Technical Supplement:
Procedures Used to Refine, Re-calibrate, and Test ORWAP version 3.1

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1.0 ORWAP Development and Refinement

1.1 Development of ORWAP 1.0 – 2.0.2 (2006-2010)

ORWAP originated in the 2003 state legislative session where a need for a statewide rapid assessment method was identified. The Department of State Lands (DSL) convened a Technical Advisory Committee (TAC) to scope out recommendations for addressing this need. In addition, an interagency "steering group" was formed to ensure that the recommendations coming out of the TAC process would result in a rapid wetland assessment method that could be endorsed and used by all agencies with a wetland regulatory role in Oregon. The final report—*Recommendations for Developing a Statewide Rapid Wetland Assessment Protocol for Oregon*, January 23, 2006—included 18 detailed recommendations for ORWAP design and development and a separate section of policy and implementation recommendations.

In 2006, DSL obtained a Wetland Program Development Grant from EPA to develop ORWAP. In a competitive solicitation, Dr. Paul Adamus was selected to create ORWAP. The expanded "Development Phase TAC" provided guidance and feedback during ORWAP development, calibration, and testing. Ideas and feedback were also provided by land managers throughout the state during an extensive field calibration effort, and by six wetland consultants contracted to independently examine the clarity of the evolving ORWAP forms (see Acknowledgments in Appendix D of the ORWAP 3.1 Manual). The resulting ORWAP calculator and manual were publicly released in May 2009, followed by several trainings for agency staffs and consultants.

1.2 Development of the Current Version of ORWAP

In 2011, an effort was initiated to refine ORWAP. The goals were:

- improve the clarity of particular questions to help ensure more consistent interpretation
- streamline the data forms to whatever extent possible to increase speed, without compromising accuracy and repeatability of results
- improve the transparency of the logic behind the spreadsheet calculations
- refine the models to reflect evolving science and observations of users
- calibrate scores to a new, more statistically-valid series of wetlands
- automate the comparison of raw scores to the scores of the new calibration wetlands
- test the repeatability of the revised version and use the results to redefine the statistical confidence intervals of the scores
- expand the capabilities and improve the efficiency of the online ORWAP Map Viewer

These are described in the following sections. The refinements were funded largely by an EPA Wetlands Program Development grant to DSL. The original ORWAP author implemented all the refinements iteratively with DSL staff.

1.2.1 Data Form Revisions

First, by means of an online survey, DSL asked known ORWAP users to identify issues they had encountered when doing assessments. As a result, several questions were reworded for

clarification; some that required users to consider multiple factors simultaneously were broken into separate questions; descriptive clarifications and more definitions were added in the Explanations column of the data forms. Also, questions were reordered so that (a) non-tidal and tidal field indicators are on separate field forms, (b) indicators that do not apply to a specific wetland are skipped, and (c) where practical, indicators are grouped by the season at which they should be assessed. Second, during the years after ORWAP version 2.0.2, the author created similar spreadsheet tools for agencies in Alaska, Alberta, Nova Scotia, and New Brunswick, and while doing so and training consultants in their use, obtained extensive input that was utilized to create a refined ORWAP (V.3.0).

Third, ORWAP v.3.0 was used with a statistically valid sample design to select and then assess 200 new calibration sites (see next section). Using data from the 200 assessed wetlands, a statistical correlation analysis was performed between their function scores and the scores of indicators (questions) which determined those scores. The analysis identified which questions tended statistically to have the least and greatest influences on scores of each function. It suggested questions that might be dropped or consolidated with others, with the caveat that the results were strictly applicable only to those particular wetlands. DSL convened a workgroup that considered the statistical significance of the correlations as well as ecological significance and user knowledge. As a result of these inputs, ORWAP scoring models were strengthened considerably and 9 questions on ORWAP's v.3.0 form OF, 16 on form F, and 4 on form S were eliminated.

1.2.2 New Calibration

Background

"Calibration" is the process of creating a database of the scores from a large number of reference wetlands, so that scores from future assessments of wetlands can be placed in the context of ("normalized to") the scores from those reference wetlands. During the initial development of ORWAP in 2006-2009, a calibration database was created that consisted of scores from 221 reference wetlands from across the state. However, although those wetlands were selected to be as representative as possible, limited resources at that time did not allow selection of wetlands likely to span a gradient of expected wetland function. Also, few of those wetlands were on private lands. Therefore, that reference database was less than optimal for comparing the scores from other wetlands. Subsequently, DSL solicited funds from USEPA to improve the statistical validity of the reference data set that provides the basis for normalizing ORWAP scores. This was necessary for ORWAP to be used appropriately in a new functions-based mitigation program.

The new calibration approach consisted of two steps:

1. Using only existing spatial data and GIS, assign categories (0 to 3 - intended to approximate low to high relative level of each function) to all mapped Oregon wetlands. Compile this in a geodatabase.

2. Using that geodatabase as the sampling frame, select a stratified sample of 200 accessible wetlands. Visit and assess them, compiling their scores into a new calibration database.

Creating the Geodatabase for the New Calibration Approach

A geodatabase was created by Matt Paroulek, an intern at DSL, as part of his graduate work at Portland State University. Termed the Level One Landscape Assessment (LOLA) geodatabase, it was built by intersecting wetland polygons from the Oregon Wetlands Geodatabase (the same ones used by the Oregon Explorer web site) with the USGS National Hydrologic Dataset (1:24,000 scale), the BLM's Oregon Hydrography Publication Dataset, and several other spatial data layers. Tiner's (2003) GIS based NWIPlus approach was used to attribute each wetland polygon with one or more descriptors to characterize hydrogeomorphic relationships to the surrounding landscape. In addition, spatial data on anthropogenic stressors in the immediate surrounding landscape were compiled into a data layer and index, and intersected with the mapped wetlands.

Assumptions were made about the likely relationship of the existing data layers to eight function groups: Surface Water Detention, Nutrient Transfer, Sediment Retention, Waterbird Support, Fish Support, Aquatic Invertebrate Support, Amphibian Support, and Temperature Regulation. Those assumptions were coded as GIS queries in the same general manner that ORWAP codes its assumptions as formulas in an Excel spreadsheet. Attempts were made to pattern the GIS queries conceptually after the models in ORWAP, with input from ORWAP's developer. However, the outputs from the ORWAP and LOLA are not comparable due mostly to different data sources measured at drastically different scales, with ORWAP featuring many more indicators and functions, most assessed directly in the field. Details about the methods used are in a report by Paroulek (2015).

Selecting Calibration Wetlands from the Geodatabase

EPA's Office of Research and Development, Western Ecology Division (Corvallis) assisted in the sampling design. Although a case could be made for selecting the calibration wetlands in a statistically random but spatially-distributed manner (e.g., Stevens & Olsen 2004), the available time, resources, and the specific objectives of this field calibration did not allow for that. Instead, a stratified sample was selected that was stratified by the range of approximate function levels (0 to 3) as hypothesized for the eight functions of every wetland by ORLAWF. This was implemented within each of Oregon's seven "Omernik level III" ecoregions. The levels defined were:

High_6_8_LowNo_0_2_Med_0_2
High_3_5_LowNo_3_5_Med_0_2
High_3_5_LowNo_0_2_Med_0_2
High_3_5_LowNo_0_2_Med_3_5
High_0_2_LowNo_6_8_Med_0_2
High_0_2_LowNo_3_5_Med_0_2
High_0_2_LowNo_3_5_Med_3_5
High_0_2_LowNo_3_5_Med_3_8

For example, High_6_8_LowNo_0_2_Med_0_2 means that 6-8 of the functions were assigned high function, 0-2 of the functions were assigned low or no function and 0-2 of the functions were assigned medium function. The total for a wetland polygon was 8.

A Generalized Random Tessellation Stratified (GRTS) survey design was used. The total base sample site draw was 200 sites that resulted in a total of 28 (or 30) sites for each ecoregion. An additional 400 oversample sites were pulled. If it was necessary for a site in a stratum to be replaced, the lowest ordered SiteID that is part of the over sample of sites in that stratum had to be used. This could occur due to (1) sites not being a member of the target population, (2) landowners deny access to a site, (3) a site is physically inaccessible (safety reasons), or (4) site not sampled for other reasons. When sites were replaced, the survey design weights were no longer correct and had to be adjusted. This approach helped ensure that the selected calibration wetlands together were diverse in terms of levels of probable functions, geography, and other factors.

Selected wetlands were visited and assessed by two ORWAP-trained wetland specialists from DSL. The forms and indicator questions they used (version 3.0) to assess the wetlands are virtually the same as the final (version 3.1) forms and questions, differing only in the wording of a few questions that did not change their meaning and deletion of 29 indicator questions Additional information about the survey design can be found in DSL's Quality Assurance Project Plan (QAPP). Section 2.3 of this report describes the subsequent use of this calibration database of wetland scores for normalizing the scores of wetlands assessed hereafter.

1.2.3 Development and Refinement of the ORWAP Map Viewer Web Site

The growing availability of spatially-explicit natural resource data on the internet has greatly expanded the opportunity for agencies to use such data to improve the accuracy and comprehensiveness of their resource assessments, including wetlands. Noticing this potential in 2007, the Institute for Natural Resources (INR) at Oregon State University received a grant from the USEPA to develop an interactive, online, spatial data portal focused specifically on compiling and delivering to ORWAP users a substantial part of the data needed to complete an ORWAP assessment. A key feature of the portal is its "online GIS" capability, created so that users who don't have the software or skills to do GIS queries in their own office may do so online with digital maps that are most relevant to wetlands. The portal was initially termed the Wetlands Reporter but has been renamed the ORWAP Map Viewer. It is part of INR's Oregon Explorer, a web site that contains more readily-accessible online information pertaining to spatial distribution of Oregon's natural resources than perhaps any other web site. The portal will be maintained permanently at the Oregon State University Library as part of its Oregon Explorer web site. In 2015, the ORWAP Map Viewer was updated, expanded, and given additional capabilities in order to provide most of the data needed to complete an ORWAP assessment. It is at: http://oregonexplorer.info/content/oregon-rapid-wetland-assessment-protocol-orwap-map-viewer. Section 3.1.2 of the ORWAP 3.1 Manual describes its use.

1.2.4 Supplemental Information

A spinoff from the creation of the geodatabase described in section 1.2.2 was a table (called FuncDeficit, now a worksheet in the ORWAP3.1_SuppInfo file) that ORWAP's author used to identify -- for every Oregon watershed (12-digit HUC) -- the wetland functions that appear to be deficient in that watershed. This is used to answer question OF15 of ORWAP 3.1. If a watershed is considered deficient in a given function, the ORWAP spreadsheet potentially increases the *value* score for any wetland in that watershed which ORWAP determines may have that function. "Deficient" was determined as follows: First, the *number* of wetlands per watershed that were rated moderate or high (2 or 3) for a particular wetland function was determined. Then the 10th percentile of that number was determined. Similarly, the cumulative *acreage* of wetlands per watershed that were rated moderate or high (2 or 3) for a particular wetland function was determined. Then the 10th percentile of that acreage was determined. Finally, every Oregon watershed that fell below the 10th percentile for either number *or* area of wetlands rated moderate-high for the given function was labeled "deficient" in that function. "Deficient" was defined as having a rating of moderate or high (2 or 3) but occurring at a frequency that is less than the 10th percentile for that watershed, or with a cumulative area that is less than the 10th percentile for that watershed.

1.2.5 Guidance from Regulatory Implementation Team

Although ORWAP is designed to be used for many purposes, the primary driver for developing ORWAP was the need for a rapid assessment method that was suitable for assessing all types of wetlands, statewide, for state permitting purposes. In order to ensure that ORWAP design and output would work well within the regulatory framework, in 2007 DSL assembled a small team to develop agency guidance on how to use ORWAP output for permitting, before ORWAP was completed. One recommendation from that effort was that functions and values also be aggregated into a smaller number of into closely related “groups.” Another recommendation was that users be allowed to compute scores for areas that are smaller than an entire wetland. The guidance document—*Guidance for Using the Oregon Rapid Wetland Assessment Protocol (ORWAP) in State and Federal Permit Programs* (Oregon Department of State Lands, May 2009)—was developed. Updated guidance for ORWAP will be released with ORWAP v.3.1 and is available from DSL.

2.0 Principles Used to Identify Indicators and Combine Into Models

2.1 Indicators

ORWAP’s indicators were mainly drawn from inferences based on scientific literature and the author’s experience throughout North America (e.g., Adamus 1983, 1992, 2013, Adamus et al. 1987, 1992, 2015, and 2016). Indicators used by other methods for rapidly assessing functions of wetlands in North America were also considered. For most of ORWAP's models of wetland functions, physical or biological processes that influence a given function were first identified and then rapid indicators of those processes were chosen and grouped accordingly into

submodels. (The term “indicators” is comparable to the term metrics used by some other methods). Indicators are manifested as "questions" on the ORWAP data forms although many are worded as true/false statements.

To qualify as an indicator, a variable not only had to be correlated with or determining of the named process or function, but it also had to be rapidly observable during a single visit to a typical wetland during the growing season, or information on the indicator’s condition had to be obtainable from aerial imagery, existing spatial data, and/or landowner interview. None of ORWAP’s field-based indicators require measurement; they all are based on visual estimates. While the precision of measurements is typically greater than for visual estimates, their accuracy in predicting functions may or may not be. That is because it is often difficult to obtain sufficient measurements of an indicator, in the span of time typically available to wetland regulators or consultants, to create a full representation of any particular indicator of wetland function, let alone all the indicators that would be needed to assess a common suite of functions.

For regulatory and management applications (e.g., wetland functional enhancement), it’s often helpful to understand to which of four categories an indicator belongs:
1. **Onsite modifiable**. These indicators are features that may be either natural or human-associated and are relatively practical to manage. Examples are water depth, flood frequency and duration, amount of large woody debris, and presence of invasive species. More important than the simple presence of these are their rates of formation and resupply, but those factors often are more difficult to estimate and control.
2. **Onsite intrinsic**. These are natural features that occur within the wetland and are not easily changed or managed. Examples are soil type and groundwater inflow rates. They are poor candidates for manipulation when the goal is to enhance a particular wetland function.
3. **Offsite modifiable**. These are human or natural features whose ability to be manipulated (in order to benefit a particular wetland function) depends largely on property boundaries, water rights, local regulations, and cooperation among landowners. Examples are watershed land use, stream flow in wetland tributaries, lake levels, and wetland buffer zone conditions.
4. **Offsite intrinsic**. These are natural features such as a wetland’s topographic setting (catchment size, elevation) and regional climate that in most cases cannot be manipulated. Still, they must be included in a wetland assessment method because of their sometimes-pivotal influence on wetland functions.

2.2 Weighting and Scoring

Explicitly or implicitly, ORWAP assigns relative weights or scores at four junctures:

1. Scoring of the conditions of an indicator variable, as they contribute to that indicator’s prediction of a given wetland process, function, or other attribute.
2. Scoring of indicators (metrics) relative to each other, as they together may predict a given wetland process, function, or other attribute.
3. Scoring of wetland processes, as they together may predict a given wetland function or other attribute.
4. Combining scores for 15 of the 16 wetland functions into function group scores (5 per wetland).

Each of these is now described.

2.2.1 Weighting of the Conditions of an Indicator

As an example of #1, consider the following conditions of the indicator, Ponded Water Percentage as it is applied by ORWAP to estimate the Waterbird Feeding Habitat function:

B	C	D	E	F	G
All Ponded Water as Percentage - Wettest (PondWpctWet)	When water levels are highest during a normal year, the surface water that is ponded continually for >6 days occupies:				0.00
	<1% or none of the AA. Surface water is completely or nearly absent then, or is entirely flowing. SKIP TO F22.	0	0	0	
	1-5% of the AA.	0	1	0	
	5-30% of the AA.	0	2	0	
	30-70% of the AA.	0	3	0	
	70-95% of the AA.	0	4	0	
	>95% of the AA.	0	5	0	

Each row following the first one describes a possible condition of this indicator. Users select the one condition that best describes the wetland being assessed by entering a "1" next to that condition in column D. In column E, ORWAP's author previously assigned relative weights to each of these conditions as they relate to the function. They cannot be altered by users. In this case, the last condition (>95%) was considered most supportive of that function, other factors being equal, and so had been given a weight of five. This does not necessarily mean it is 5 times more influential than the condition which has a weight of 1, because this is not a mechanistic model. However, available literature seemed to suggest that this condition is distinctly better than the other condition choices, and so it was assigned a weight of 5. When the same indicator is used to score a different function or value, the weight scheme might be reversed or otherwise differ.

In many instances, considerable scientific uncertainty surrounds the exact relationship between various indicator conditions and a function, and thus which weights should be assigned. However, keep in mind that Ponded Water is just one of 34 indicators used to assign a score to the Waterbird Feeding Habitat function. To some degree, the use of so many indicators, some of them seemingly redundant, will serve to buffer the uncertainty in our knowledge of exact relationships, and the additional time they add to performing the assessment is miniscule.

Also, in the ORWAP worksheets it is apparent that the weighting scale for some indicators ranges from 1 to 8 while for others it ranges only from 0 to 2, or some other range. This does not mean that the first indicator is secretly being weighted 4 times that of the second, because before the indicators are combined, their scores are normalized" to a 0 to 1.00 scale. The Excel spreadsheet accomplishes that by multiplying the "1" signifying a user's choice (in column D) by the pre-determined condition weight in column E, and placing the product in the last column, whereupon a formula (not visible here) in the green cell takes the maximum of the values

pertaining to this indicator in that last column and divides it by the maximum weight in column E, the condition weight column. The formula in the green cell could just as easily have taken the only non-zero value in the last column and divided it by the maximum weight pre-assigned to the indicator conditions.

Note also that the weight scale for some indicators begins at 0 while for others it begins at 1. Often, "0" was reserved for instances where, if the indicator was the only one being used, that condition of the indicator would suggest a nearly total absence of the function. Because each of the indicator scores is normalized, this difference (0 vs. 1) at the bottom end of the scales for different indicators is probably trivial.

2.2.2 Weighting and Scoring of the Indicators of Wetland Functions and Values

Many models in ecology and especially hydrodynamics are mechanistic. That is, rates are first estimated or measured for individual processes that comprise (for example) a river channel function, and then mathematical formulas (e.g., hydraulic or thermodynamic equations) are prescribed to combine variables that determine those processes into an actual rate for a function, e.g., grams of phosphorus retained per square meter per year. However, generally applicable measurements of the processes and the variables that determine them simply do not exist for the types of wetlands occurring in much of the study area. Attempts have been made to build such models on whatever regional data do exist but due to the lack of data involving direct measures of wetland function from a broad array of wetlands, ORWAP uses a different approach to model the various things that wetlands do naturally. Rather than being mechanistic, that approach is at times speculative but logic-based and heuristic. Such approaches are well-regarded as an interim or alternative solution when knowledge of system behavior is scant (e.g., Haas 1991, Starfield et al. 1994).

The particular mathematical-logic formulas used in ORWAP's scoring models were drawn initially from the scientific literature and the principal author's understanding of wetlands, with consideration for the usual importance of different indicators and their relative contribution to ecosystem processes that determine specific wetland functions (i.e., whether and when a given indicator is likely to be controlling/ limiting or simply additive/compensatory). Each indicator's potential interactions with other indicators and its likely repeatability were also considered.

Although each scoring model has a theoretical minimum score of 0 and a maximum of 10 (even without scaling), the actual range may be narrower because the conditions of some indicators rarely or never occur together in the natural world. Thus, as depicted by the histograms in Appendix A, the output scores of all models will not necessarily have the same statistical distribution. That is, scores generated by some models will skew high (e.g., more than half the time they will be above 8 on the 0 to 10 scale) whereas the scores generated by other models will skew low (e.g., more than half the time they may be 0). Because these are scoring models, not mechanistic equations, the high or low skew could be due to either (a) one function tending to be inherently less effective than another among wetlands generally, or (b) the relative conservativeness (or lack thereof) of the particular indicators and their criteria as used in a model for a particular function or other attribute. It is not possible to determine which is more often the case. One implication of the factors described in this paragraph is that ORWAP may be

somewhat more reliable in distinguishing differences of levels of a single function among wetlands, than in distinguishing differences among functions in a single wetland, i.e., ranking correctly the effectiveness or value of those functions relative to each other.

When developing models of any kind, the factors that contribute to the output can be categorized in three ways: (1) unknown influencers, (2) known influencers that are difficult to measure within a reasonable span of time, and (3) influencers that can be estimated visually during a single visit and/or from existing spatial data. ORWAP provides an incomplete estimate of wetland functions because it incorporates only #3. Also, some of the indicator variables it uses may be correlates of wetland functions rather than actual influencers. For example, changes in water levels are correlated with changes in nutrient cycling, but it is the difficult-to-measure changes in sediment oxygen and pH that induce the changes in nutrient cycling, not the water level changes themselves (which happen to correlate loosely with those changes in oxygen and pH). These types of limitations apply to all rapid assessment methods.

In most cases, ORWAP does not assign weights so explicitly (i.e., as multipliers) to the various indicators of a function. More often, weights are implicit in the manner in which indicators are combined. For example, if a function model is:

Indicator A + (Average of: Indicator B, Indicator C, Indicator D)

This implies that Indicators B, C, and D individually are likely to contribute less to the function score than Indicator A because they are only contributing to an average rather than standing alone, and as such, a low score for one may compensate somewhat for a high score of another.

If the occurrence of a particular condition of an indicator is so important that it can solely determine whether a function even exists in a wetland, then conditional ("IF") statements are used in ORWAP models to show that. For example, if a wetland's water regime is ephemeral, it is not in a floodplain, and it contains no inlets or outlets, the Anadromous Fish Habitat function is automatically scored "0". In this case, "access" (presence/absence of inlets or outlets) is a controlling indicator. If a few indicators are not individually so controlling but at least one is likely to be strongly limiting in some instances, ORWAP takes the maximum among of the indicators. The average is applied to situations where indicators are thought to be compensatory, collinear, or redundant. ORWAP uses averaging as the default operator unless situations can be identified where there is compelling evidence that an indicator is controlling or strongly limiting.

There also are instances where the condition of one indicator (such as wetland type) is used to determine the relevance of others for predicting a wetland function. For example, the effect of vegetation structure within a wetland on the wetland's ability to slow the downslope movement of water in a watershed can be ignored if the wetland has no outlet channel. In the ORWAP calculator spreadsheet, all such contingent relationships among indicators that we identified and incorporated into ORWAP models are documented in the Rationale column.

2.2.3 Weighting and Scoring (Modeling) of Wetland Processes That Influence Functions

For many functions, dozens of hydrologic (e.g., evapotranspiration) and/or ecological (e.g., juvenile dispersal) processes contribute to its ultimate level of performance. Often, too little is

known about the relative importance of these processes in determining a wetland function, and for some processes there are no known indicators that can be estimated visually. Nonetheless, we identified processes as an organizing framework for the many indicators ORWAP employs to score most functions. For most functions, the processes are weighted like indicators and used as a "subscore" when computing the score for a function. For example, for the function Phosphorus Retention, the function model contains these processes:
[(3*Adsorb + 2*AVERAGE(Connec, Desorb) + AVERAGE(IntercepWet, IntercepDry)] /6

That means that Adsorption was given half (3/6) of the weight, the average of Connectivity and Desorption was given one-third (2/6) of the weight, and the average of Dry Interception and Wet Interception was given 1/6 of the weight. They are divided by 6 because that is the sum of their weights (3 + 2 + 1) and the resulting function score, for the sake of clear comparisons, must be normalized to the 0 to 1 scale used by all functions.

2.3 Normalizing of ORWAP Function and Value Scores

The term "normal" (as in "normalizing") as used by ORWAP is not used in the same sense statisticians use it to denote a distribution of scores that is statistically normal. Rather, it describes the process by which raw scores from the 200-wetland data set, which collectively did not always fill out the full 0 to 10 scale, were reset so that, for each function or value, the minimum raw score became 0 and the maximum became 10. Normalizing is the first step (followed by assigning relative ratings; see section 2.4) in preparing the data to more fairly address the question, “How does this wetland compare with a large set of others in Oregon?” The normalizing process, which was applied to the scores for each function, employed this widely-recognized formula:

$$\frac{\text{raw score of “wetland x” – minimum raw score from all calibration wetlands}}{\text{maximum raw score of all calibration wetlands - minimum raw score of all calibration wetlands}}$$

The calibration wetlands are the 200 wetlands of all types that were carefully selected using the statistical procedures described in section 1.2.2. The number of calibration wetlands was not sufficient to allow statistically-valid normalizing of function scores by major watershed or wetland type, e.g., comparing tidal wetlands only to other tidal wetlands, comparing subalpine depressions only to other subalpine depressions.

2.4 Assigning Descriptive Terms (Ratings) to Scores

To more readily convey meaning to the scores, a rating (Lower, Moderate, Higher) was placed next to each function and value score after the scores were computed and normalized. For a given function or value, this was based on natural breaks in the statistical distribution of the normalized scores among all calibration wetlands. Those natural breaks were identified using a popular statistical procedure called Jenks Optimization (Jenks 1967). This procedure is relatively objective and uses iterative calculations with gradual adjustments in group membership to minimize variance within groups while maximizing the variance between groups. Because different functions had different statistical distributions of their calibration wetland scores

(**Table 1** and Appendix A histograms), the natural breaks for any given function will typically occur at different numeric thresholds than those of other functions. That is why, say, a score of 4.7 for one function will result in a rating of Moderate whereas for another function the same score will result in a rating of Lower. The terms Lower (instead of Low) and Higher (instead of High) are used to remind users that ORWAP represents relative (i.e., compared to the 200 reference sites) rather than absolute measures of function and value.

The ORWAP 3.1 Scores worksheet also contains columns titled "Rating Break Proximity". In those columns, “LM” indicates that the score is close to (within the statistical confidence interval of) the break between Lower and Moderate ratings. “MH” indicates that the score is close to the break between Moderate and Higher ratings. Confidence intervals (**Table 2**) were based on testing of score repeatability among users. If conditions at a site are being compared at different points in time (e.g., pre- vs. post-restoration, pre- vs. post-impact) and ORWAP shows a shift in a particular function or value occurring between Lower and Moderate **but** the LM notation appears next to that function or value, it indicates that the apparent change may not be statistically significant because it is within the expected range of variation measured among ORWAP users. Likewise with a shift between Moderate and Higher. And likewise if two wetlands (rather than one wetland at two points in time) are being compared.

Table 1. Thresholds of normalized scores used to determine ratings of functions and values scored by ORWAP 3.1.

	Thresholds for Function Rating		Thresholds for Value Rating	
Function or Other Attribute:	"Lower" IF:	"Higher" IF:	"Lower" IF:	"Higher" IF:
Water Storage & Delay (WS)	≤ 4.07	≥ 6.69	≤ 2.85	≥ 6.56
Water Cooling (WC)	≤ 2.46	≥ 5.05	≤ 2.00	≥ 4.75
Sediment Retention & Stabilization (SR)	≤ 3.60	≥ 6.62	≤ 3.15	≥ 5.89
Phosphorus Retention (PR)	≤ 3.12	≥ 6.08	≤ 3.42	≥ 6.54
Nitrate Removal & Retention (NR)	≤ 3.91	≥ 6.96	≤ 3.40	≥ 7.42
Carbon Sequestration (CS)	≤ 3.84	≥ 6.15	N.A.	N.A.
Organic Nutrient Export (OE)	≤ 0.01	≥ 6.93	N.A.	N.A.
Anadromous Fish Habitat (FA)	≤ 0.01	≥ 7.77	≤ 1.67	≥ 5.58
Resident Fish Habitat (FR)	≤ 0.01	≥ 6.08	≤ 1.21	≥ 4.86
Aquatic Invertebrate Habitat (INV)	≤ 4.44	≥ 6.92	≤ 3.07	≥ 5.83
Amphibian & Reptile Habitat (AM)	≤ 4.16	≥ 6.82	≤ 4.45	≥ 6.67
Waterbird Feeding Habitat (WBF)	≤ 2.51	≥ 6.30	≤ 2.50	≥ 6.67
Waterbird Nesting Habitat (WBN)	≤ 0.01	≥ 6.98	≤ 1.72	≥ 6.61
Songbird, Raptor, & Mammal Habitat	≤ 3.69	≥ 5.70	≤ 4.17	≥ 7.50
Native Plant Diversity (PD)	≤ 0.01	≥ 6.60	≤ 4.29	≥ 6.67
Pollinator Habitat (POL)	≤ 0.01	≥ 6.73	≤ 2.27	≥ 5.15
Public Use & Recognition (PU)	N.A.	N.A.	≤ 3.97	≥ 6.72
Wetland Sensitivity (SEN)	N.A.	N.A.	≤ 2.25	≥ 4.44
Wetland Stressors (STR)	N.A.	N.A.	≤ 3.93	≥ 7.47
Wetland Ecological Condition (EC)	N.A.	N.A.	≤ 2.92	≥ 5.16

2.5 Groups

In the Scores worksheet, ORWAP function and value ratings are also automatically rolled up into five groups based on thematic categories. The five groups are:

- Hydrologic Function – represented by Water Storage & Delay (WS);
- Water Quality Support – represented by Sediment Retention & Stabilization (SR), Phosphorus Retention (PR), or Nitrate Removal & Retention (NR);
- Fish Habitat – represented by Anadromous Fish Habitat (FA) or Resident Fish Habitat (FR);
- Aquatic Habitat – represented by Amphibian & Reptile Habitat (AM), Waterbird Nesting Habitat (WBN), or Waterbird Feeding Habitat (WBF);
- Ecosystem Support – represented by Aquatic Invertebrate Habitat (INV), Water Cooling (WC), Native Plant Diversity (PD), Songbird, Raptor & Mammal Habitat (SBM), or Organic Nutrient Export (OE).

The Department of State Lands determined that, in any assessed wetland, the specific function selected to represent a function group is that with the highest-rated function and the highest-rated associated value from among the group's members. This method results in a selection order of (function rating/value rating): H/H → H/M → H/L → M/H → M/M → M/L → L/H → L/M → L/L.

One function, Carbon Sequestration, was not assigned to any group. Additionally, there are no groups representing the other scored attributes of Public Use & Recognition (PU), Wetland Sensitivity (SEN), Wetland Stressors (STR), and Wetland Ecological Condition (EC).

It is recognized that some thematic overlap exists among the groups. For example, water quality functions also provide ecosystem support, and the Water Cooling function -- currently in the Ecosystem Support Group -- could also be considered a hydrologic or water quality function.

2.6 Other Considerations

It is not possible to state with certainty for how long the scores of any wetland, including those in ORWAP's calibration database, will remain valid. That will depend on forecasting the likelihood of short and long-term changes in climate, sea level change, beaver activity, natural succession of vegetation, land cover changes in nearby areas, and a host of other factors. A particular wetland's capacity to resist functional change in response to these individual or cumulative factors usually cannot be predicted with confidence. Major changes in any of these factors that are apparent in a wetland or within a few miles, especially along connected streams, could suggest a need to reassess the wetland at future times using the same version of ORWAP.

Also, note that the indicators and models featured in ORWAP are intended to represent wetland science as it currently exists. As with all science, continued research in this region and elsewhere could yield new discoveries that might suggest a need to change some of the indicators and assumptions currently embedded in ORWAP. However, any future changes made to the

indicators ORWAP uses, the wording of its questions, or the weights and combination rules of its models will require that all 200 of the calibration wetlands be reassessed, or a new calibration series selected and assessed with the changed protocol.

3.0 Testing ORWAP's Repeatability

3.1 Background

Repeatability is the tendency of different people, using a standardized protocol, to independently select the same answers and arrive at the same scores and/or ratings when assessing the same wetland. It sometimes is also called consistency or precision. In both 2008 and 2014, DSL undertook repeatability testing of ORWAP to quantify variation among users with regard to the resulting score for each function and other attributes. Results from testing the original ORWAP were described in the original version of the ORWAP Manual (Adamus et al. 2009). Results from testing version 3.0 (slightly different wording of some questions compared to version 3.1 and some indicators dropped, but final models from 3.1 were used to calculate the scores) are presented herein.

DSL selected six wetlands for repeatability testing: 4 non-tidal wetlands in the Willamette Valley and 2 tidal wetlands on the coast. Although the number of wetlands was small and geographically limited, they were selected to encompass differences in water regime, land use, and vegetation and were typical of wetlands that will be assessed for regulatory purposes. A pool of 19 volunteers consisting of wetland specialists from consulting firms, as well as DSL wetland specialists and permit staff, did the testing. Testers were asked to read thoroughly the draft manual before applying ORWAP, but levels of prior ORWAP training and experience differed somewhat among the testers. The small sample size limited the ability to statistically test that potential effect. Testers were provided with some basic information about the site(s) they were to assess, including a location map and an aerial photo with the boundaries chosen for the Assessment Area (AA). This was intended to minimize this potential source of variation common to all assessment methods. If a wetland delineation had been completed, the delineation map was also provided. In some but not all cases, the AA was the entire wetland. Each wetland was assessed independently by 11 to 13 persons. Testers then visited (as a group) one or more of the six wetlands. Testers were monitored closely to ensure no information-sharing occurred. Data from all the hard-copy data forms were entered into ORWAP's calculator spreadsheet by DSL staff.

3.2 Results of Repeatability Testing

The repeatability of scores was analyzed and expressed as statistical confidence intervals around the mean for each function in each of the six wetlands (Table 2). Averaged across all six sites, the confidence intervals for the normalized function scores ranged from ±0.38 (around a mean normalized score of 2.56 for the function, Water Storage & Delay) to ±1.21 (around a mean normalized score of 2.99 for the function, Resident Fish Habitat). Across all six sites and their functions, the average confidence interval was ±0.68 around a mean normalized score of 5.12. The confidence intervals might have been even narrower if the data from one or two "outlier"

testers had been excluded, or if a full two days of training and field practice had been provided beforehand.

For the normalized scores of values and other ORWAP attributes, the statistical confidence intervals across the six sites ranged from ±0.21 (around a mean score of 5.78 for the value associated with Songbird-Raptor-Mammal Habitat) to ±1.43 (around a mean score of 5.20 for the function, Resident Fish Habitat). Across all six sites and their functions, the average confidence interval was ±0.66 around a mean normalized values score of 4.57.

Table 2. Confidence intervals (+/-) for normalized scores of functions and attributes based on ORWAP 3.0 repeatability testing in six wetlands.

	Function Scores		Value & Other Attribute Scores	
Functions and Other Attributes	Mean (n=6)	Confidence Interval (+/-)	Mean (n=6)	Confidence Interval (+/-)
Water Storage & Delay (WS)	2.56	0.38	4.27	0.53
Sediment Retention & Stabilization (SR)	5.03	0.67	5.76	0.87
Phosphorus Retention (PR)	6.36	0.71	3.93	0.56
Nitrate Removal & Retention (NR)	5.89	0.66	7.36	0.77
Anadromous Fish Habitat (FA)	6.03	0.74	7.25	0.82
Resident Fish Habitat (FR)	2.99	1.21	5.20	1.43
Amphibian & Reptile Habitat (AM)	4.48	0.57	5.23	0.48
Waterbird Nesting Habitat (WBN)	3.76	0.50	2.11	0.34
Waterbird Feeding Habitat (WBF)	3.44	0.65	5.57	0.55
Aquatic Invertebrate Habitat (INV)	3.89	0.69	3.85	0.27
Songbird, Raptor, & Mammal Habitat (SBM)	4.74	0.65	5.78	0.21
Water Cooling (WC)	3.77	0.83	3.78	0.54
Native Plant Diversity (PD)	5.99	0.96	5.37	1.13
Pollinator Habitat (POL)	5.33	0.78	3.64	0.65
Organic Nutrient Export (OE)	5.59	0.51		
Carbon Sequestration (CS)	5.65	0.44		
Public Use & Recognition (PU)			6.03	0.62
Wetland Sensitivity (SEN)			3.14	0.58
Wetland Ecological Condition (EC)			5.32	0.67
Wetland Stressors (STR)			4.73	0.82
	Average:	0.68	Average:	0.66

Ultimately, perhaps the most important question related to a method's repeatability is: Is the variation among independent users assessing the same site generally less than the variation in scores among sites? If it is, then the scores can be judged to have a high degree of repeatability. When this standard is applied to the testing data from ORWAP 3.0, the standard was met for all functions except Resident Fish Habitat (function and value) and Nitrate Removal & Retention

(value) (**Table 3**). That is, the coefficient of variation (CV) of the function scores was considerably greater among test sites (0.76) than among the independent testers (0.32). Similarly, the CV for the value and other attribute scores was considerably greater among test sites (0.57) than the testers (0.21). There is no certainty that the results would be the same if ORWAP was tested again with a different group of testers or with a different set of wetlands. However, these results closely parallel those found with the original version of ORWAP when it was tested by different set of testers on a different set of wetlands.

Table 3. Coefficient of variation of normalized scores among sites vs. among testers based on ORWAP 3.0 repeatability testing in six wetlands.

	Function Scores		Value & Other Attribute Scores	
Functions and Other Attributes	Among Sites	Among Testers	Among Sites	Among Testers
Water Storage & Delay (WS)	0.45	0.31	0.93	0.27
Sediment Retention & Stabilization (SR)	0.88	0.27	0.44	0.11
Phosphorus Retention (PR)	0.86	0.23	0.72	0.09
Nitrate Removal & Retention (NR)	0.91	0.23	0.22	**0.24**
Anadromous Fish Habitat (FA)	0.95	0.26	0.30	0.19
Resident Fish Habitat (FR)	0.66	**0.85**	0.63	**0.65**
Amphibian & Reptile Habitat (AM)	0.54	0.26	0.69	0.12
Waterbird Nesting Habitat (WBN)	0.47	0.28	1.19	0.49
Waterbird Feeding Habitat (WBF)	0.90	0.39	0.65	0.17
Aquatic Invertebrate Habitat (INV)	0.87	0.37	0.45	0.09
Songbird, Raptor, & Mammal Habitat (SBM)	0.79	0.28	0.19	0.10
Water Cooling (WC)	0.47	0.46	0.78	0.38
Native Plant Diversity (PD)	0.83	0.33	0.36	0.24
Pollinator Habitat (POL)	0.91	0.30	0.46	0.17
Organic Nutrient Export (OE)	0.96	0.19		
Carbon Sequestration (CS)	0.78	0.16		
Public Use & Recognition (PU)			0.50	0.10
Wetland Sensitivity (SEN)			0.29	0.08
Wetland Ecological Condition (EC)			0.91	0.11
Wetland Stressors (STR)			0.55	0.10
Average:	0.76	0.32	0.57	0.21

There are many factors—other than the method being tested—that potentially contribute to lower repeatability among independent users, including:

- Users not remembering key details from the Manual
- Overlooking Definitions/ Explanatory notes on data forms
- Delimiting the Assessment Area (AA) differently
- Delimiting the Runoff Contributing Area (RCA) differently
- Delimiting the Streamflow Contributing Area (SCA) differently

- Not noticing the spatial context of the question
- Not consulting the database worksheet or the Wetlands Map Viewer site when required
- Differences in the parts of the site that were walked
- Differences in visual interpretation
- Differences in skills at identifying plants and texturing soils
- Differences in prior knowledge of the particular wetland
- Differences in willingness and ability to make informed judgments
- Data entry errors
- Fatigue

4.0 Comparison with Oregon's Hydrogeomorphic (HGM) Methods

In some parts of Oregon (Willamette Valley, Oregon Coast) reference-based HGM methods are also available for assessing functions and values of specific wetland types (riverine and slope/flat wetlands; tidal wetlands, respectively). In vernal pool wetlands in southwestern Oregon, a DSL-funded assessment method (Packenham-Walsh et al. 2006) is also available. These methods can be downloaded from folders at: http://people.oregonstate.edu/~adamusp

Even in the regions already covered by existing methods, it will be necessary to use ORWAP whenever out-of-kind comparisons among wetlands must be made.

Important note: If assessing wetlands for state or federal permit purposes, it is important to be familiar with all pertinent DSL and Corps of Engineers regulations and guidance regarding permissible methods for different situations. Consult with DSL and the Corps for information, as needed.

ORWAP and Oregon's HGM methods have many similarities and several important differences. They are similar in: (1) being relatively rapid to apply during a single site visit, (2) using indicators to assess mainly the same functions and values on an ordinal scale, and (3) requiring personal computers to process data collected both in the field and in the office. Aside from ORWAP's inclusion of all wetland types and regions of Oregon, they differ as follows:

1. ORWAP allows comparisons to be made among any and all wetland types in Oregon, whereas the HGM methods were limited to a few specific types and regions for which HGM guidebooks have been developed. HGM methods cannot be used to compare two wetlands if they differ in their HGM classifications.

2. The scores from the HGM methods were normalized in two separate ways. Once, by normalizing to scores of a few reference wetlands that were perceived to be among the least-altered of their type in their region and secondly, by normalizing to the wetland with the highest score for a given function (regardless of whether that wetland was perceived as the least-altered) and to the wetland with the lowest score (regardless of whether it was perceived as the most-altered).

3. ORWAP includes a standardized process for scoring indicators of wetland values, and then aggregating those indicator scores into a score for the relative value of each function. The value

score reflects the landscape and social context within which a particular function is being performed and is calculated independently of the function score. The HGM methods did not provide a value score. ORWAP also provides a systematic process for scoring wetland stressors, whereas the Willamette Valley HGM method does not.

4. ORWAP combines closely related functions and their values into groups (without losing the scores for the individual functions and values) to facilitate ease of use in regulatory applications. The HGM methods do not.

5. Data forms for ORWAP are slightly longer and use more indicators. That is partly due to the need to address the wider variation among all wetland types across an entire state. It also reflects increasing understanding of wetland functions and values, and increasing availability of critical spatial information (aerial imagery, maps) now obtainable via the internet.

6. Although ORWAP uses nearly all the indicators used by the HGM methods, ORWAP defines or explains some of those indicators slightly differently (and hopefully more clearly) based on feedback from HGM users and users of draft versions of ORWAP.

7. A few of the indicators used by the HGM methods that required the most time, effort, or expertise to assess (e.g., measurement of width and depth of tidal channels, identification of plant cover by species in quadrats) have not been included in ORWAP.

8. For some indicators, ORWAP provides different thresholds or choices of condition. This is again due to the larger region encompassed.

9. ORWAP includes two functions (Carbon Sequestration and Pollinator Habitat) not covered by the HGM methods as well as an additional value (Public Use and Recognition). It also includes a score for wetland Sensitivity. Two other wetland attributes (Ecological Condition and Stressors) included in ORWAP were scored by Oregon's tidal wetland HGM method but not by the Willamette HGM method.

10. ORWAP does not require the user to fill out different data forms for different wetland types or regions of the state. A single three-part data form can be used for all Oregon wetlands. While it is obvious that different HGM classes tend to have different levels of some wetland functions, ORWAP's models do not require the user to first determine a wetland's HGM class. Rather, the information the user provides about a wetland's indicators is used by the scoring models to automatically evaluate the likelihood of the wetland belonging to various wetland types (HGM classes). The ORWAP spreadsheets implicitly contain different sub-models for different wetland types or regions when so warranted to increase the sensitivity and efficiency of the scoring. The spreadsheet automatically recognizes the wetland type and shunts the data analysis and scoring process through the most applicable sub-model. For many functions, the main distinctions that warranted separate sub-models, each with a wider or more restrictive set of indicators, are (a) tidal wetlands, (b) non-tidal wetlands that almost always lack surface water during most years), (c) non-tidal wetlands that contain surface water at least seasonally, and (d) wetlands with inlets and outlets, vs. those without. ORWAP data forms also instruct users to skip some questions if their wetland is not of a particular type. To shorten the time required for an assessment, the

questions on the data forms have been placed in a sequence that maximizes the number of potential skips

11. For questions that a user was instructed to skip, and for other indicators that are expected to be irrelevant in a particular context, ORWAP drops them automatically from scoring models that involve averaging rather than counting them as 0's. For example, many of the indicators that involve woody vegetation are dropped from the calculations if the response to one indicator question shows that the wetland is in a landscape whose wetlands historically are not wooded (e.g., parts of the Great Basin in eastern Oregon). Dozens of other situations are embedded in the spreadsheet formulas and are identified in the last column of each function's worksheet. Thus, in attempts to represent wetland processes more realistically and give greater recognition of the interactions and potentially contingent or limiting relationships among indicators, the models in the ORWAP spreadsheet use Boolean logic extensively, mainly in the form of multiple nested "if" statements in their formulas.

12. For a few indicators, ORWAP allows the user to choose "do not know" or "data unavailable" without such a response counting as a "0" in the scoring model (which then would artificially reduce the function's score). When such a choice is selected, ORWAP drops that indicator from calculations that involve averaging.

13. ORWAP was tested in more wetlands by more potential users than either of Oregon's HGM methods. The 2009 version as well as the near-final 3.1 (2016) version were tested in several wetlands to determine the repeatability of scores among independent users assessing the same wetland.

14. In addition to having a web site with supporting data and a data archiving feature, ORWAP provides users with several supporting databases as worksheets in the ORWAP_SuppInfo file.

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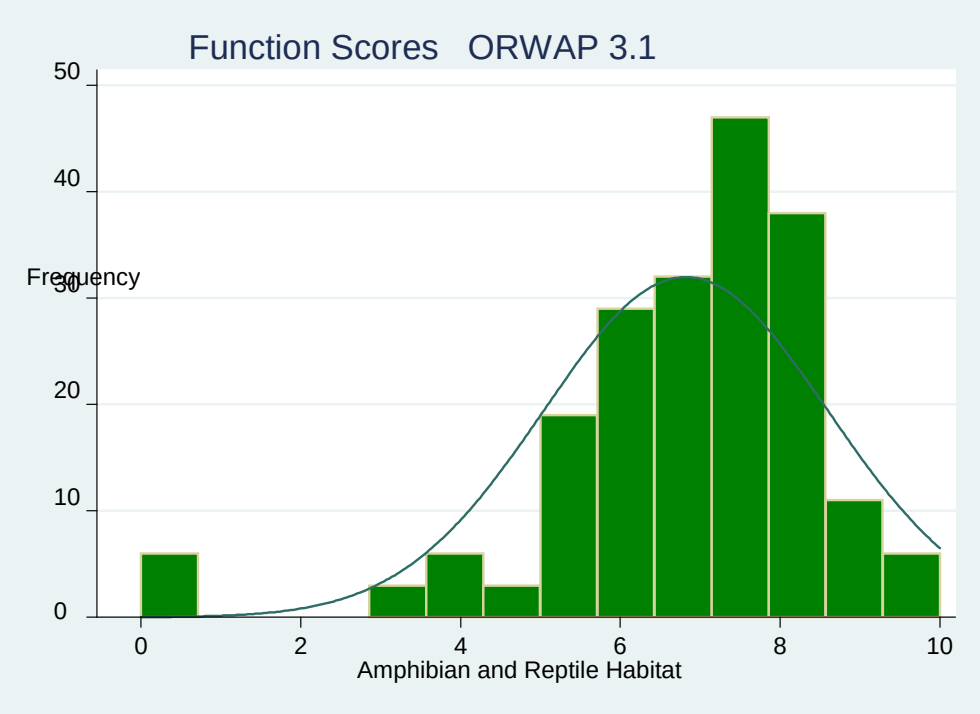
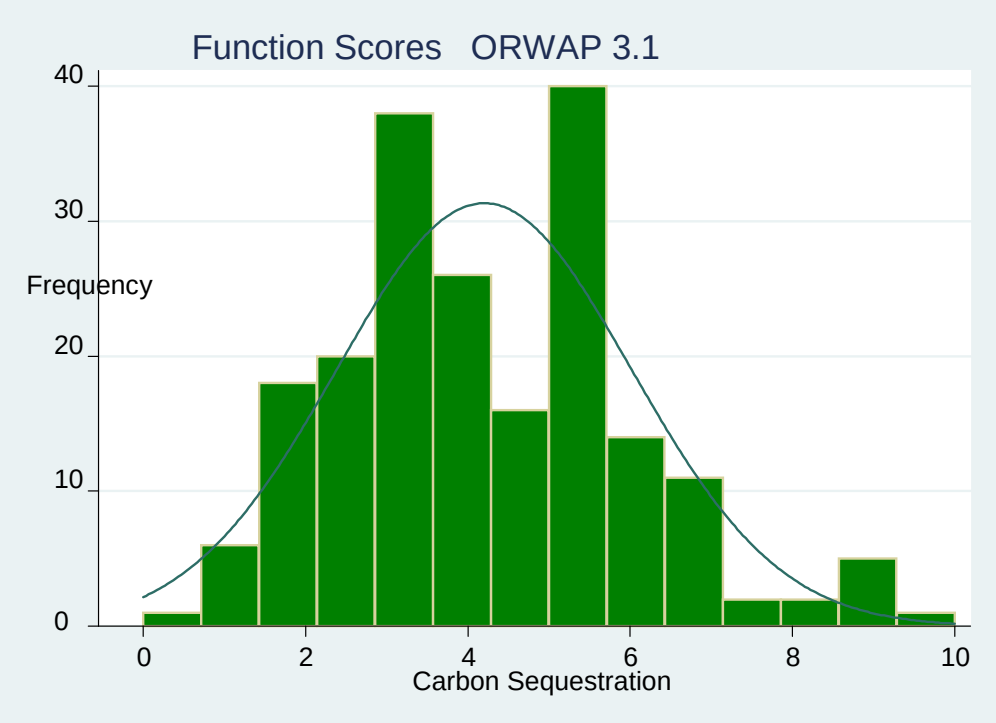
Appendix A.

Appendix A. Score Distribution Histograms

A-1. Function Scores

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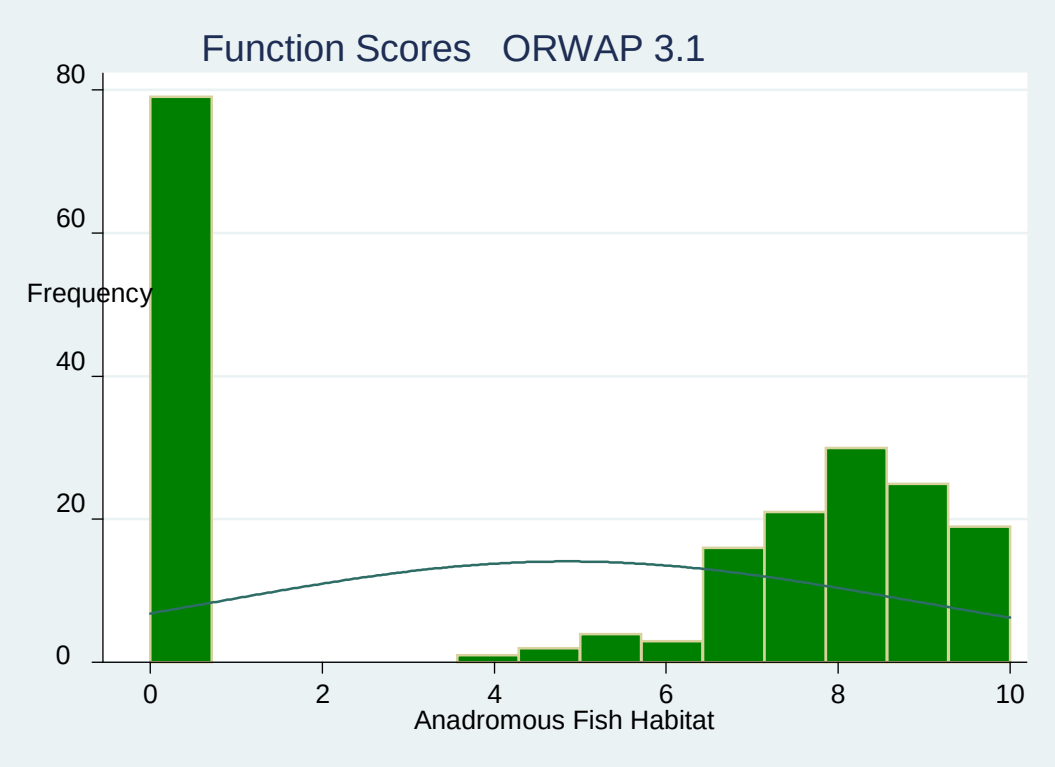
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10
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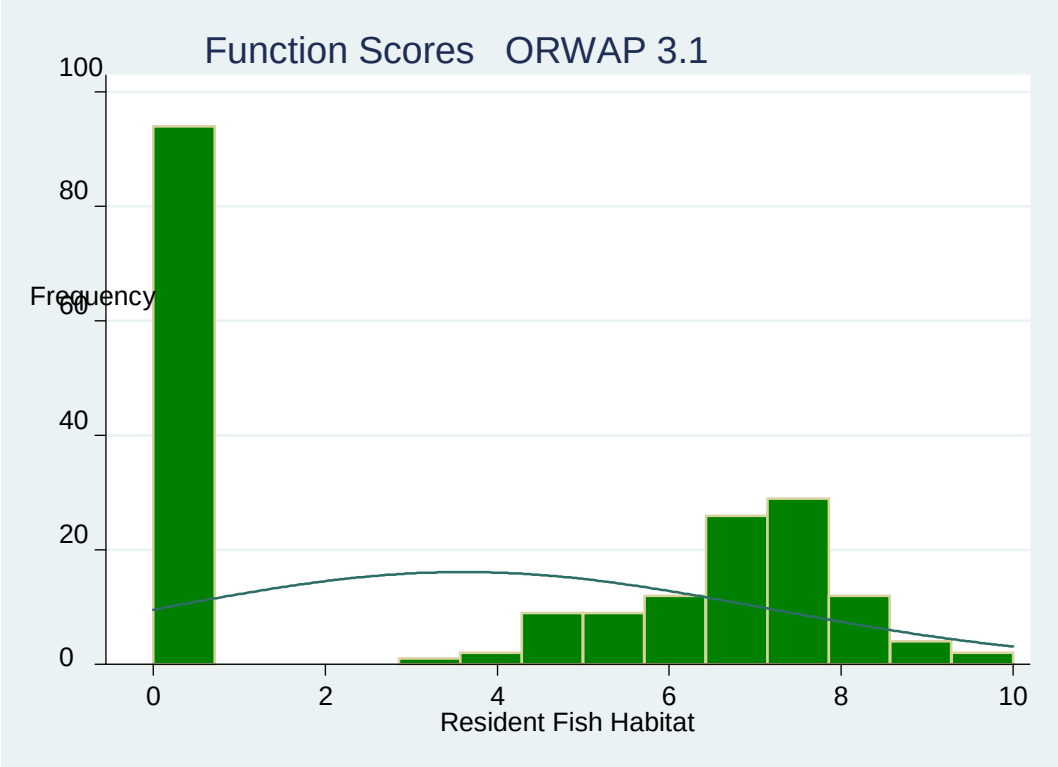
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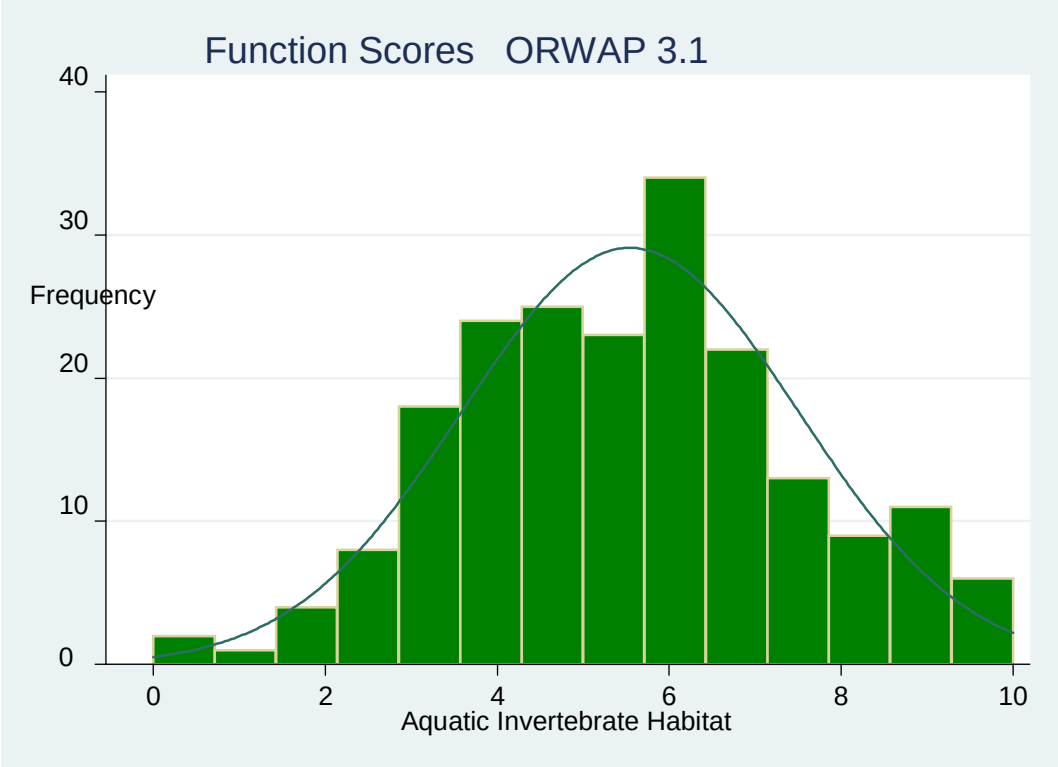
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10
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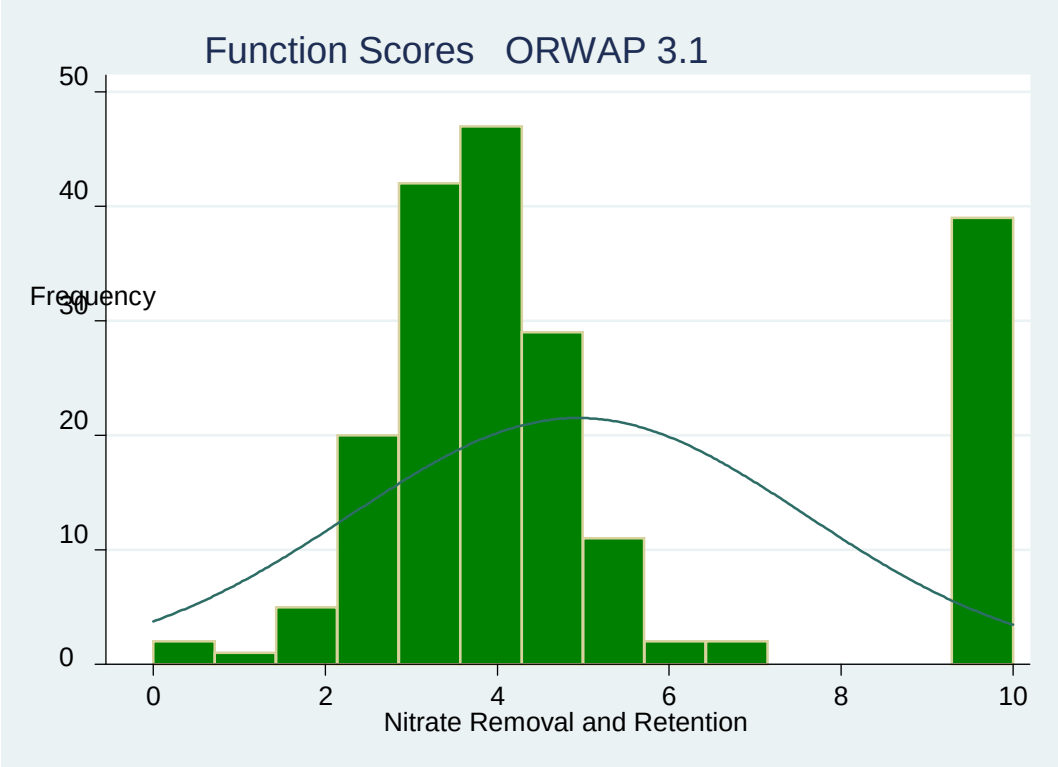
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2
4
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8
10
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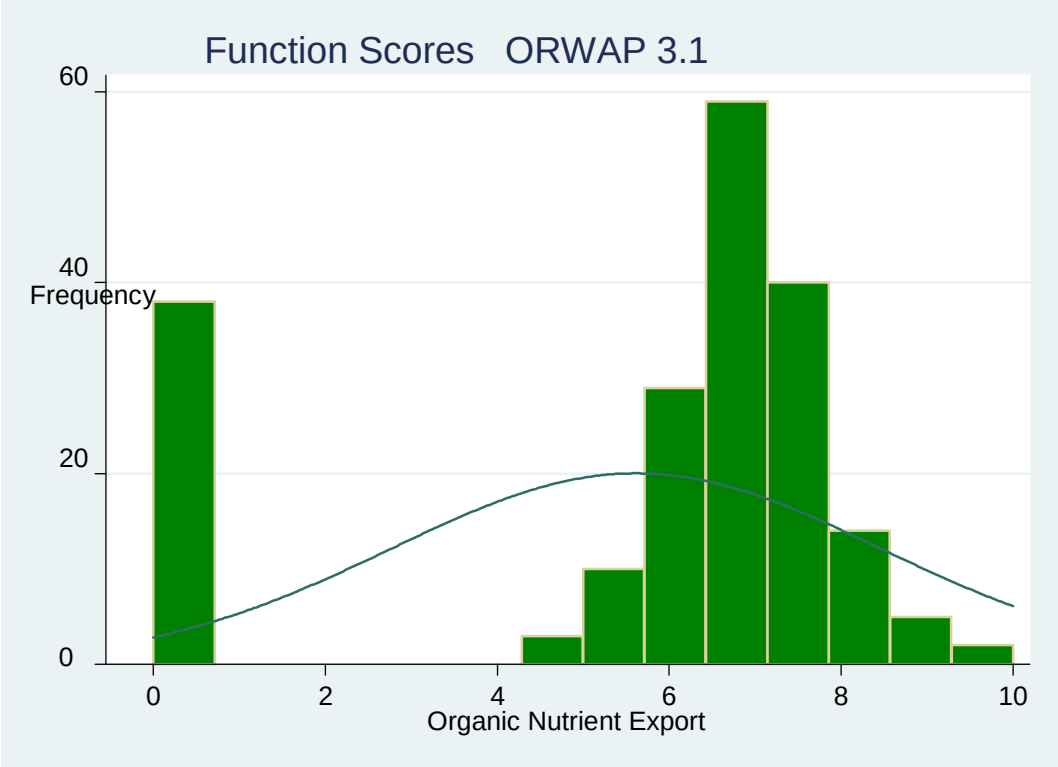
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0
2
4
6
8
10
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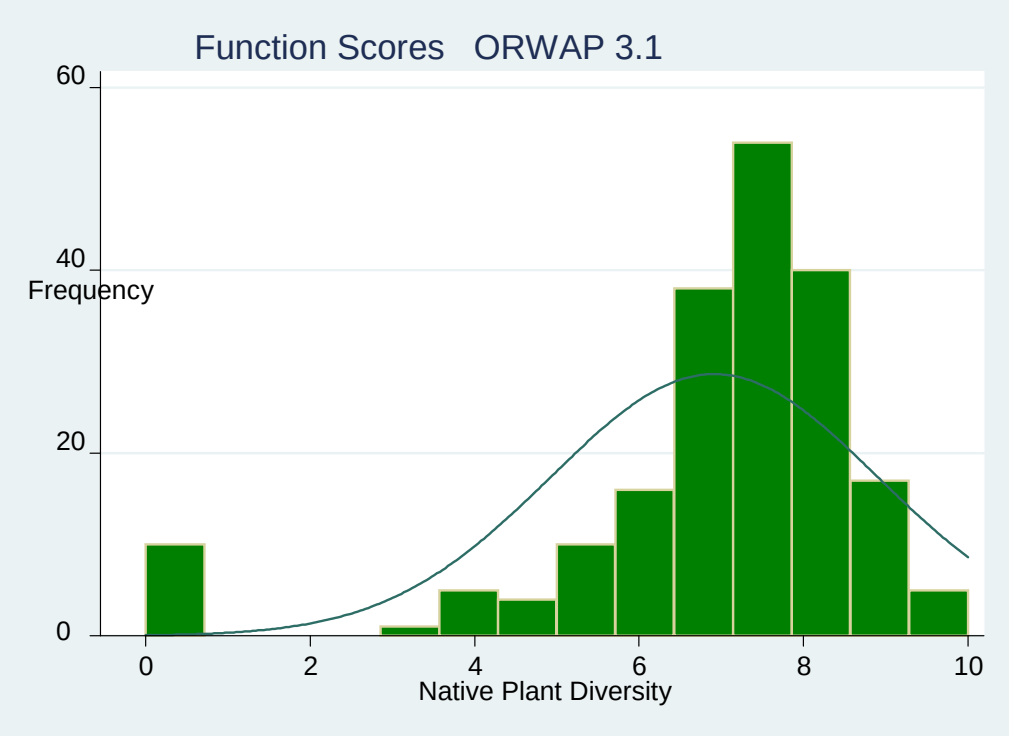
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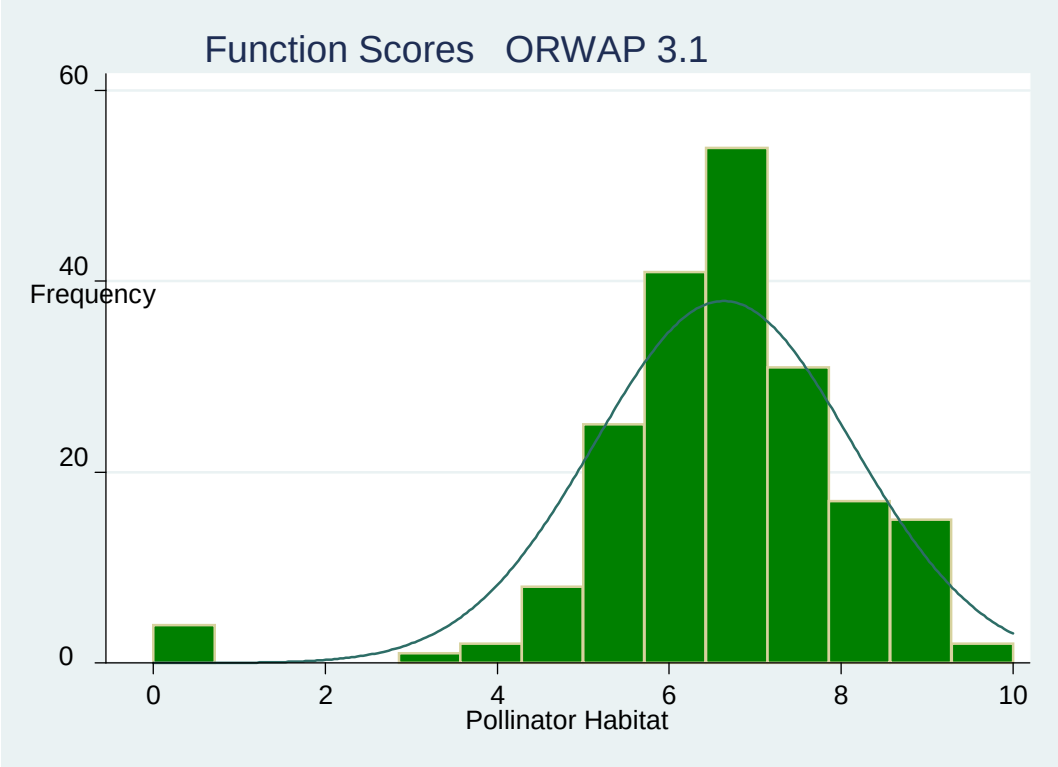
40
20
0
Frequency
0
2
4
6
8
10
Native Plant Diversity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40
20
0
Frequency
0
2
4
6
8
10
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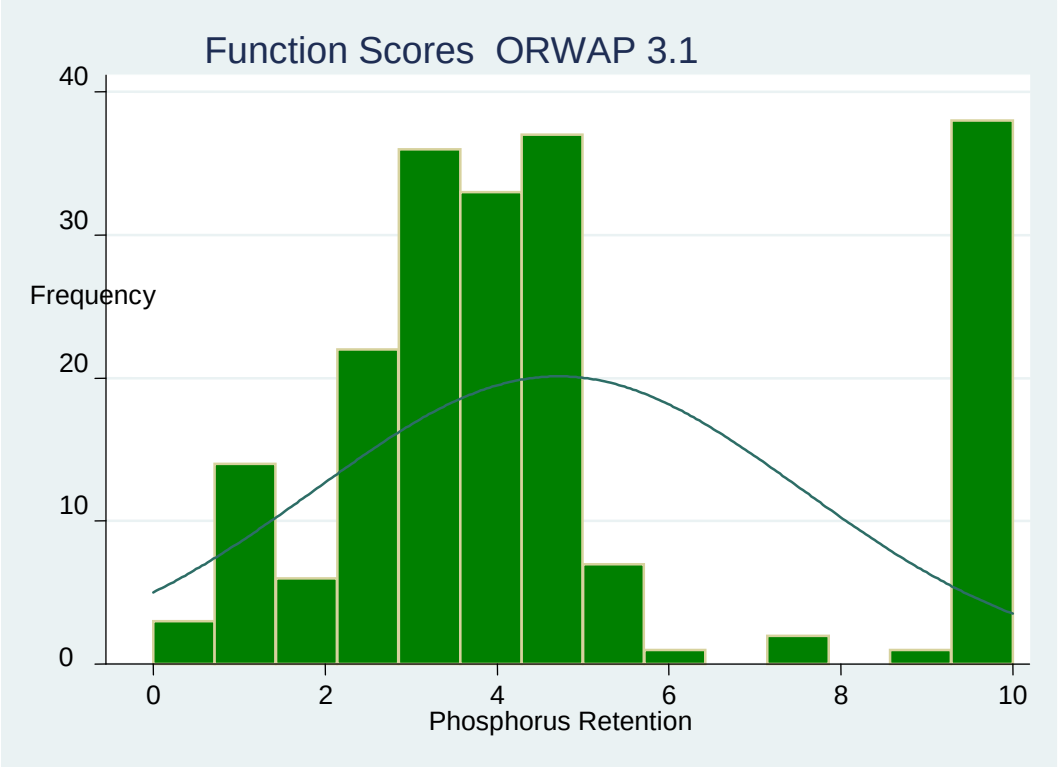
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20
30
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0
2
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6
8
10
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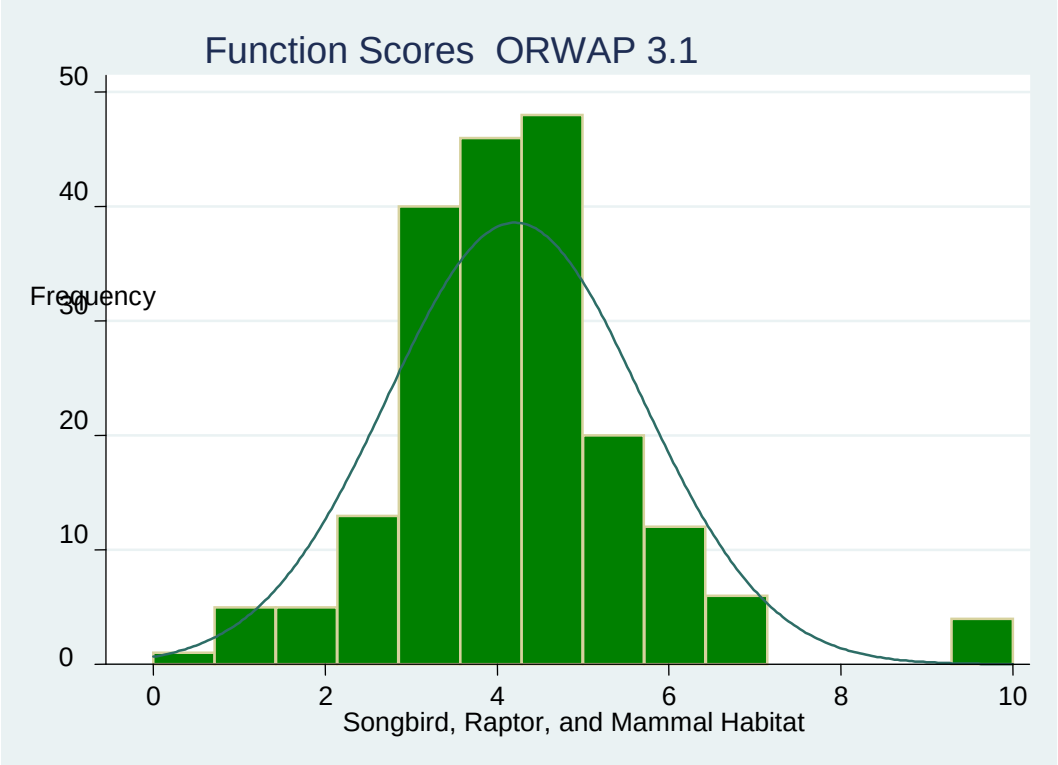
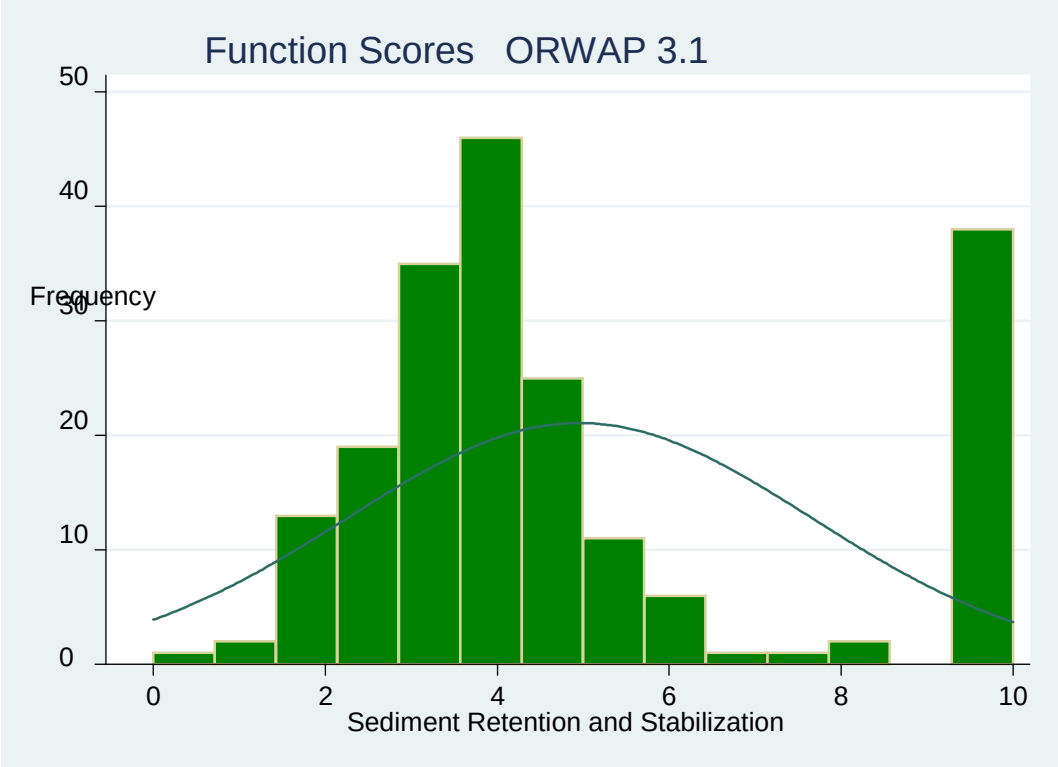

Function Scores ORWAP 3.1
Frequency
0
10
20
30
40
50
0
2
4
6
8
10
Songbird, Raptor, and Mammal Habitat


Function Scores ORWAP 3.1
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8
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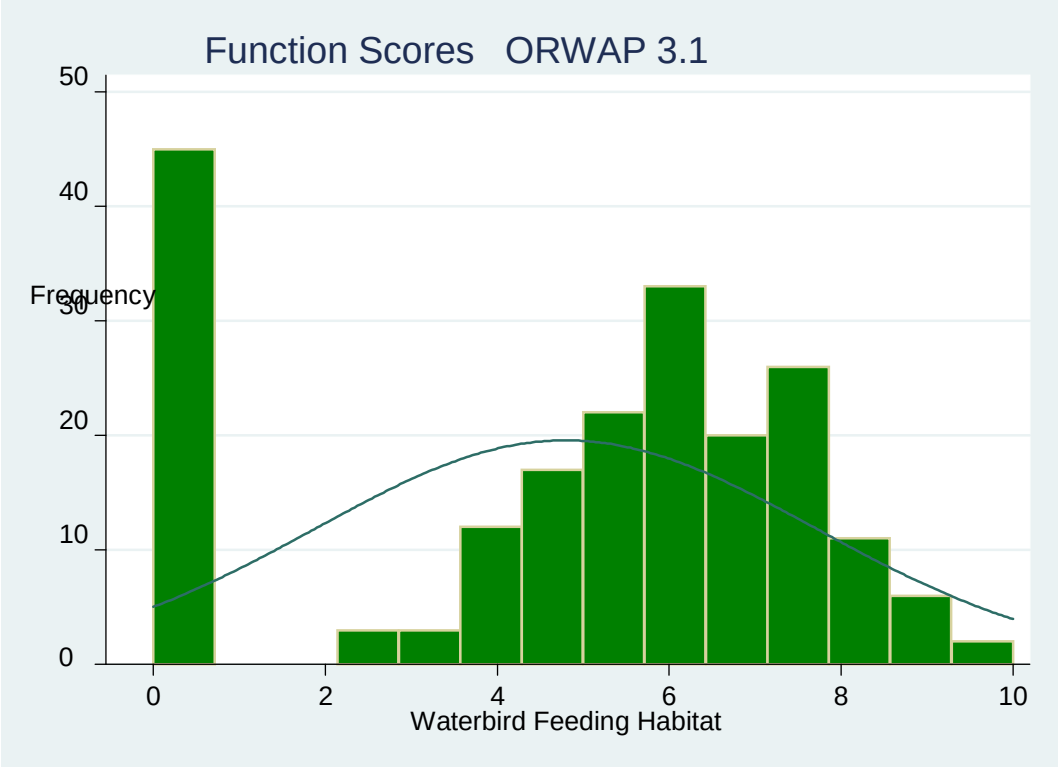
Sediment Retention and Stabilization


Function Scores ORWAP 3.1
Frequency
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2
4
6
8
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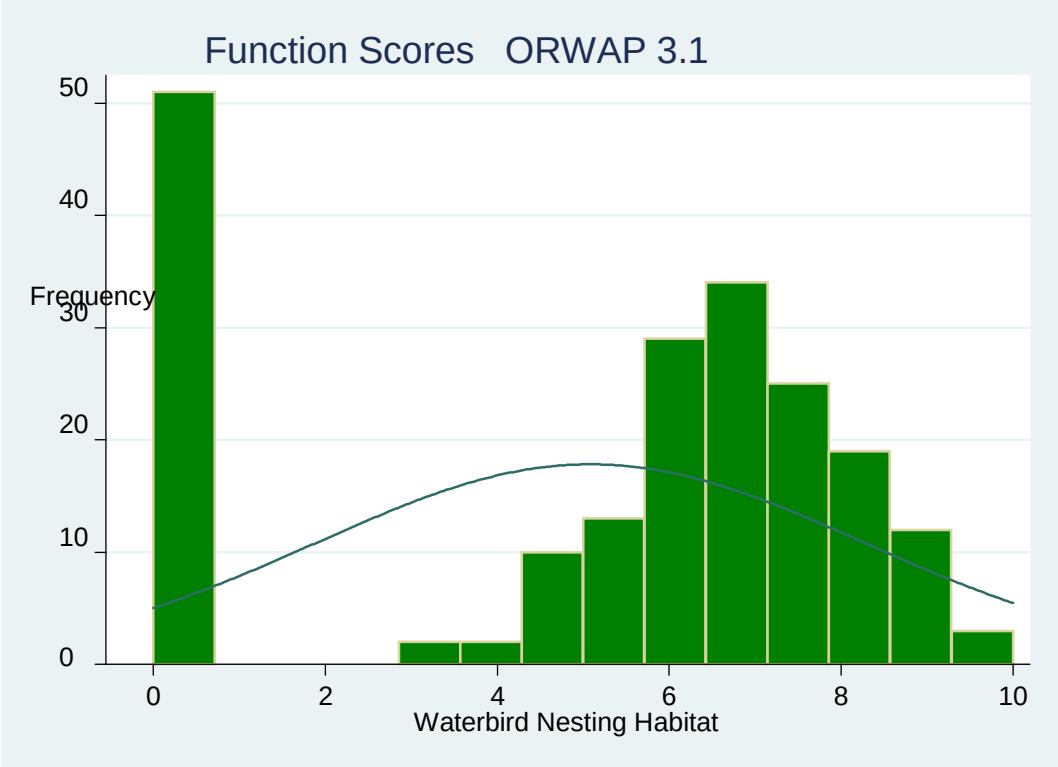
Waterbird Feeding Habitat


Function Scores ORWAP 3.1
Frequency
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2
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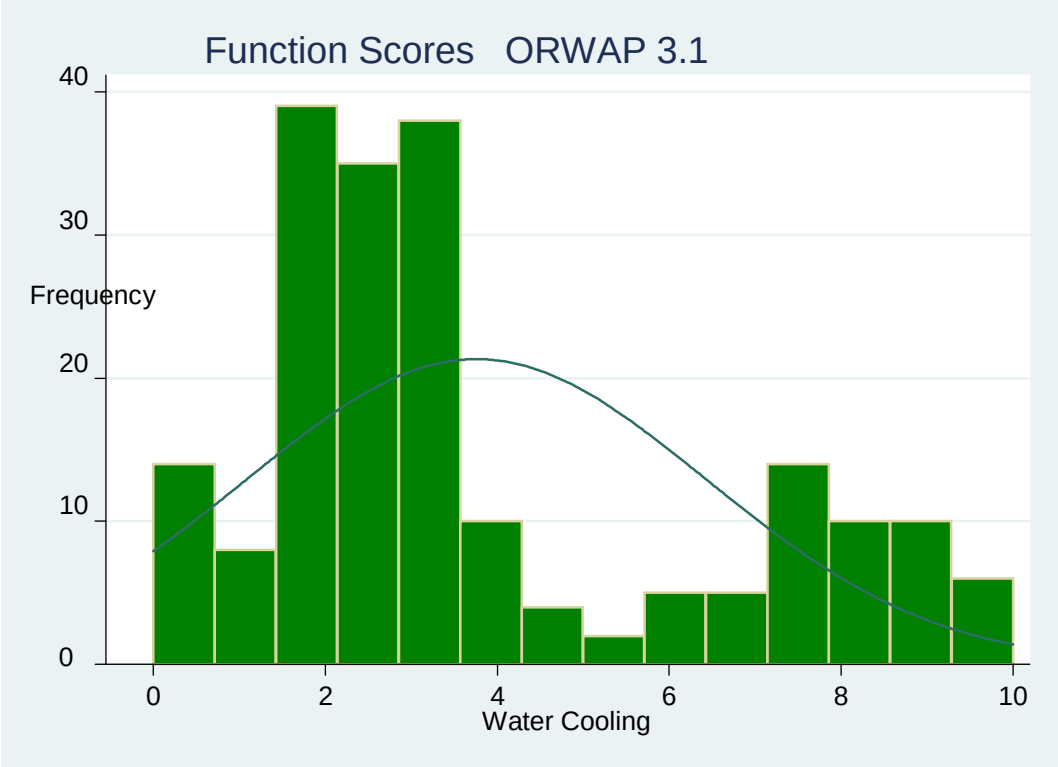
Waterbird Nesting Habitat


Function Scores ORWAP 3.1
Frequency
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4
6
8
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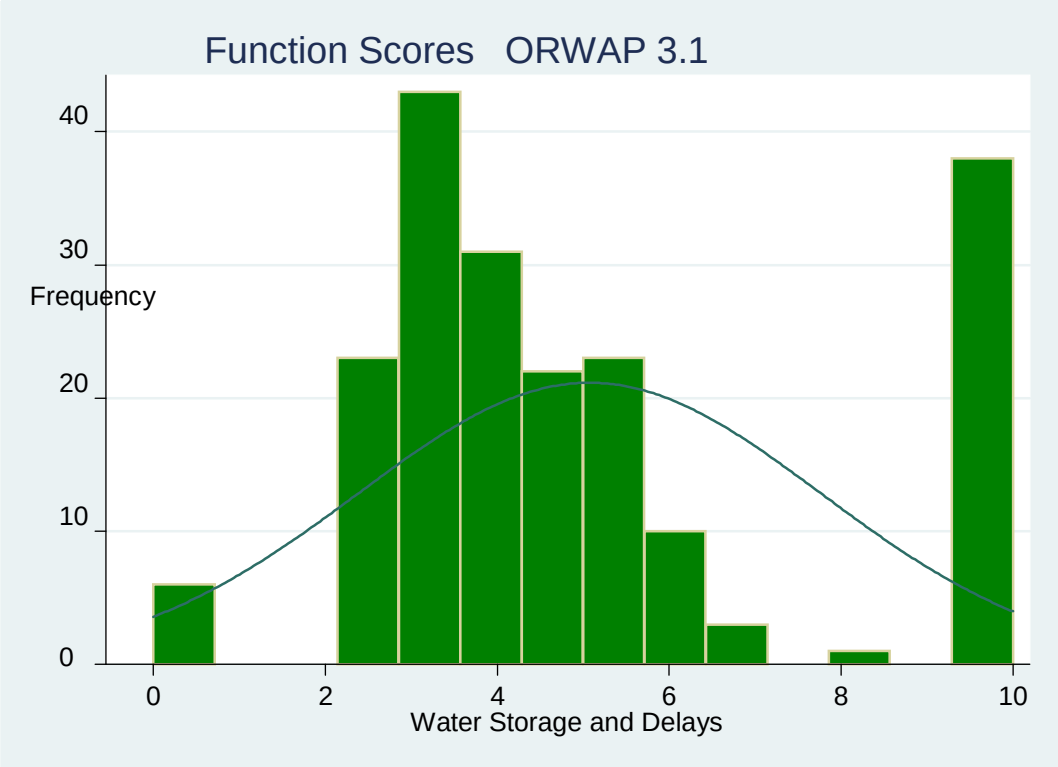
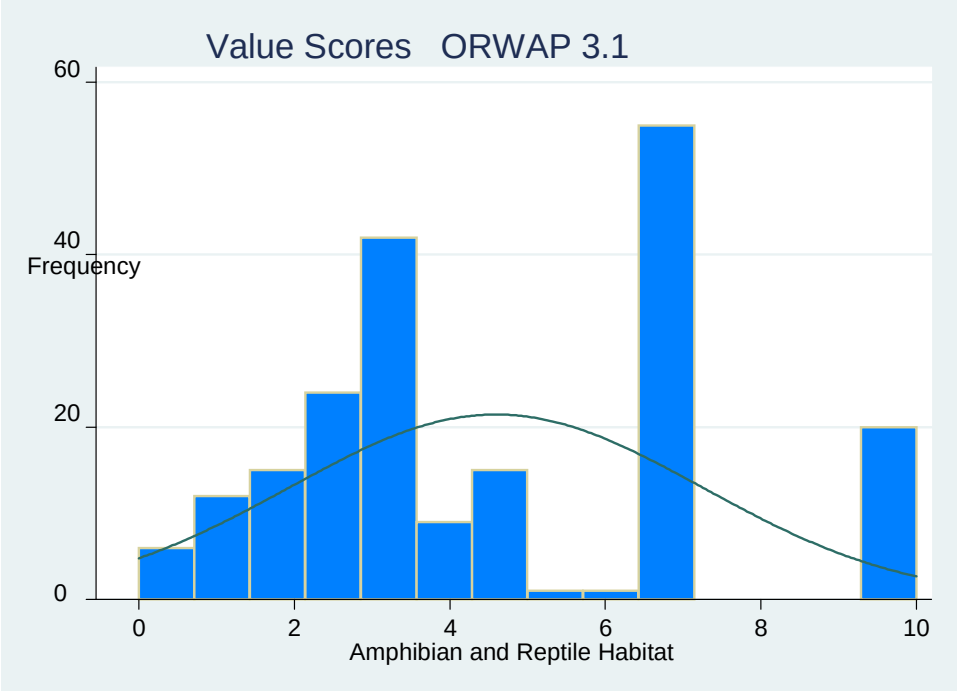
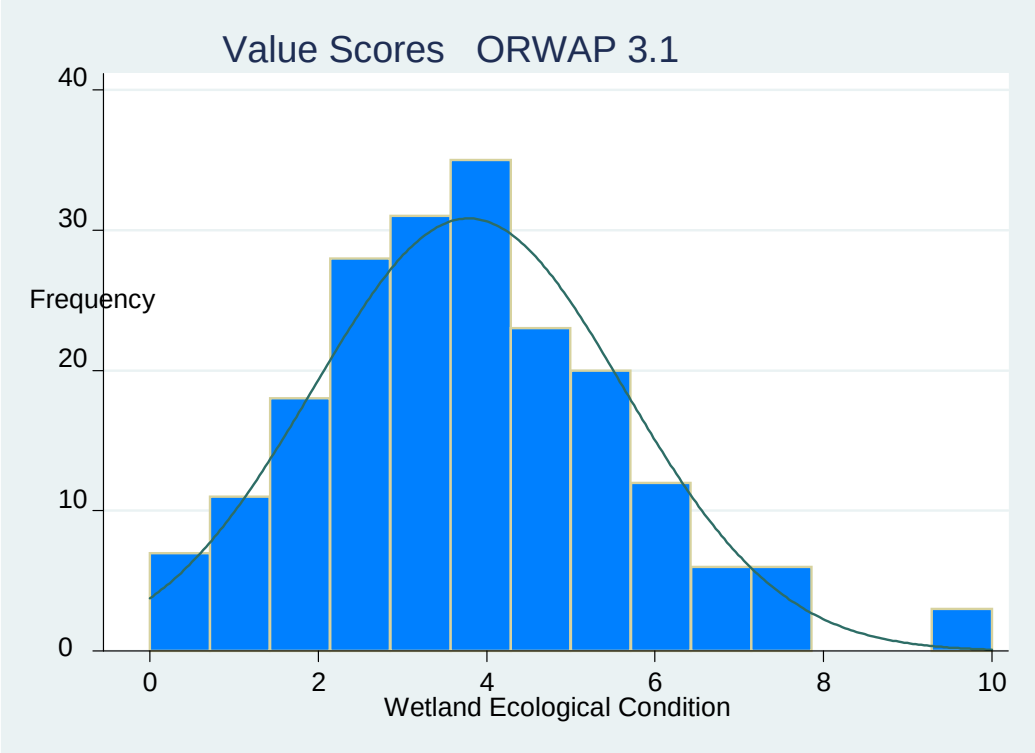
Water Cooling



A-2 Value Scores




Value Scores ORWAP 3.1
Frequency
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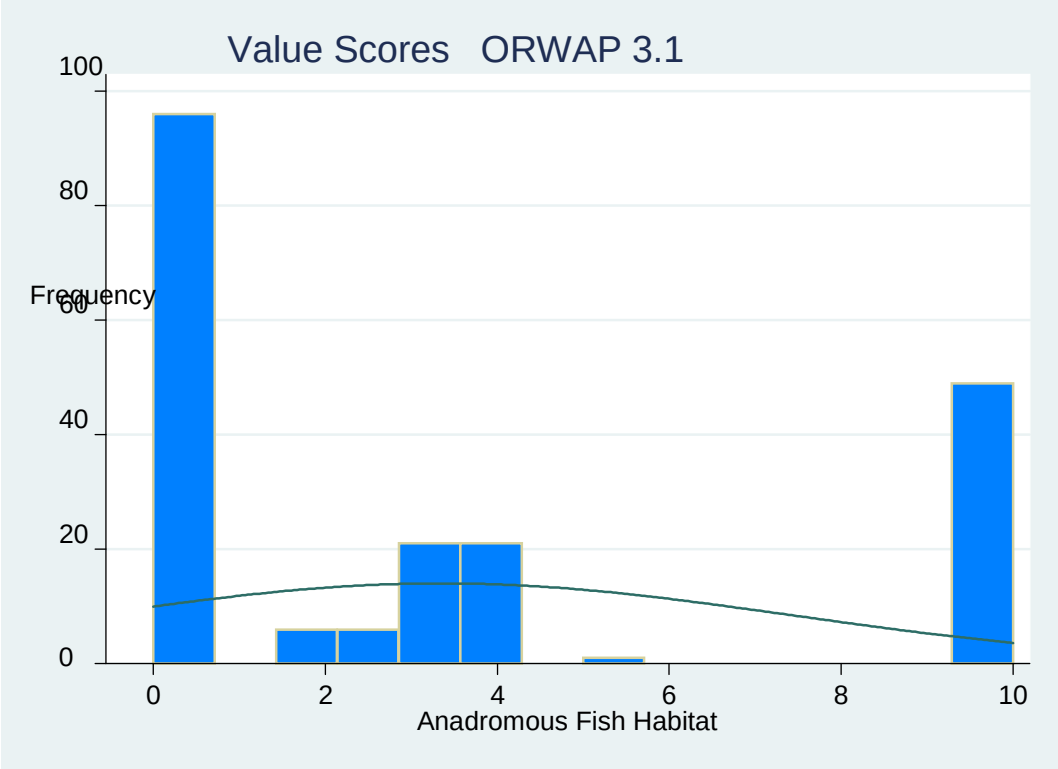
20
30
40
0
2
4
6
8
10
Wetland Ecological Condition


Value Scores ORWAP 3.1
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2
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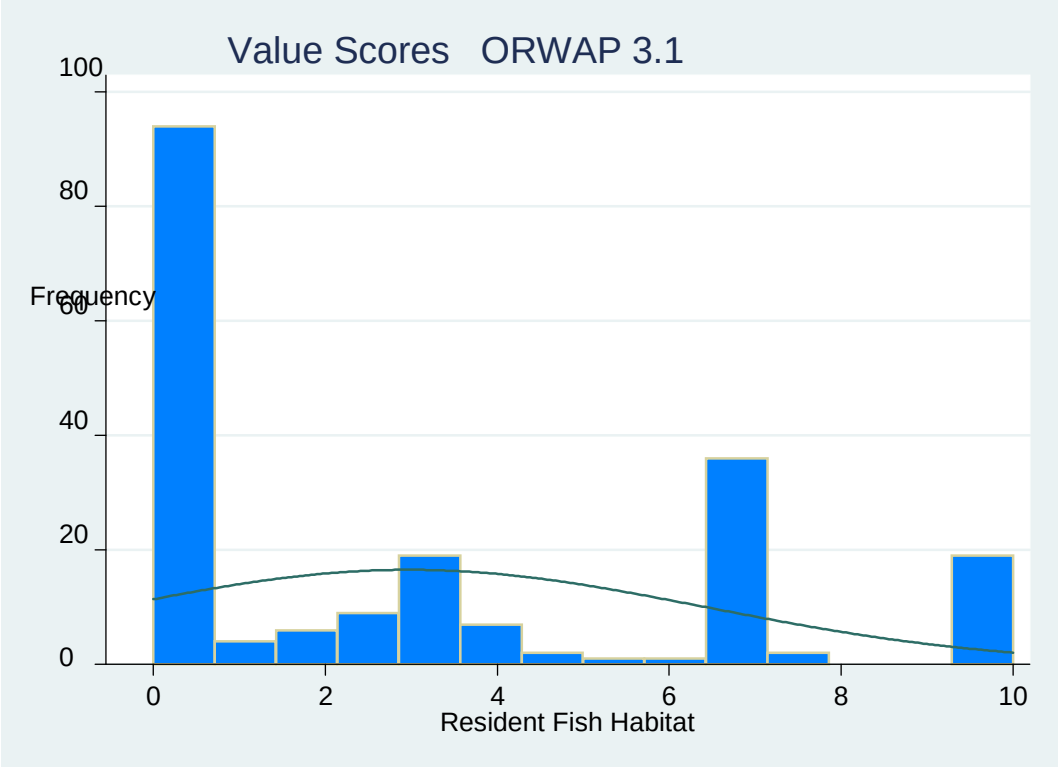
8
10
Anadromous Fish Habitat


Value Scores ORWAP 3.1
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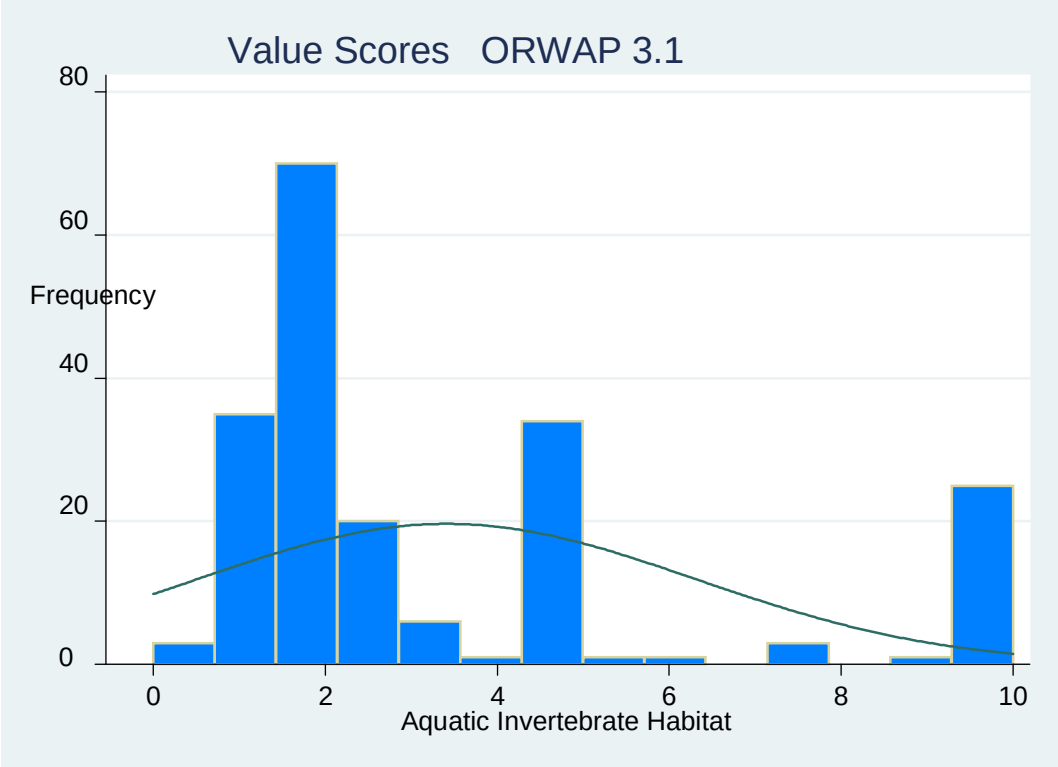
2
4
6
8
10
Resident Fish Habitat


Value Scores ORWAP 3.1
Frequency
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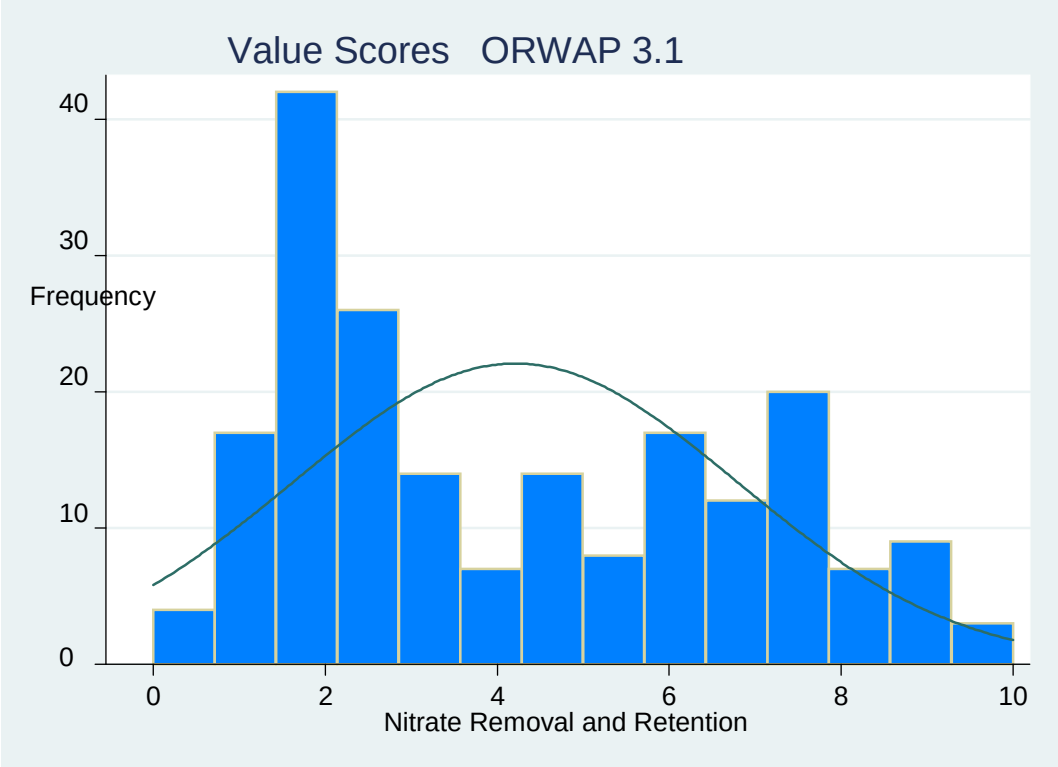
10
Aquatic Invertebrate Habitat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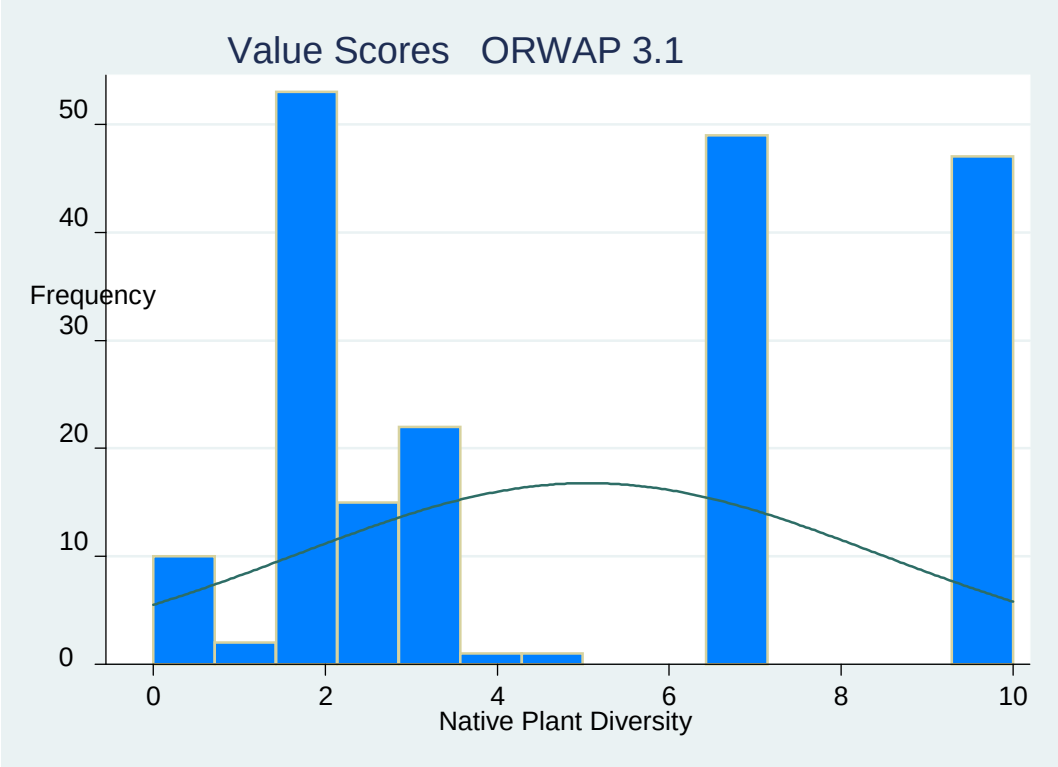
Nitrate Removal and Retention


Value Scores ORWAP 3.1
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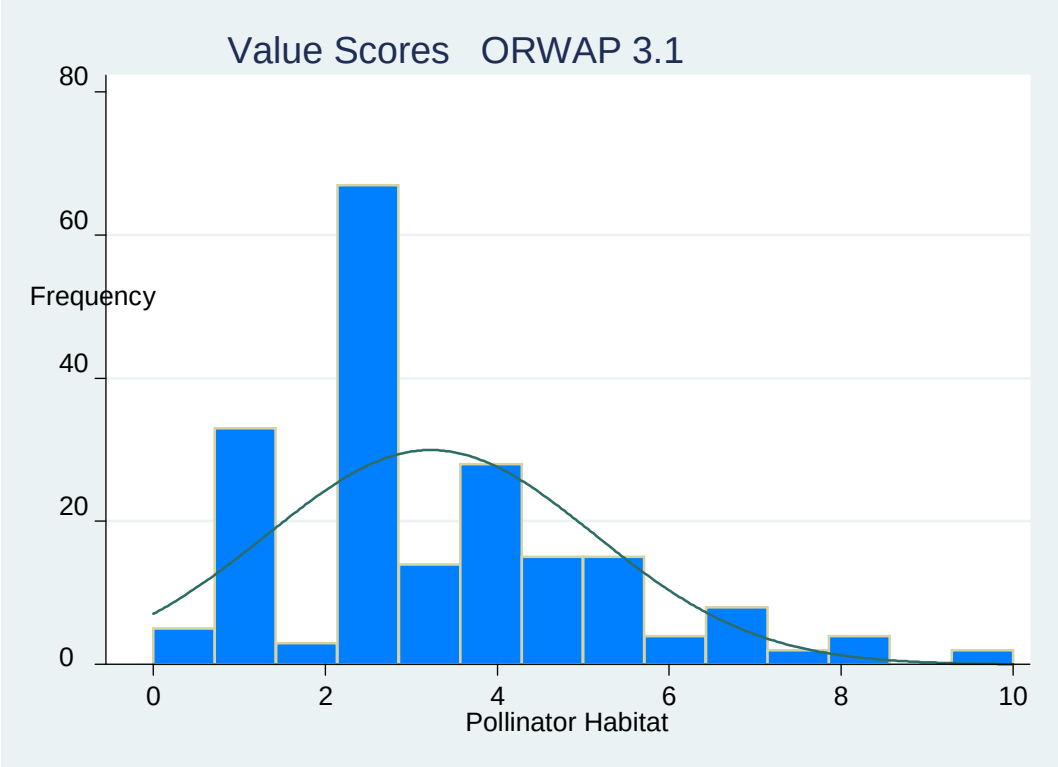
4
6
8
10
Native Plant Diversity


Value Scores ORWAP 3.1
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Frequency
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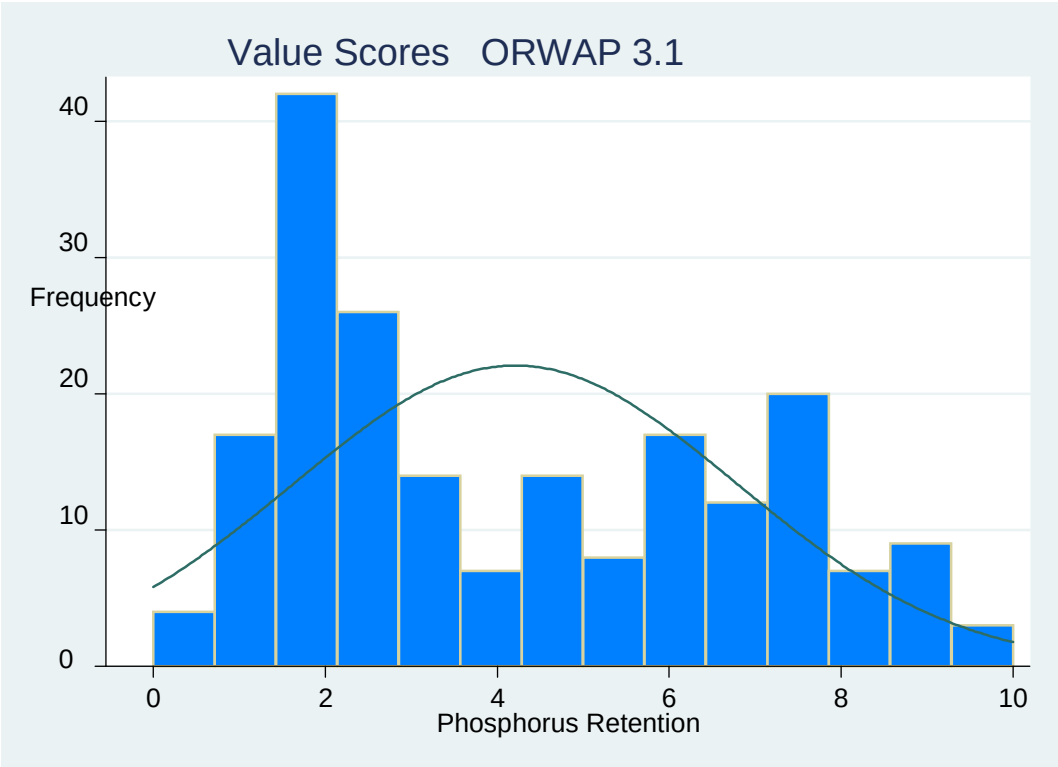
2
4
6
8
10
Pollinator Habitat


Value Scores ORWAP 3.1
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Frequency
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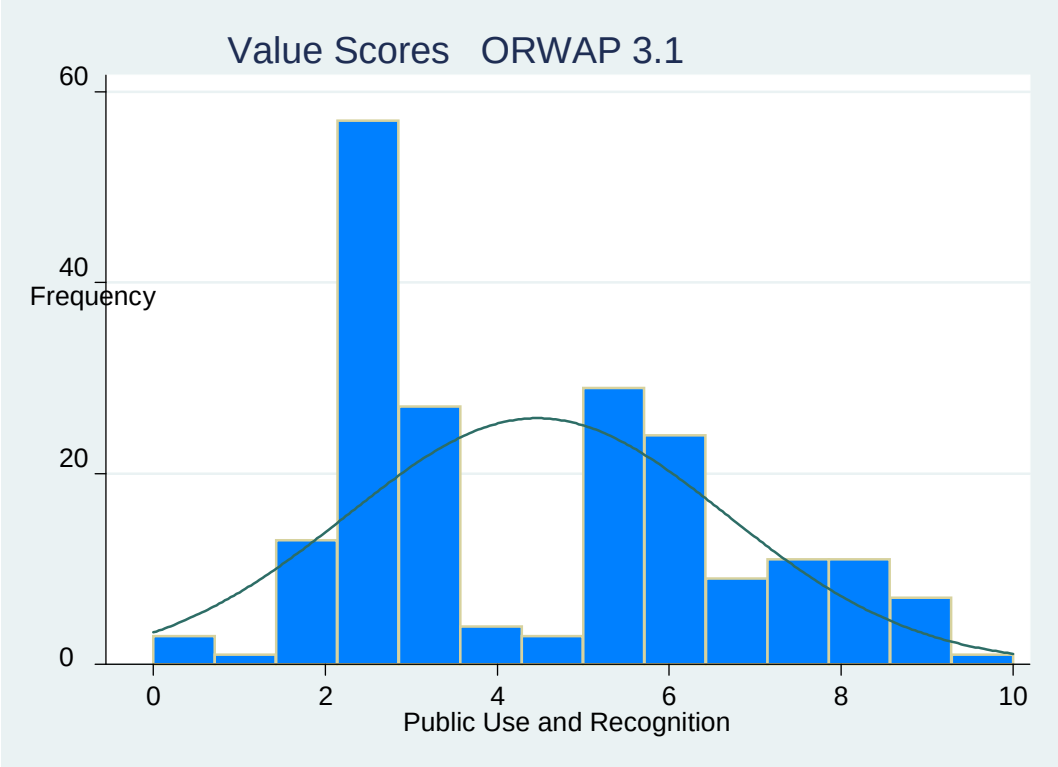
2
4
6
8
10
Phosphorus Retention


Value Scores ORWAP 3.1
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Frequency
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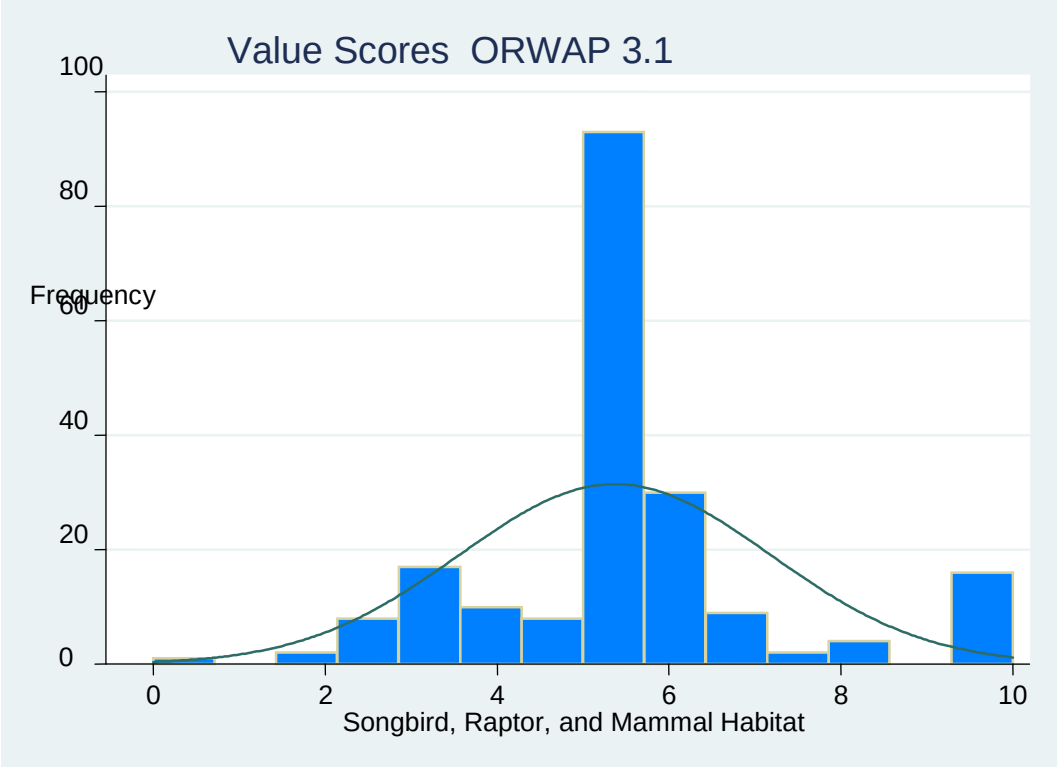
2
4
6
8
10
Public Use and Recognition


Value Scores ORWAP 3.1
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Frequency
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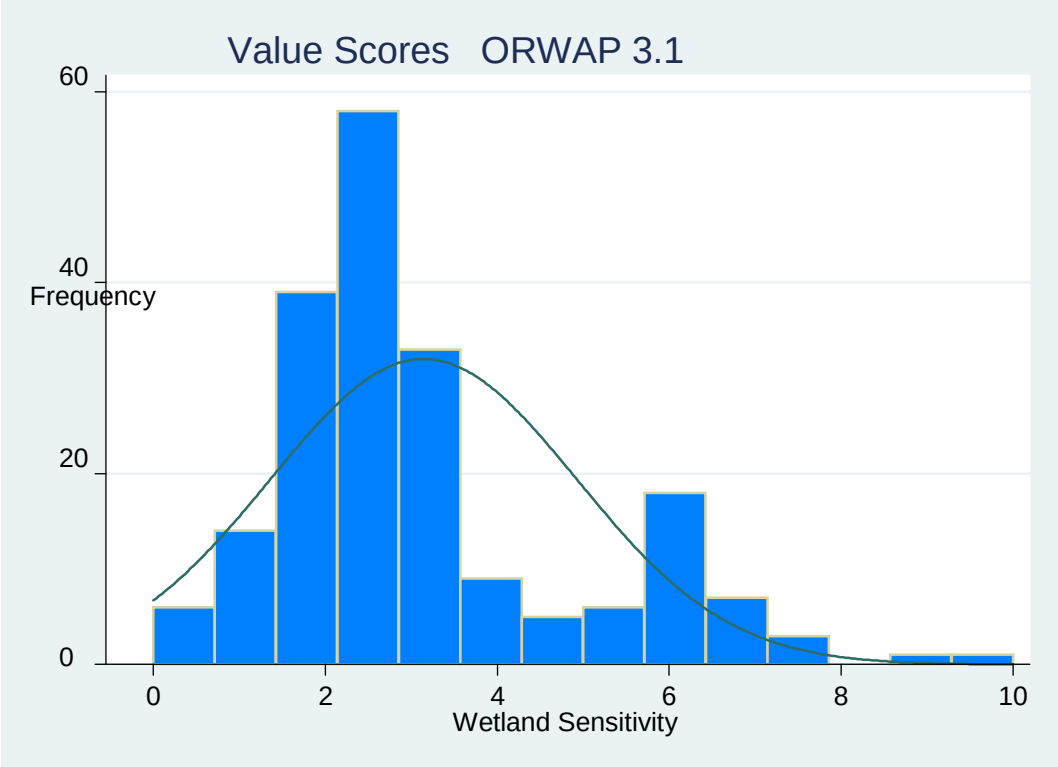
2
4
6
8
10
Songbird, Raptor, and Mammal Habitat


Value Scores ORWAP 3.1
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Frequency
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2
4
6
8
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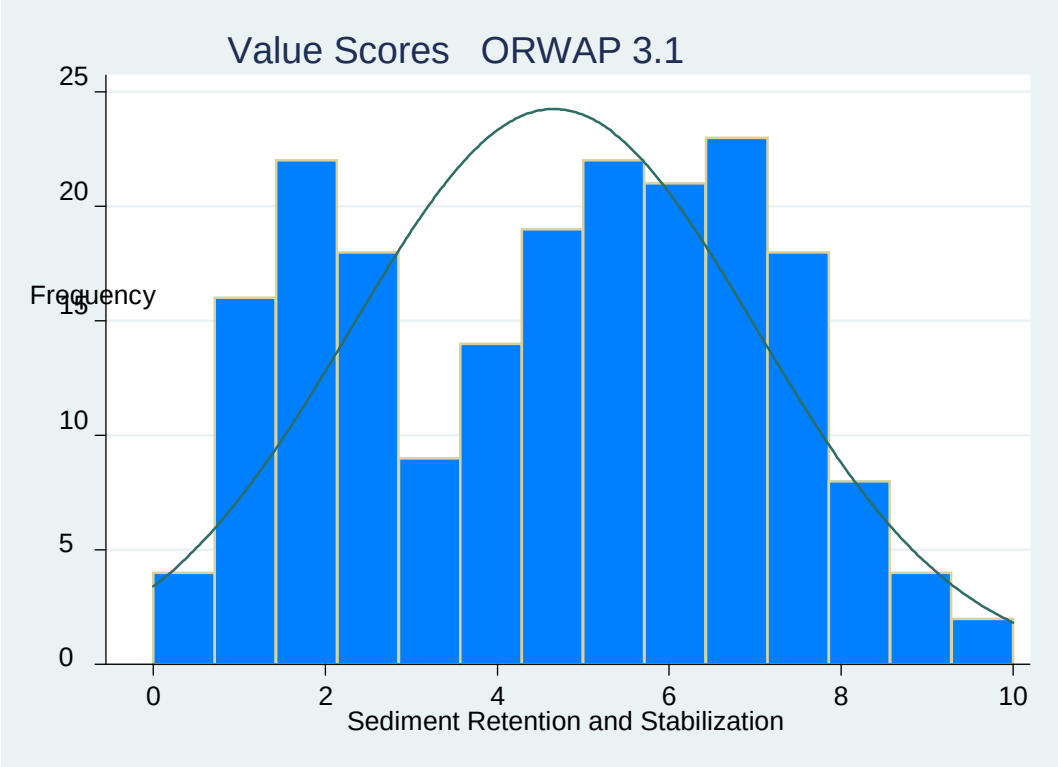
Wetland Sensitivity


Value Scores ORWAP 3.1
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2
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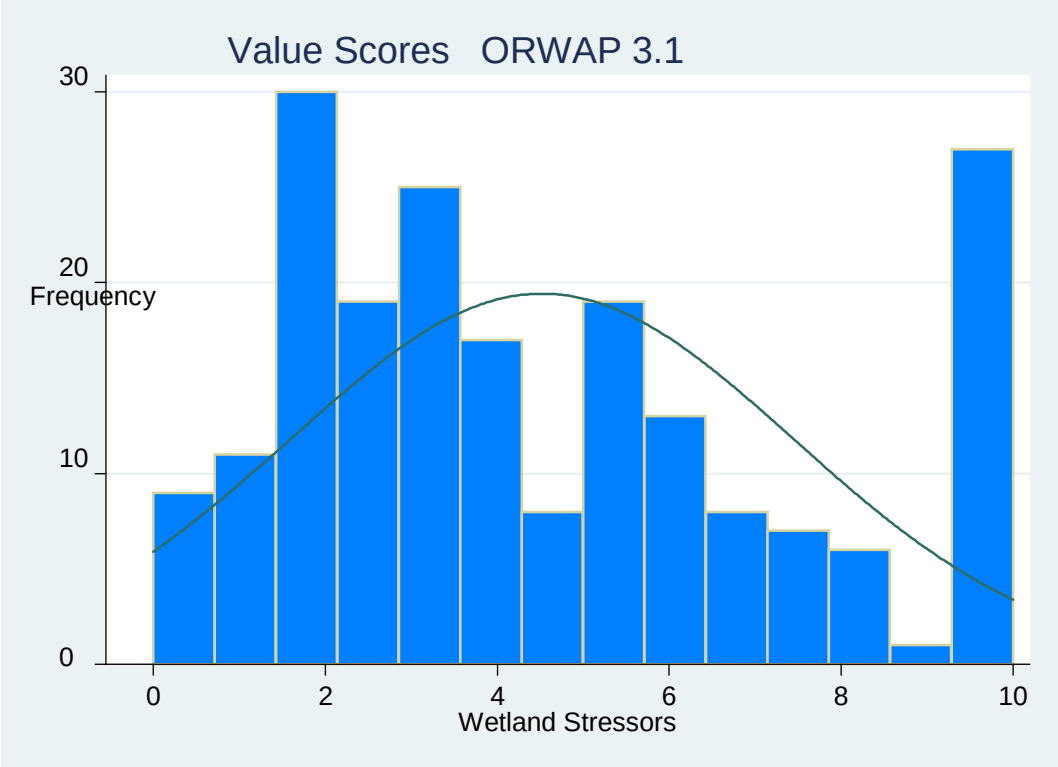
Sediment Retention and Stabilization


Value Scores ORWAP 3.1
Frequency
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2
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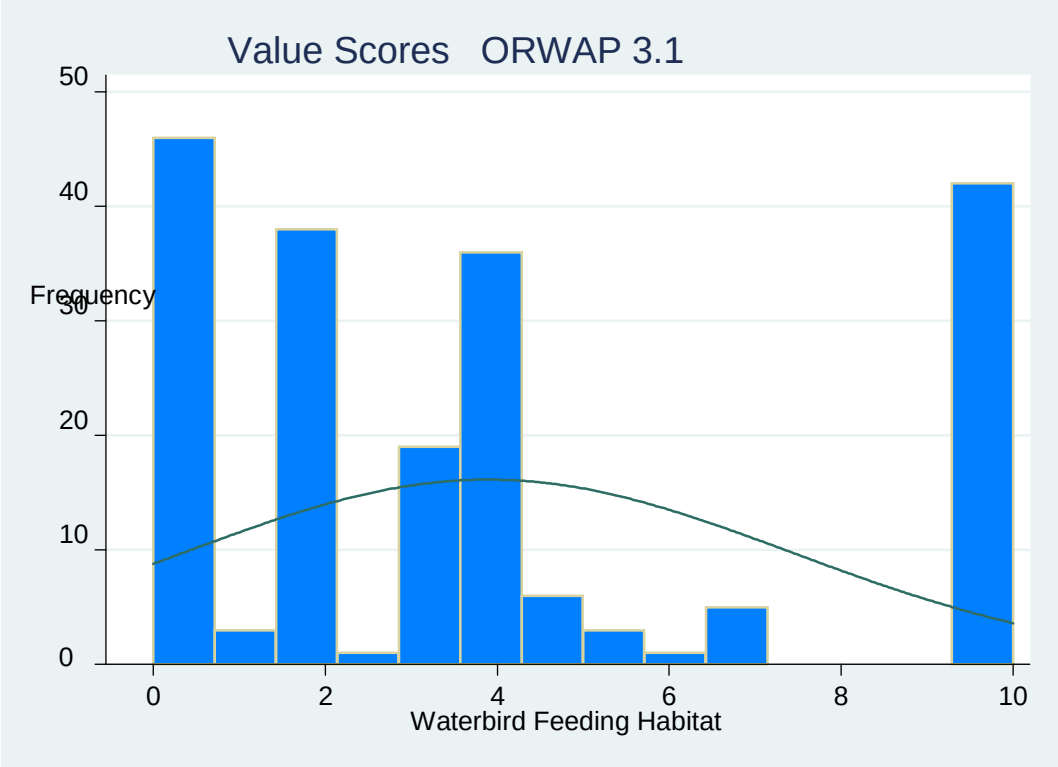
Wetland Stressors


Value Scores ORWAP 3.1
Frequency
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4
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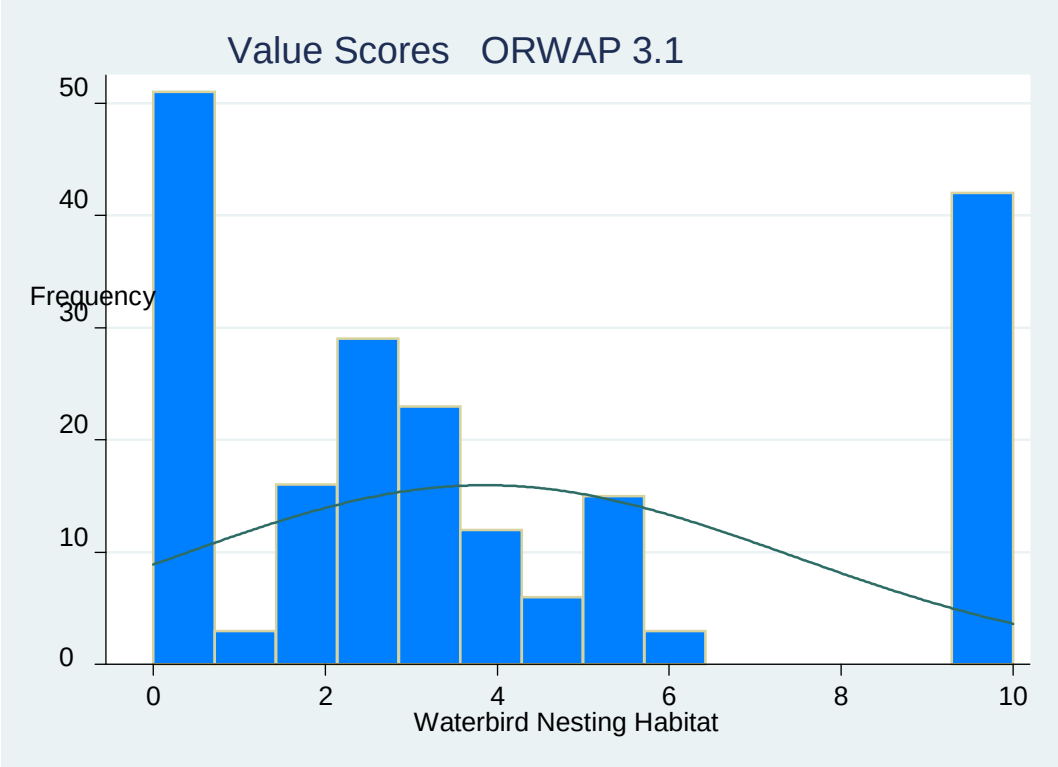
Waterbird Feeding Habitat


Value Scores ORWAP 3.1
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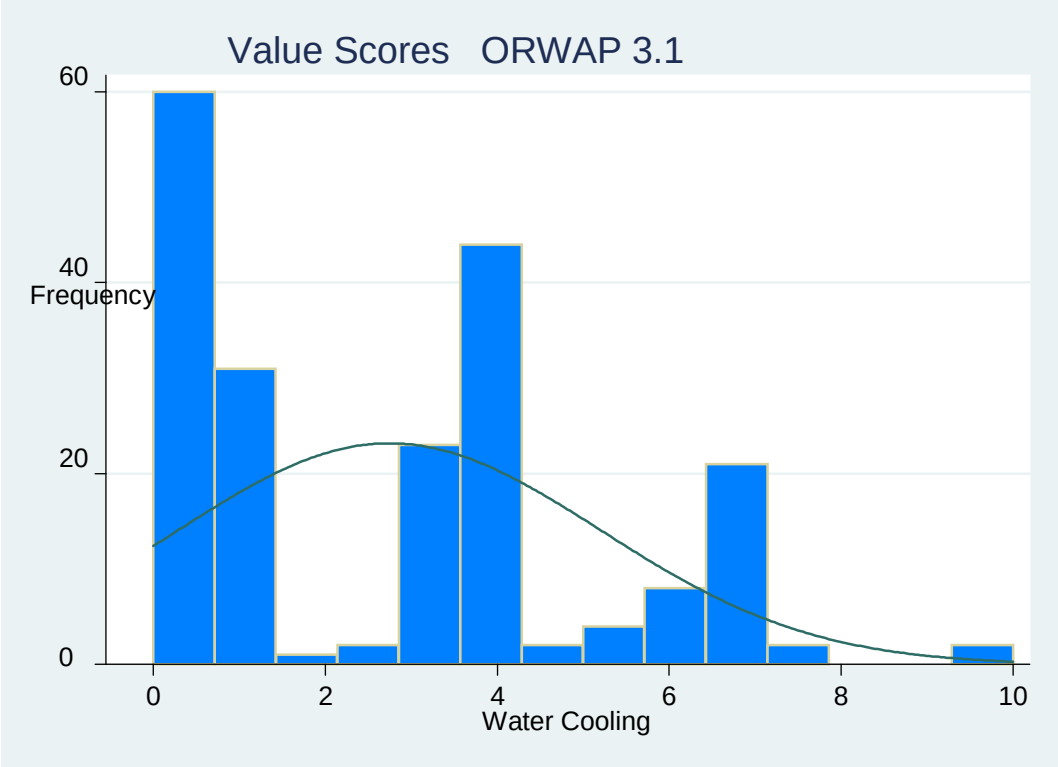
Waterbird Nesting Habitat


Value Scores ORWAP 3.1
Frequency
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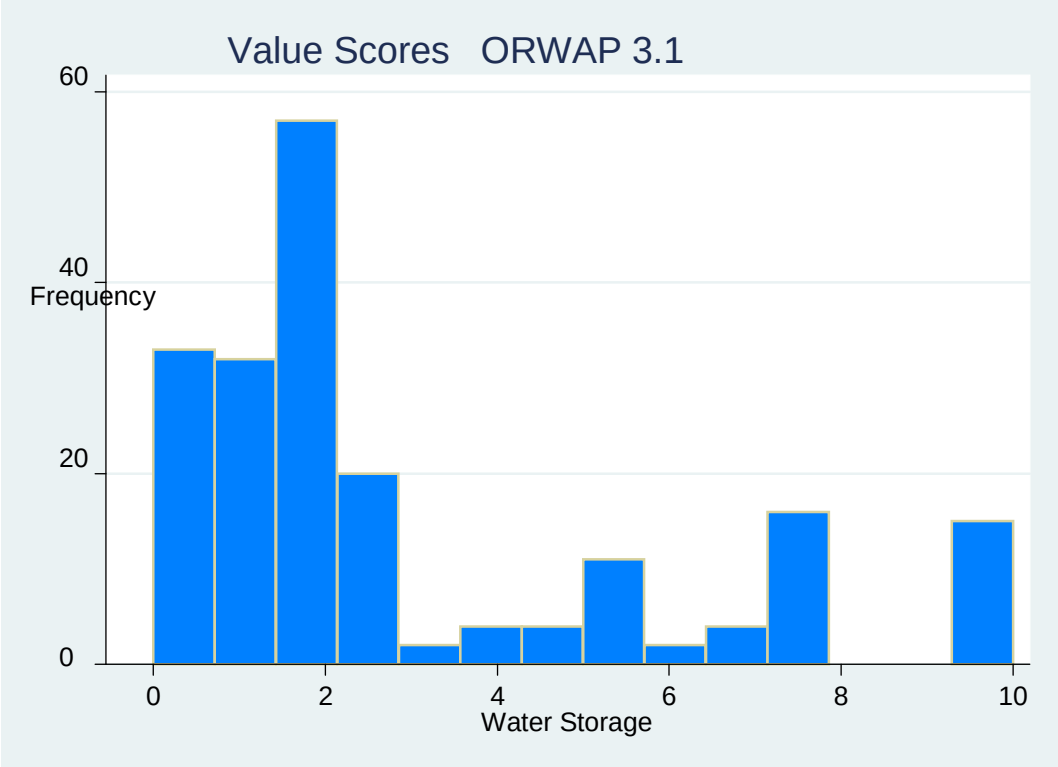
Water Cooling


Value Scores ORWAP 3.1
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Frequency
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2
4
6
8
10
Water Storage