

❖ Standard 10: Screen all target/biodiversity element occurrences for viability or ecological integrity.

Case Study: **Derivation of Suitability Index Yakima/Palouse EDU Washington**

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Purpose and region of analysis

An index of suitability was developed for Yakima/Palouse Ecological Drainage Unit in Washington. This Suitability Index can then be used in site selection algorithms to assist with freshwater portfolio selection.

Criteria/Methods

A suitability index is a function that relates a variety of factors that affect the relative conservation opportunity across the landscape, or among watersheds. The suitability index considers measurable impacts, or factors which are known to be highly correlated with impacts, to freshwater habitat and biodiversity. The suitability index also considers the probable cost, or investment of resources necessary for, conservation action. A related concept to suitability is “cost”, or the relative cost of conservation action. Cost is the opposite of suitability. Input to the site selection algorithm requires that all suitability, or cost, factors be represented by a single value. This single value must represent the combination of factors and their relative importance.

A wide range of factors was considered for the suitability index for freshwater biodiversity conservation in Eastern Washington. Selection of factors considered the following criteria:

- Data are available and consistent across the entire assessment area (EDU)
- Resolution of data is appropriate relative to scale of assessment unit and the impact or cost measured
- Applicable (quantifiable) metrics can be related to relative impact
- Data are of adequate quality and reliability

The Freshwater Advisory Group developed a preliminary list of suitability factors on May 10, 2004. This list was then further evaluated and refined in light of available data by a subcommittee consisting of Kirk Krueger and Brad Thomson (Department of Fish and Wildlife), Rob Plotnikoff (Department of Ecology), and Mike Heiner, Mark Goering and Peter Skidmore (Nature Conservancy of Washington). The subcommittee met a number of times to develop the suitability index function. The resultant function was presented to the full Advisory Group, at which point it was resolved to simplify the structure of the final function by eliminating internal coefficients within factors. For example, the land use factor in its first iteration included 5 classes of land use, each of

which was weighted within the main factor. The final version maintains land use as a main factor, but evaluates only the percent non-natural land use.

Factors selected for the suitability index

1. *Land use.* This factor refers to non-natural land uses at the watershed scale. Land use is a primary determinant of sediment and chemical inputs to a stream and impacts to hydrologic regime. NLCD data (30m resolution) will be used to determine the percent non-natural area. Non-natural land area will include the following NLCD categories: residential, recreational, mines, cropland, orchards, vineyards, pasture, small grain and fallow. Natural lands will include grassland and herbaceous, forest, shrub, wetland, bare rock, and water. Land use characterization of the watershed will exclude that area within riparian buffers, which are assessed separately.
2. *Riparian buffers.* Percent non-natural land use within riparian buffers will be evaluated to estimate the relative impact of reach-scale physical impacts. In agricultural areas in particular, riparian area land use can significantly influence or mitigate impacts to the stream. Riparian buffers will be created in a GIS by buffering NHD blue lines, and evaluating non-natural land use within these using the same NLCD land use data and categories developed for the land use factor. Buffer widths will vary by stream size according to the following guideline:
 - *Class 1:* 30m on either side of streamline
 - *Class 2:* 60 m on either side of streamline
 - *Class 3:* 120 m on either side of streamline or streambank where stream is defined by two lines
3. *Dam density.* Dam density will be measured as the ratio of number of dams to number of stream kilometers within a watershed. Dams significantly impact the timing and magnitude of flows within a stream, water temperature, and geomorphologic processes. Dam data are derived from the StreamNet database (<http://www.streamnet.org>). It is acknowledged that dams vary considerably in size, impoundment volume, and impacts to downstream and upstream habitat, biota and geomorphic processes, and that dam density is likely a very rough estimate of this impact at best.
4. *Land ownership.* The type of land ownership relates to management and the relative opportunity for cost-effective conservation efforts. Sites within publicly owned lands are and presumably less costly to enact conservation measures appropriate for freshwater species and habitats. The land ownership factor will measure percent privately owned lands (includes Tribal) within each watershed. Available land ownership data has been generated and enhanced by the Conservancy from a number of data sources.
5. *Irrigated land.* Withdrawals and diversions of water from streams can greatly impact the natural hydrologic regime, water quality and temperature, and physical habitat. However, in eastern Washington, many, if not most withdrawals and diversions are

from water bodies that have seasonally augmented flows. Withdrawal and augmentation data are not available in a format that can be consistently evaluated across the EDU. However, certain types of agricultural land use are assumed to be highly correlated with surface and subsurface water withdrawal and return flows. Using infrared satellite imagery and NLCD land agricultural land use categories, we determined that row crops, orchards, and irrigated pastureland use categories were strongly correlated with irrigated lands evidenced in satellite imagery. Diversions and withdrawals are estimated in this suitability index using this land use surrogate.

Factors that were considered but not selected for the suitability index are explained below. Where noted, some of these factors may be considered outside of the context of suitability once a preliminary conservation portfolio is generated.

- *Network location*: Network location refers to the position of a stream system relative to other reaches downstream. There will likely be occurrences of systems with relatively high suitability, but which are limited due to downstream conditions. For example, if a downstream reach has a temperature or other water quality limitation, it may affect the connectedness of upstream reaches. Evaluation of this aspect of network location, however, is considered too cumbersome for practical application. It will instead be evaluated on a case by case basis and through expert review. Upstream systems selected as important for conservation will also consider downstream limitations, but outside of the suitability index.
- *Channelization* – Channelization refers to physical alteration of the channel and its floodplain. Channelization is not explicitly included because there are no appropriate datasets. However, the riparian corridor suitability factor is intended to account for this by assuming a high degree of correlation between channelized streams and land use categories.
- *Water quality* – Available water quality data (303d) is not considered adequate in coverage to apply as a suitability factor. However, the land use across the watershed and within the riparian corridor is likely highly correlated with water quality. The combination of these two factors is intended to account for water quality.
- *Area in Conservation Reserve Program (CRP)* – Land held in CRP status can improve the quality of freshwater habitat relative to adjacent lands not held in CRP. However, CRP data is very temporal, and inconsistent in availability. Riparian buffer and land use data are intended to account for the potential influence of CRP status on habitat quality and impacts.
- *Road density* – Road density is commonly used in suitability indices. However, it is likely highly correlated with land use, and therefore considered redundant. Furthermore, in eastern Washington, where large-scale agriculture dominates much of the landscape, road density is not considered a valuable measure of impact. In agricultural landscapes there may be very low road density while 100% of the land area may be converted with substantial impact to freshwater systems. Other areas within the EDU may be forested areas with relatively high road densities, but substantially smaller impacts to habitat.
- *Barriers* – Stream barriers include small dams, culverts, and diversion dam structures. While there is a fairly comprehensive data set that identifies barriers, data has been

inconsistently collected across watersheds, and barriers are not described sufficiently to differentiate between detrimental and relatively benign impacts.

Derivation of Suitability Function

Percent non-natural land, percent non-natural riparian corridor, dam density, percent private/tribal ownership, and percent irrigated land are the five terms in the freshwater suitability index. Suitability for each freshwater planning unit (HUC-6) was calculated as:

$$\begin{aligned} 1/\text{SUITABILITY} = & A \times N(\% \text{ non-natural land use}) + \\ & B \times N(\% \text{ non-natural riparian corridor}) + \\ & C \times N(\text{dam density}) + \\ & D \times N(\% \text{ private ownership}) + \\ & E \times N(\% \text{ irrigated land}) \end{aligned}$$

where $A+B+C+D+E=1$; $N(x)$ is the normalized value of x . Because dam density is the only non-percentage value, it was also normalized by dividing each HUC's dam density value by the maximum dam density value of all HUCs so that all values for all factors fall within the range of 0 and 1.

The relative weights for A, B, C and D were determined through expert opinion using the pair-wise comparisons technique. The value for E was added to the index subsequently. To simplify the elicitation process, we used the abbreviated pair-wise comparisons technique. That is, we assumed perfect internal consistency for each expert, which allowed us to reduce the number of comparisons. A list of experts whose input was included is provided below. Weights were calculated for each expert from the eigenvalues of their pair-wise comparisons matrix. The weights from all experts for an initial suitability function with four factors were averaged and then normalized, resulting in the following relative weights: $A = 0.39$, $B = 0.36$, $C = 0.20$ and $D = 0.05$. (George Wilhere of WDFW performed the pair-wise comparisons for the Conservancy.)

The irrigated agriculture suitability factor was added after the formal expert review process. In applying the initial expert derived index, it became apparent that irrigated agricultural lands and streams that are more impacted by diversion, withdrawals and return flows were receiving higher suitability values than non-irrigated, non-diverted streams and lands. In a dominantly agricultural landscape, the distinction between irrigated and non-irrigated lands was deemed very important in the expert review process. To address this, we added percent irrigated land as a surrogate for water quality, hydrologic regime, and physical habitat impacts associated with irrigation, diversions, withdrawals, and return flows. To determine the relative weight of this factor when the others had previously been determined through an intricate expert input process, we valued withdrawal/diversion impacts as equal to dam impacts. The five values were then normalized to percentages.

Products/Outcomes

Thus the final suitability index is represented by the equation:

$$\text{Cost} = 0.32*A + 0.30*B + 0.17*C + 0.04*D + 0.17*E$$

where:

- A = % non-natural land use, excluding riparian buffers
- B = % non-natural land use within riparian buffers
- C = normalized dam density
- D = % private ownership
- E = % irrigated land

Experts consulted in suitability index:

- Dr. Robert Bilby, Chief Environmental Scientist, Weyerhaeuser Co.
- Dr. Susan Bolton, Professor of Hydrology, University of Washington, College of Forest Resources
- Carol Cloen, Washington Department of Natural Resources, Aquatic Resources Program
- Dr. Rex Crawford, Ecologist, Washington Department of Natural Resources, Heritage Program
- Dr. Peter Kiffney, Fishery Biologist, NOAA Fisheries, Northwest Fisheries Science Center
- Kirk Krueger, Research Scientist, Washington Department of Fish and Wildlife, Salmon and Steelhead Habitat Inventory and Assessment Program
- Rob Plotnikoff, Senior Aquatic Ecologist & Freshwater Monitoring Supervisor, Washington Department of Ecology
- Peter Skidmore, Manager of Freshwater Conservation Programs, The Nature Conservancy
- Dr. Ashley Steel, Quantitative Ecologist, NOAA Fisheries, Northwest Fisheries Science Center
- Dr. Brad Thompson, Research Scientist, Washington Department of Fish and Wildlife, Fish Program Science Division

Strengths and Weaknesses

This suitability index has been derived from expert opinion and using the best data available that meet data criteria. The depth and breadth of expertise and perspective of the advisors that provided guidance in the development of this analysis brings substantial credibility to this index.

The suitability index has a number of limitations that should be acknowledged:

- The data sets used for different suitability factors represent varying dates. As such, it represents the costs, impacts and suitability at varying points in time. Typically, the data are less than 10 years old. As such, the index may not capture recent changes in management or land use, nor does it represent trends or predictions for future changes.

- Quantification of suitability is a complicated nut to crack. Many suitability indices consist of numerous weighted factors, each with a suite of weighted subfactors. For example, the Land Use factor may consist of numerous classes of land use. We have opted to simplify all factors, and not include subfactors. In the opinion of our advisors, the uncertainty resulting from the mathematical complexity associated with weighted factors and weighted subfactors diminishes the value and legitimacy of the resultant index. However, this also limits the suitability index by generalizing relatively specific data. Land use, for example, has been simplified to two classes, natural and non-natural. While this does not allow us to differentiate among finer land use distinctions, it provides for a total suitability index that is more transparent and mathematically valid.
- Assessment units for the suitability indices included HUC6s, Class 2 watersheds, and Class 3 watersheds. HUCs are convenient because they provide wall-to-wall coverage and are widely recognized and used by state and federal agencies. Using HUCs for suitability has limitations. First and foremost, HUCs are not true watersheds, particularly in the arid areas and regions with poorly defined drainage networks of this EDU. As such, the assessment units often represent arbitrary clusters of small watersheds, and arbitrary boundaries dividing larger basins. Where suitability is assessed for the entire HUC or Class 2 or 3 watershed, it does not differentiate among varying degrees of suitability within smaller watersheds.

A number of additional data sets have been identified that may prove useful to improving the suitability index in future iterations or applications. These include:

- *Aquatic Integrity Measures (ICBEMP)*: Aquatic Integrity Measures is a dataset developed by ICBEMP that evaluates the integrity of fifth field HUC watersheds with respect to their species composition and the sensitivity of component populations. It is primarily a measure of native species richness, but has many component data fields which may be of interest or value.
- *Management Area Categories (ICBEMP)*: This dataset classifies Columbia Basin lands into 6 categories of current management direction of the US Forest Service and BLM. This may be valuable in checking selected occurrences of freshwater systems for suitability, but will not be incorporated in the suitability index.