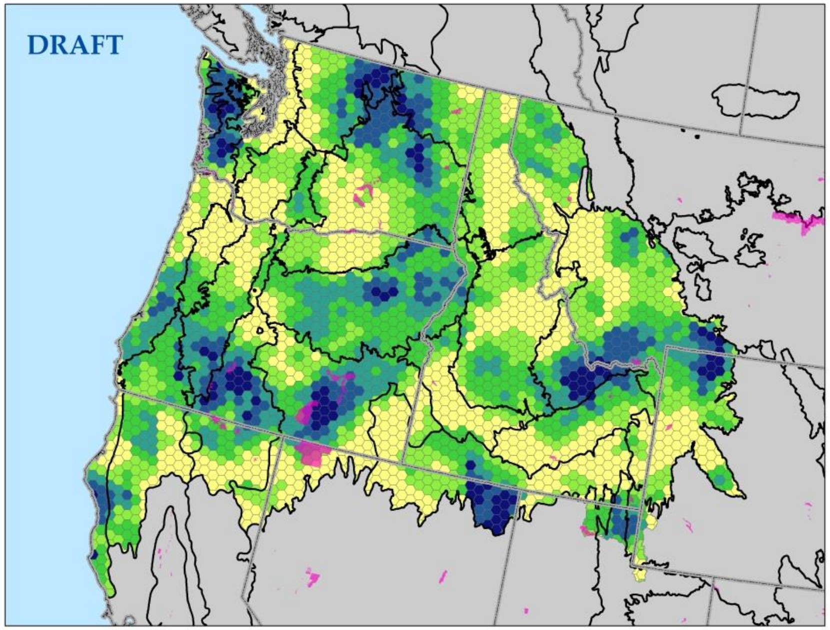
Sum of all Solutions at 10% Goals - No Locks

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



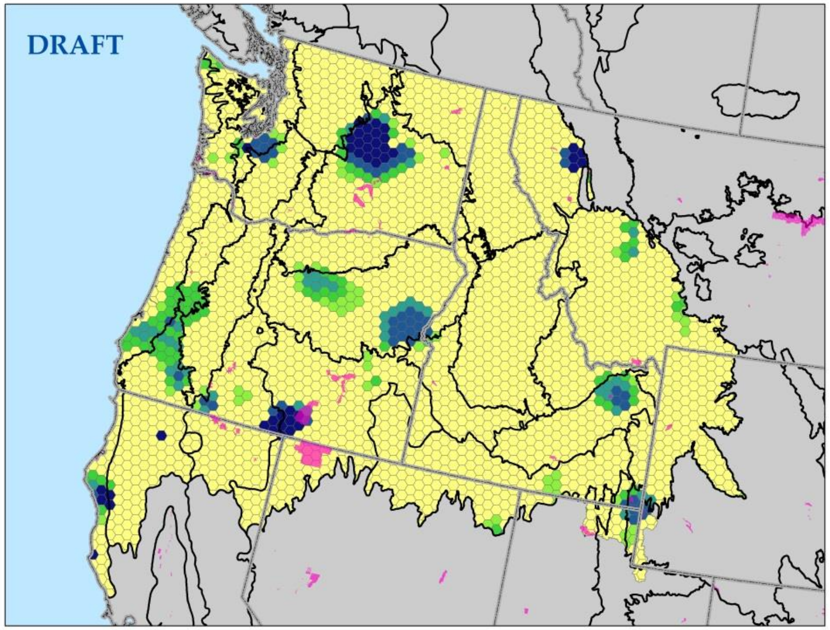
Sum of all Solutions at 30% Goals - No Locks

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



Conservation Opportunity Inverse Cost: 10% Goals, No Public Land Targets

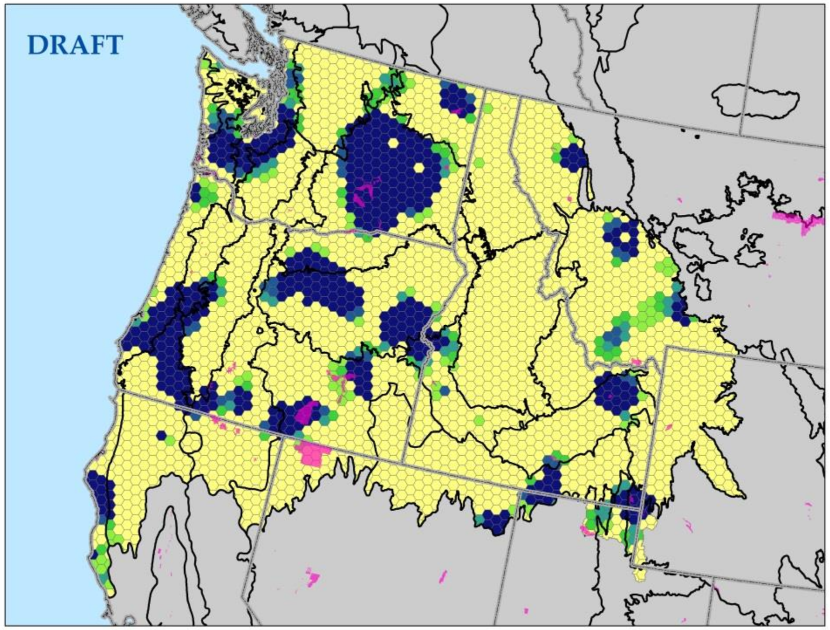
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Conservation Opportunity Inverse Cost: 30% Goals, No Public Land Targets

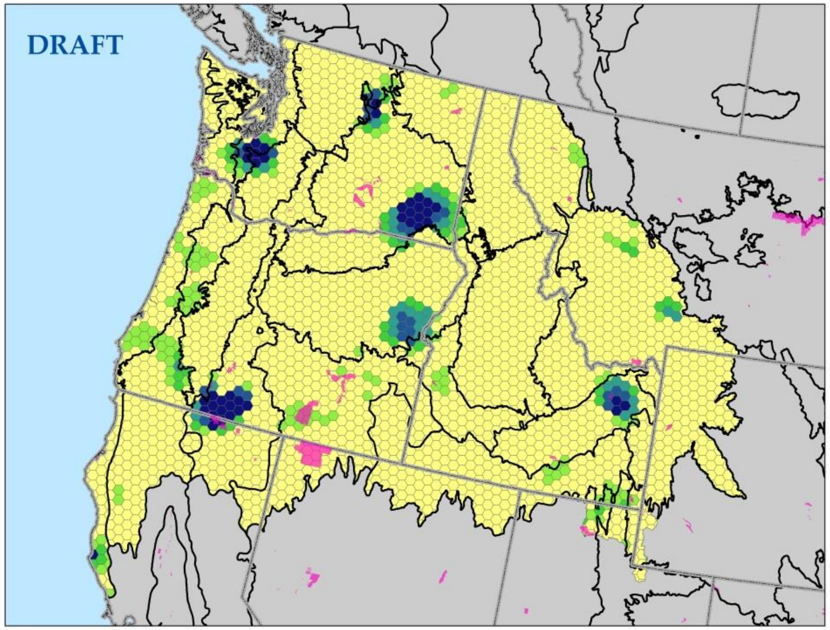
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Climate Stress Index Cost: 10% Goals, No Public Land Targets

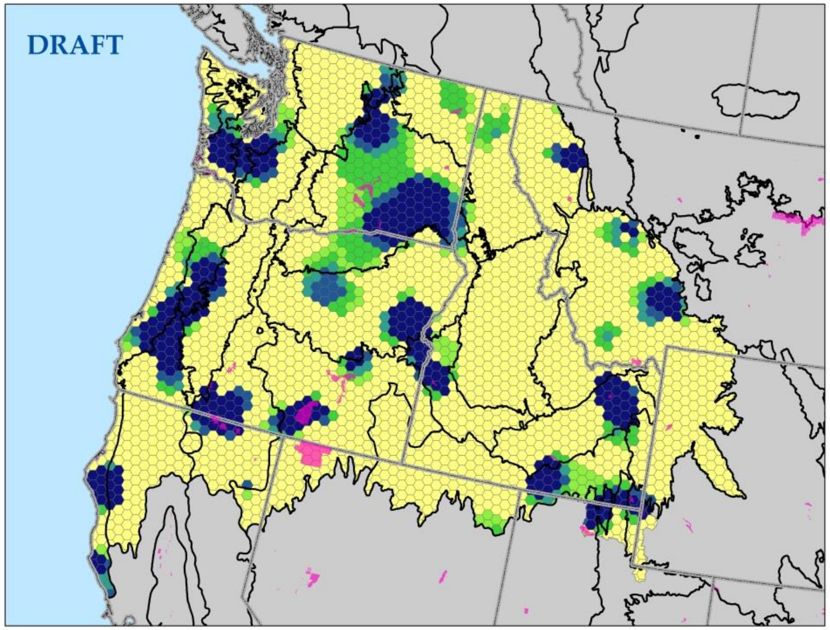
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Climate Stress Index Cost: 30% Goals, No Public Land Targets

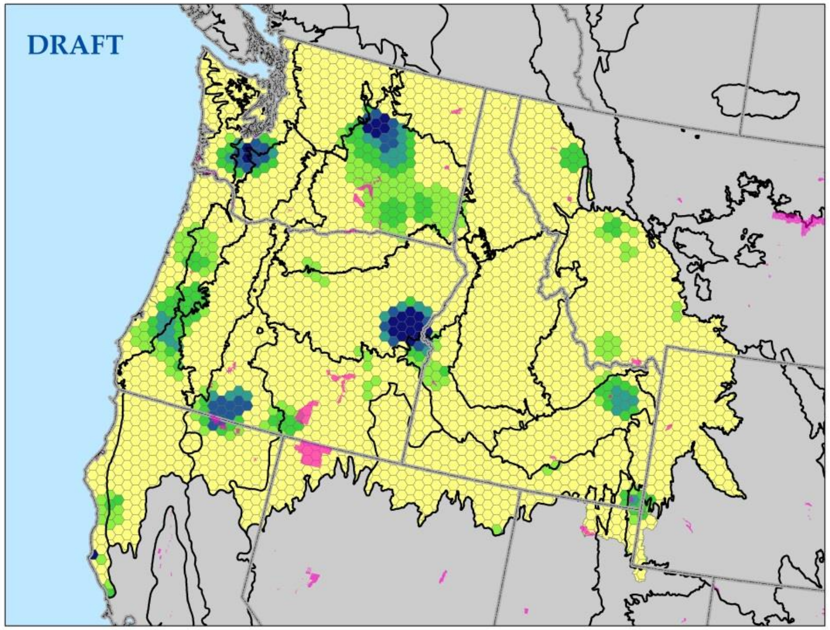
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Equal Cost: 10% Goals, No Public Land Targets

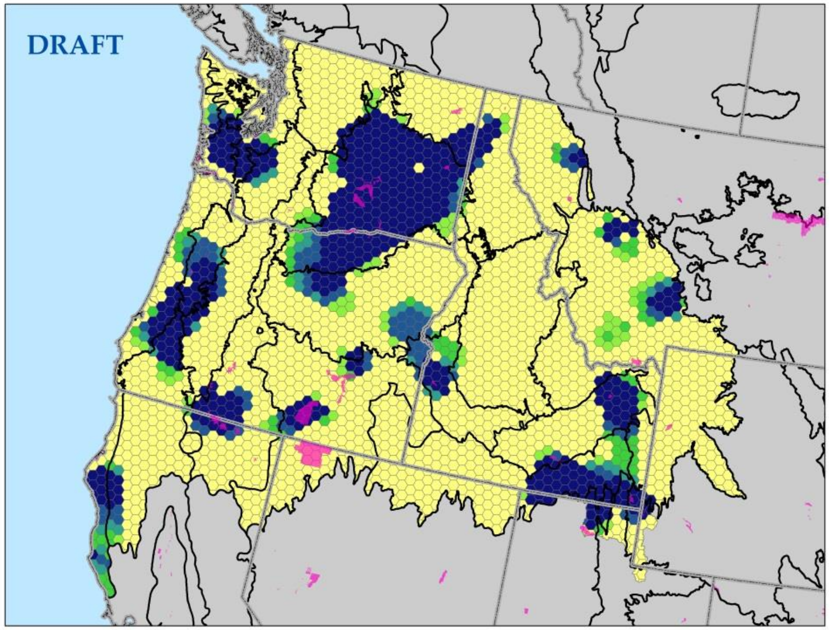
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Equal Cost: 30% Goals, No Public Land Targets

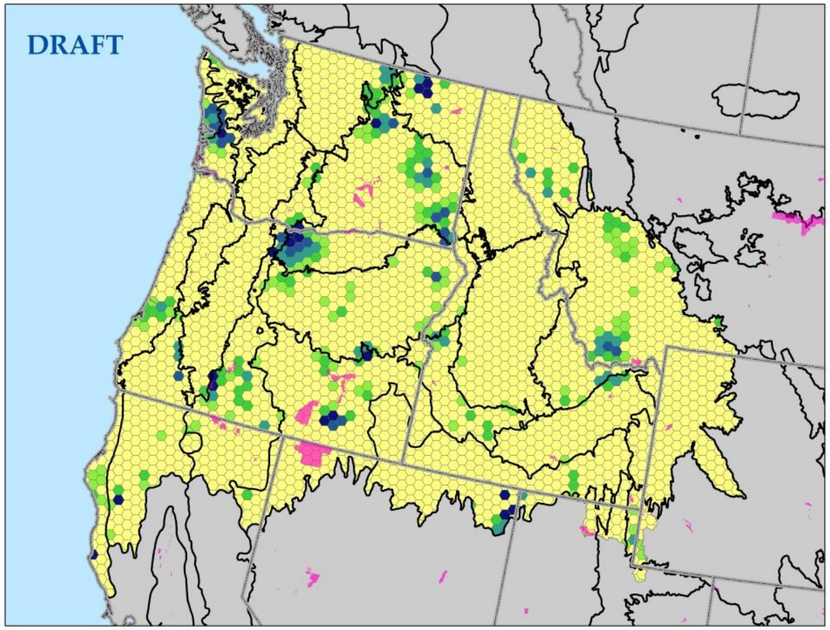
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



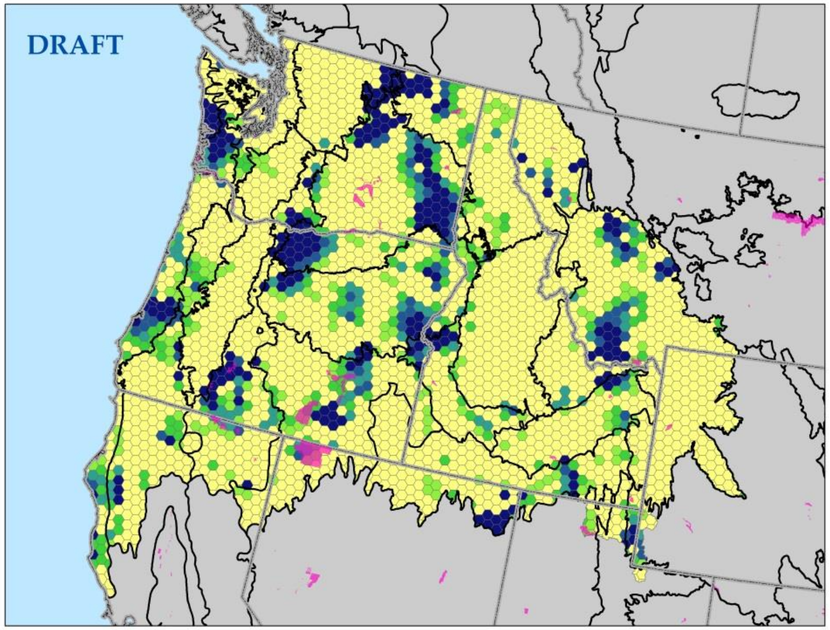
Land Value Cost: 10% Goals, No Public Land Targets

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



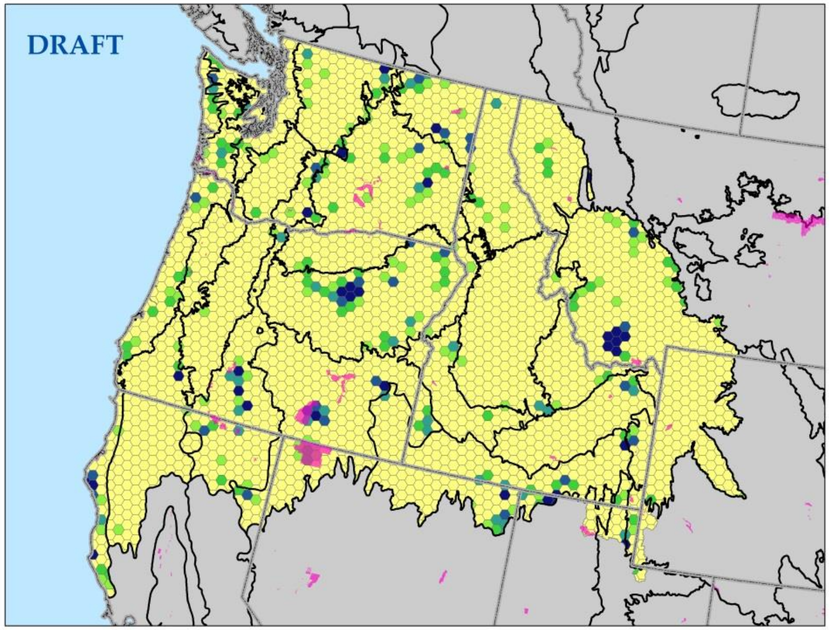
Land Value Cost: 30% Goals, No Public Land Targets

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



Landscape Integrity Cost: 10% Goals, No Public Land Targets

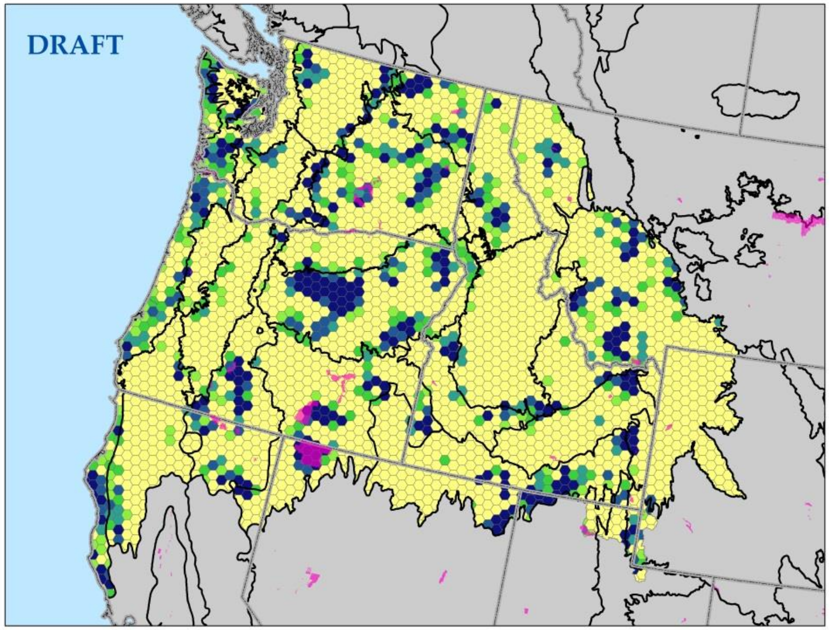
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Landscape Integrity Cost: 30% Goals, No Public Land Targets

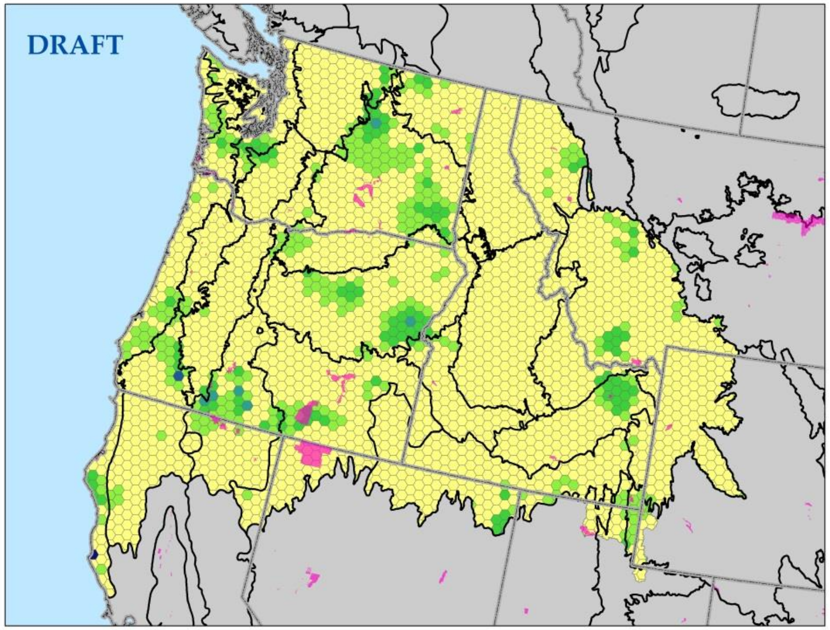
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

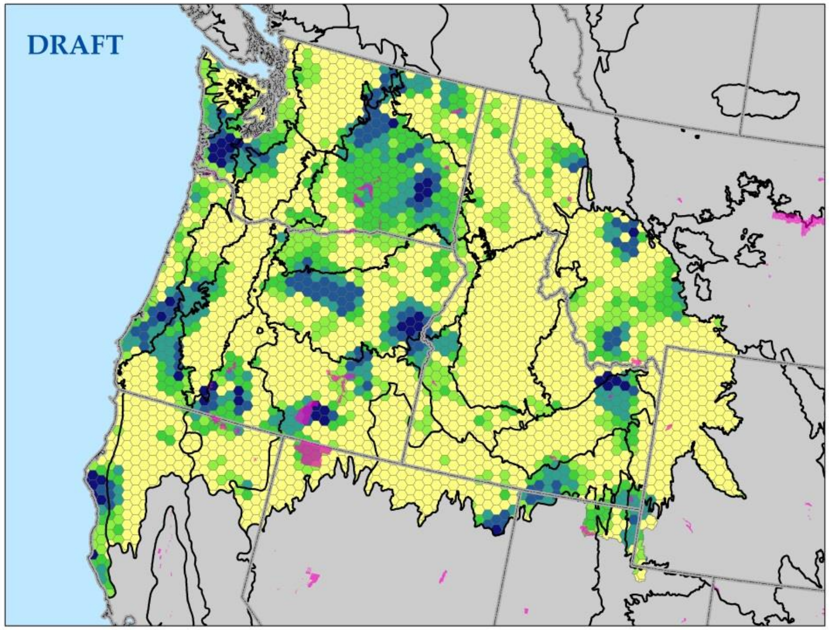
Selection frequency in solution

Low

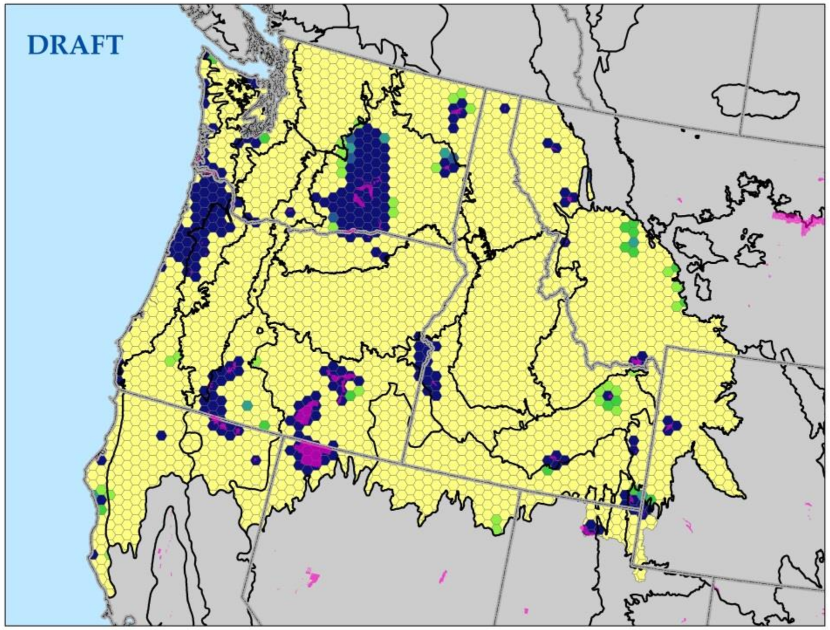
High



Sum of all Solutions at 10% Goals:
No Public Land Targets



Sum of all Solutions at 30% Goals:
No Public Land Targets



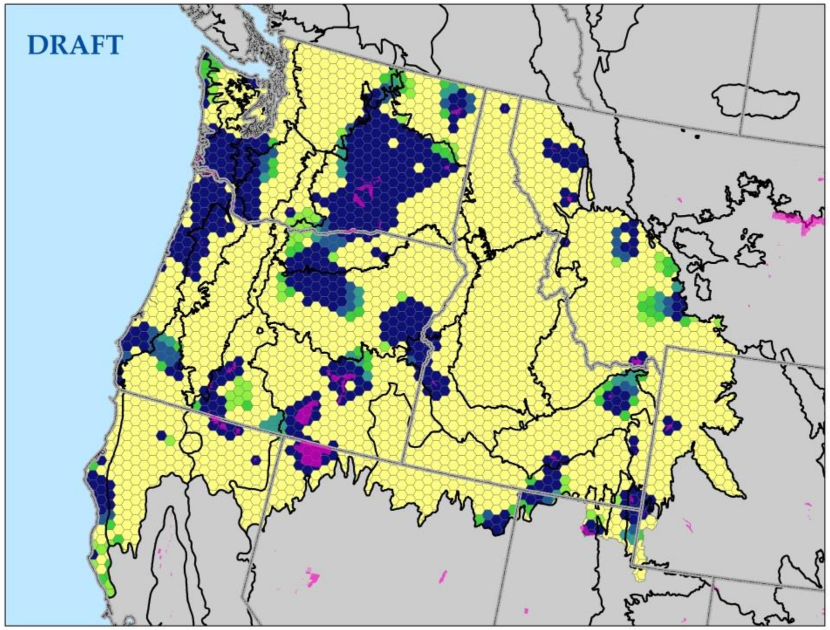
Conservation Opportunity Inverse Cost: 10% Goals, No Public Land Targets, Refuges Locked In

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



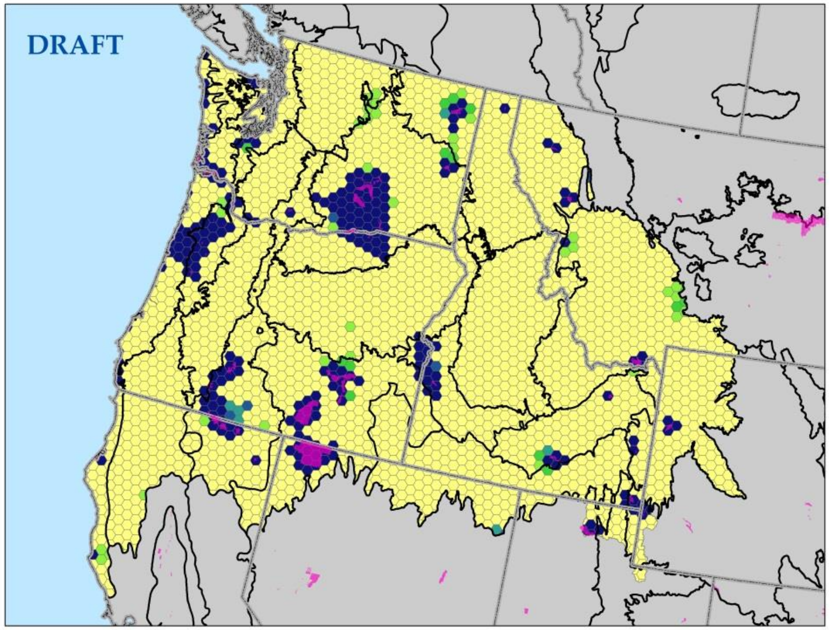
Conservation Opportunity Inverse Cost: 30% Goals, No Public Land Targets, Refuges Locked In

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



Climate Stress Index Cost: 10% Goals, No Public Land Targets, Refuges Locked In

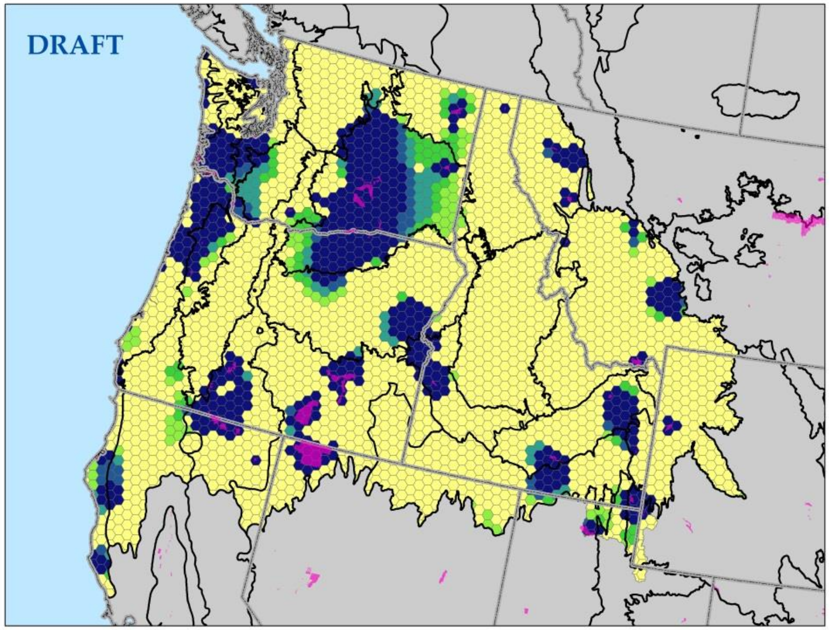
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Climate Stress Index Cost: 30% Goals, No Public Land Targets, Refuges Locked In

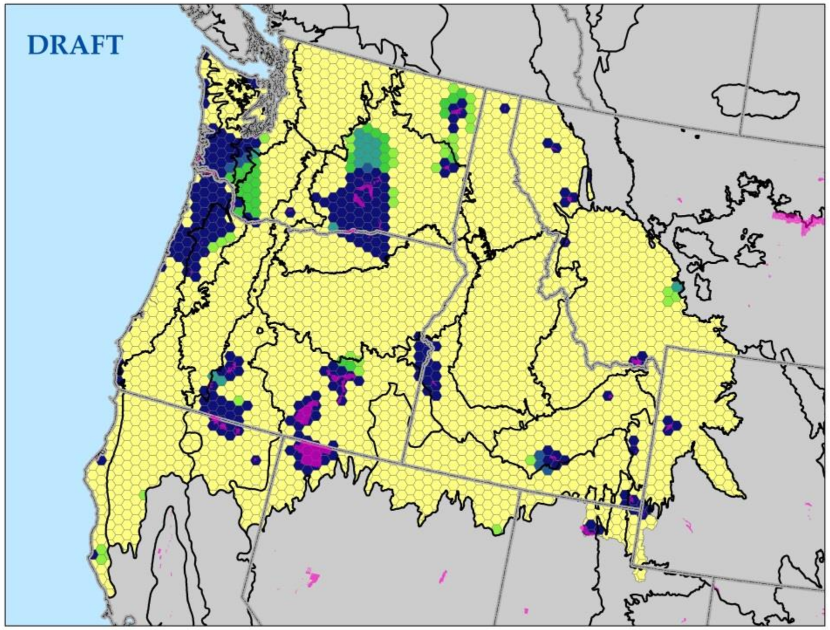
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

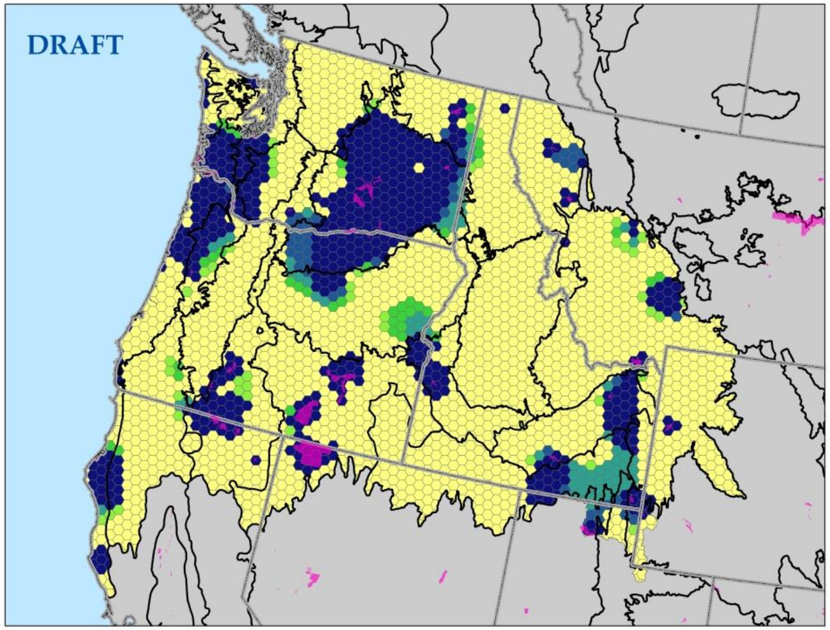
Selection frequency in solution

Low

High



Equal Cost: 10% Goals, No Public Land Targets, Refuges Locked In



Equal Costs: 30% Goals, No Public Land Targets, Refuges Locked In

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

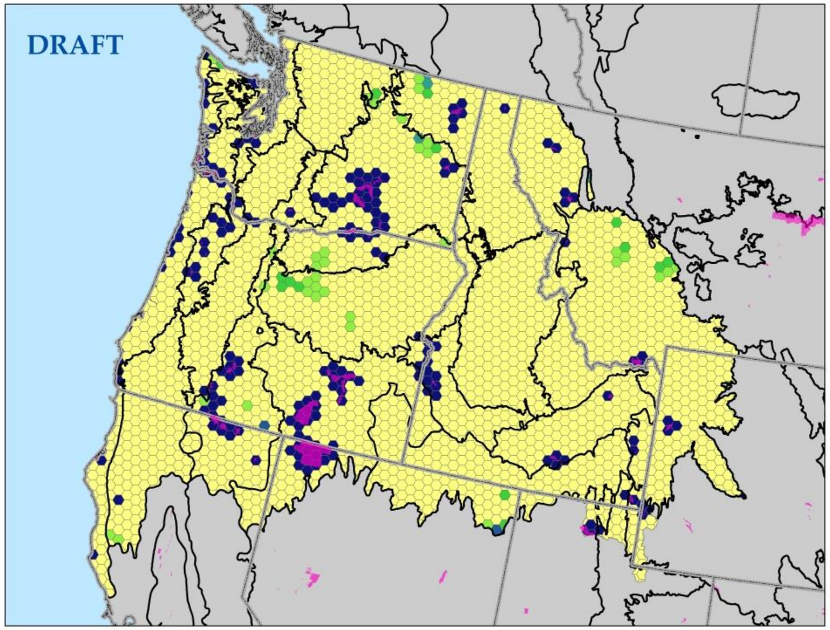
Low
High

Boundaries

FWS Refuge
State and Province
Omernik Level 3 Ecoregions

Selection frequency in solution

Low
High



Land Value Cost: 10% Goals, No Public Land Targets, Refuges Locked In

Boundaries

FWS Refuge

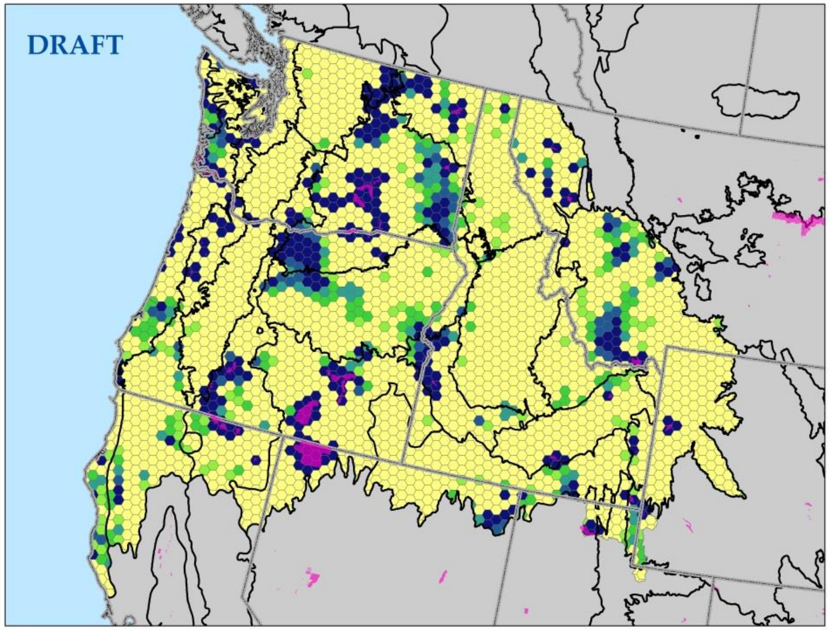
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Land Value Cost: 30% Goals, No Public Land Targets, Refuges Locked In

Boundaries

FWS Refuge

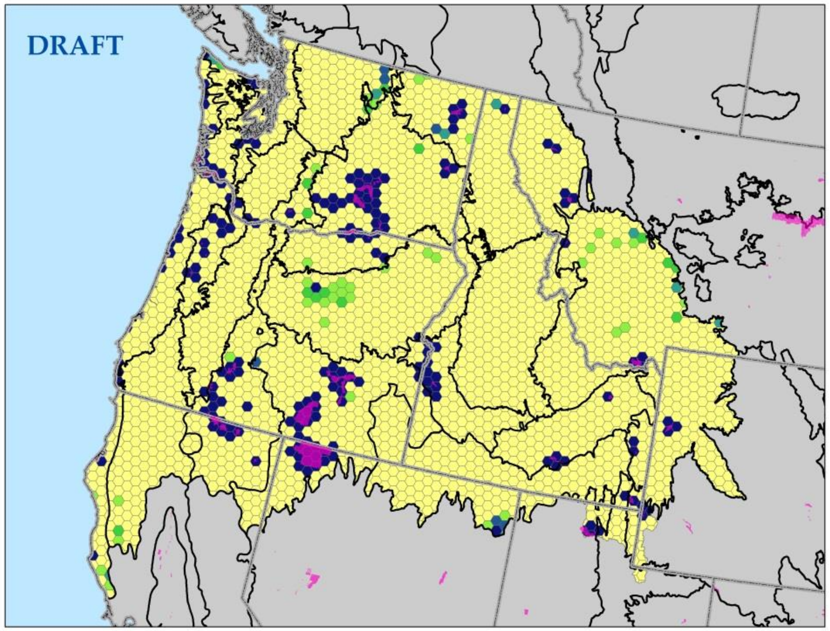
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Landscape Integrity Cost: 10% Goals, No Public Land Targets, Refuges Locked In

Boundaries

FWS Refuge

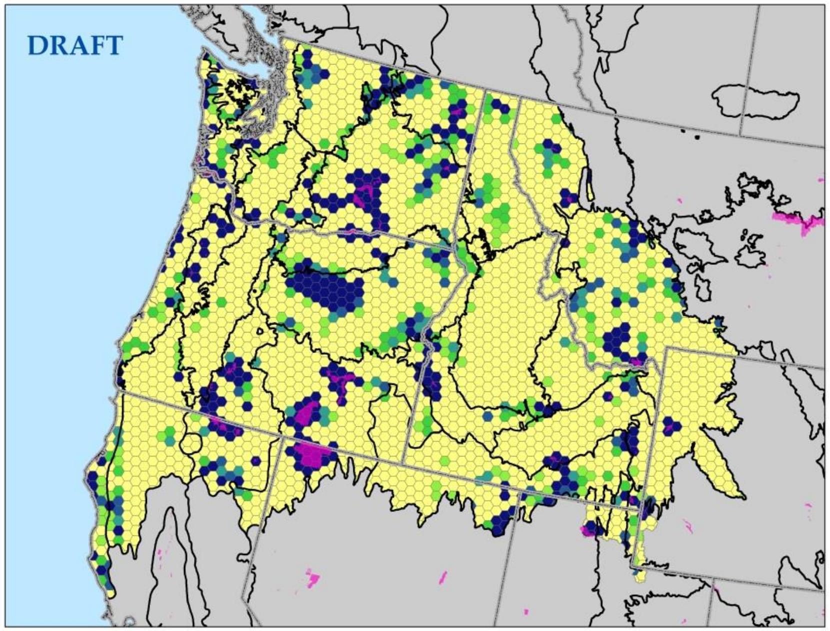
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Landscape Integrity Cost: 30% Goals, No Public Land Targets, Refuges Locked In

Boundaries

FWS Refuge

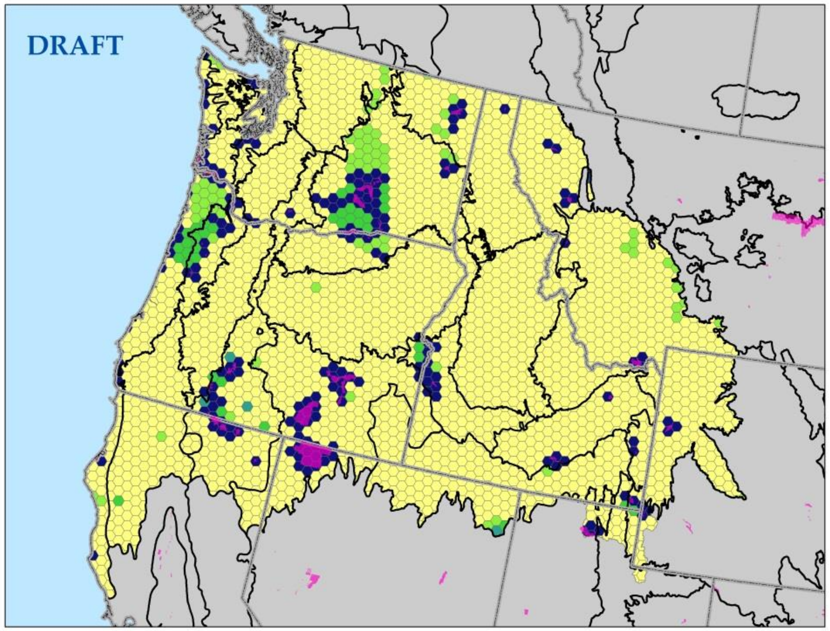
State and Province

Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Sum of all Solutions at 10% Goals:
No Public Land Targets, Refuges Locked In

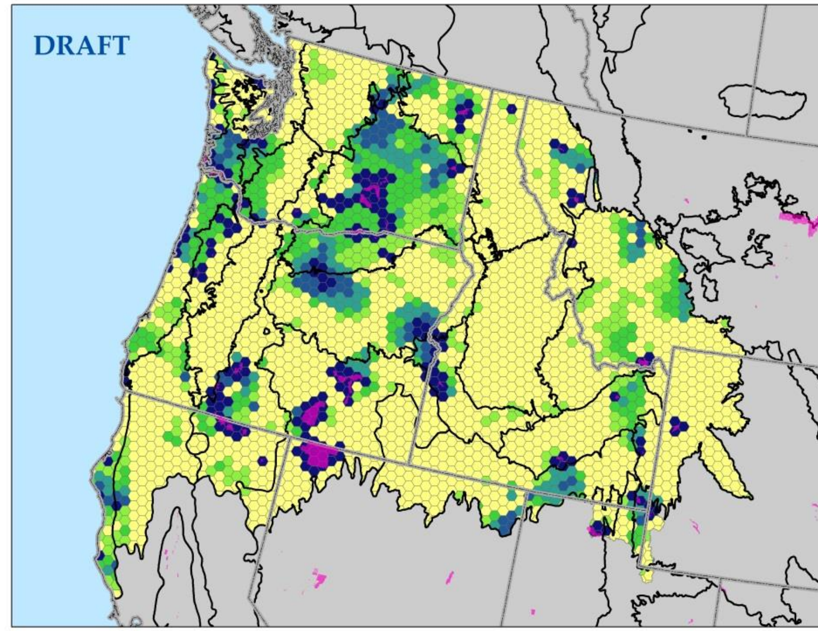
Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High



Sum of all Solutions at 30% Goals:
No Public Land Targets, Refuges Locked In

Boundaries

- FWS Refuge
- State and Province
- Omernik Level 3 Ecoregions

Selection frequency in solution

Low

High