**Development of a Statistical Predictor of Wetland Stress Caused by Alteration of Surface Water Levels**

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# Introduction

The material below presents a statistical approach to predict the likelihood of causing changes in the stress status of wetlands (i.e., causing unstressed wetland to become stressed, or causing stressed wetlands to recover to unstressed conditions) as a result of changing the wetland water levels. The development of the method is illustrated with some idealized data designed to facilitate understanding of the various relevant probability functions, and the relationships between them. After the section that demonstrates development of the statistical method, the following section presents application of the method to real data that were collected for the CFWI.

For those familiar with statistics it is possible to move directly to development of the statistical method using continuous distribution functions. However, for readers less familiar with statistics, it may be easier to start from consideration of discrete statistical functions developed from sample histograms.

# Choice of a Hydrologic Stress Predictor Variable

As presented earlier, work by Bays and Janicki (ref?) demonstrated that the occurrence of stress in wetlands is strongly related to the range of water levels that are experienced by the wetland. This range can be expressed in a number of ways, for instance:

1. Standard deviation of water level observations
2. The difference between a water level that is exceeded most of the time (e.g., the level that is exceeded 90% of the time) and a water level that is exceeded relatively seldom (e.g., the level that is exceeded 10% of the time)
3. Elevation/duration/frequency curves

Each type of expression has its own advantages and disadvantages, depending on the desired application. In general, simpler forms of expression involve a significant loss of available information, but are easier to compare across a sample of many observations, while more complex forms of expression tend to have the opposite advantages and disadvantages.

In this application, it was observed that a variant of example 2 above was a useful predictor of wetland stress. Specifically, the elevation difference between the water elevation that is exceeded 5% of the time (the P05 water elevation) and the water elevation that is exceeded 80% of the time (the P80 water elevation) was found to be a strong predictor of wetland stress. However, this predictor has one substantial disadvantage: it does not capture the importance of the absolute values of wetland water elevations. Consider the case of an unstressed wetland in which the occurrence of future water elevations is similar to current elevations, except that all elevations are raised by 10 feet. If the difference between the and water levels were the only important predictor of stress, we would predict no change in wetland stress because both these elevations are increased by the same value, and the resulting difference between them remains unaltered. In reality, such a change might indeed eventually support an unstressed wetland after reestablishment of species had taken place, but it would not be the same wetland; it would be a similar wetland with different characteristic areal footprints of wetland species and open water. This distinction is significant to us because we are trying to protect the existing expression of unstressed wetlands. To capture this factor, we need to include an aspect of the current absolute values of water level variations. Since the P05 water elevation tends to correspond fairly closely to the observable edge of wetland systems (the elevation at which wetland plant species and soil types transitions to upland plant species and soil types), we chose to substitute the observed elevation of the existing edge of the wetland system in place of the water level. This substitution provides almost identical values for the wetland hydrologic index, and ties them to the absolute values of the natural water elevation range that gave rise to the wetland in its current form. By using an edge of wetland reference elevation that in the calculation, the index value will no longer remain unaltered if the entire distribution of water elevations is changed by some constant value. The resulting wetland hydrologic index, , is calculated as:

(1)

Where:

= Wetland hydrologic index (ft)

= Wetland edge reference elevation (ft NGVD 29)

= The water level in the wetland that is exceeded 80% of the time (ft NGVD 29)

# An Exhaustive Sampling and Enumeration Approach

Imagine that you wished to assess the relationship between the wetland hydrologic index (described above) and the probability of hydrologic stress in wetlands, and that resources of time, money and personnel were of no consequence. One approach to developing the desired relationship would be to assess the stress status and measure the water elevations of all wetlands in the region of interest over a long enough period to determine an estimated water elevation of every single wetland. The impracticality of this approach is obvious, but it provides a basis for developing ideas about statistical models from first principles that may be helpful to some readers.

Having tabulated the results for all the wetlands, you decide to sort them into defined intervals of observed values, as shown in Table 1, counting the number of unstressed and stressed wetlands found in each interval. From this tabulation you construct histograms as shown in Figures 1 and 2. As shown in Table 1, you also calculate the total number of wetlands in each interval, and the percentage of those wetlands that are observed to be stressed. Note that the data shown in the example are hypothetical, but they are based on statistical characteristics that are very similar to the real data set. For clarity, the example data are shown as a statistically pure set without the variability or “noise” observed in real data because of measurement errors and data sampling effects.

**Table 1. Tabulation of Hypothetical Example Unstressed and Stressed Wetlands by Intervals of Values**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Class Interval No., "*i*"** | **Lower Limit of Interval** | **Upper Limit of Interval** | **Plotting Position,** | **No. of Unstressed Wetlands** | **No. of Stressed Wetlands** | **Total No. of Wetlands** | **% of Wetlands Stressed** |
| 1 | -1.75 | -1.25 | -1.50 | 0 | 0 | 0 | N/A |
| 2 | -1.25 | -0.75 | -1.00 | 0 | 1 | 1 | 100% |
| 3 | -0.75 | -0.25 | -0.50 | 1 | 2 | 3 | 67% |
| 4 | -0.25 | 0.25 | 0.00 | 3 | 4 | 7 | 57% |
| 5 | 0.25 | 0.75 | 0.50 | 11 | 6 | 17 | 35% |
| 6 | 0.75 | 1.25 | 1.00 | 33 | 11 | 44 | 25% |
| 7 | 1.25 | 1.75 | 1.50 | 79 | 17 | 96 | 18% |
| 8 | 1.75 | 2.25 | 2.00 | 145 | 26 | 171 | 15% |
| 9 | 2.25 | 2.75 | 2.50 | 210 | 37 | 247 | 15% |
| 10 | 2.75 | 3.25 | 3.00 | 236 | 49 | 285 | 17% |
| 11 | 3.25 | 3.75 | 3.50 | 210 | 60 | 270 | 22% |
| 12 | 3.75 | 4.25 | 4.00 | 145 | 70 | 215 | 33% |
| 13 | 4.25 | 4.75 | 4.50 | 79 | 77 | 156 | 49% |
| 14 | 4.75 | 5.25 | 5.00 | 33 | 80 | 113 | 71% |
| 15 | 5.25 | 5.75 | 5.50 | 11 | 77 | 88 | 88% |
| 16 | 5.75 | 6.25 | 6.00 | 3 | 70 | 73 | 96% |
| 17 | 6.25 | 6.75 | 6.50 | 1 | 60 | 61 | 98% |
| 18 | 6.75 | 7.25 | 7.00 | 0 | 49 | 49 | 100% |
| 19 | 7.25 | 7.75 | 7.50 | 0 | 37 | 37 | 100% |
| 20 | 7.75 | 8.25 | 8.00 | 0 | 26 | 26 | 100% |
| 21 | 8.25 | 8.75 | 8.50 | 0 | 17 | 17 | 100% |
| 22 | 8.75 | 9.25 | 9.00 | 0 | 11 | 11 | 100% |
| 23 | 9.25 | 9.75 | 9.50 | 0 | 6 | 6 | 100% |
| 24 | 9.75 | 10.25 | 10.00 | 0 | 4 | 4 | 100% |
| 25 | 10.25 | 10.75 | 10.50 | 0 | 2 | 2 | 100% |
| 26 | 10.75 | 11.25 | 11.00 | 0 | 1 | 1 | 100% |
| 27 | 11.25 | 11.75 | 11.50 | 0 | 0 | 0 | N/A |
| **Total** |  |  |  | **1,200** | **800** | **2,000** | **40%** |

In each class interval, , of values, we observe unstressed wetlands, and stressed wetlands, for wetlands in the class interval:

(2)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Index counter for tabulation of class intervals |
|  | = | Number of wetlands (both stressed and unstressed) observed in the class interval of values |
|  | = | Number of unstressed wetlands observed in the class interval of values |
|  | = | Number of stressed wetlands observed in the class interval of values |

Summing the numbers across all class intervals of values yields the numbers of wetlands of each type:

(3)

(4)

(5)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Index counter for tabulation of class intervals |
|  | = | Number of class intervals |
|  | = | Number of wetlands observed in all the class intervals of values |
|  | = | Number of unstressed wetlands observed in all the class intervals of values |
|  | = | Number of stressed wetlands observed in all the class intervals of values |

The population distribution histograms of the tabulated unstressed and stressed wetlands are shown in Figures 1 and 2, respectively. By stacking the bars of the histograms, we can also develop a corresponding population distribution histogram of all the wetlands (both unstressed and stressed), as shown in Figure 3. The histogram of unstressed wetlands shows that the most prevalent class interval for unstressed wetlands is for the range (units = ft NGVD 29). By contrast, the histogram of stressed wetlands shows that the most prevalent class interval for stressed wetlands is for the range (units = ft NGVD 29), a difference of 2.0 feet. In addition, the histogram of stressed wetlands shows a broader spread of values than the one for unstressed wetlands. These attributes are characteristic of the real data set.

Figure 1. Histogram of Example Unstressed Wetland Hydrologic Index, , Values

Figure 2. Histogram of Example Stressed Wetland Hydrologic Index, , Values

Figure 3. Histogram of Example Wetland Hydrologic Index, , Values for All Wetlands

Note that the population distribution histograms for unstressed and stressed wetlands (Figures 1 and 2) were symmetrical, but the resulting population distribution histogram for all wetlands (Figure 3) is skewed to the right. When the difference between the mean of the unstressed and the stressed wetland values is large enough, we see that the resulting total population distribution histogram for all wetlands becomes right-skewed and bi-modal (two distinct “humps”). The total population distribution histogram can only be symmetrical if the distributions of unstressed and stressed wetlands have identical mean values of , which would be an outcome inconsistent with our present understanding of the physical processes that govern these systems).

For each class interval of values we can calculate the percentage of unstressed and stressed wetlands observed in that class interval.

(6)

(7)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The fraction of unstressed wetlands in the class interval of values, expressed as a percentage |
|  | = | The fraction of stressed wetlands in the class interval of values, expressed as a percentage |
| Other terms | = | As previously defined |

The total fraction of unstressed and stressed wetlands in the class intervals of values is calculated similarly.

(8)

(9)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The total fraction of unstressed wetlands observed in all the class intervals of values |
|  | = | The total fraction of stressed wetlands observed in all the class intervals of values |
| Other terms | = | As previously defined |

The fractions of unstressed and stressed wetlands observed in each class interval of values are shown as bar charts in Figures 4 and 5, respectively. These two bar charts are combined as a stacked bar chart in Figure 6, demonstrating that the sum of and is always 100%.

Figure 4. Probability of Occurrence of Example Unstressed Wetlands as a Function of Hydrologic Index,

Figure 5. Probability of Occurrence of Example Stressed Wetlands as a Function of Hydrologic Index,

Figure 6. Probability of Occurrence of Example Stressed & Unstressed Wetlands as a Function of Hydrologic Index,

The exhaustive sampling and enumeration approach outlined above has the virtues that it is easy to understand, requires very little knowledge of statistics, and it effectively illustrates the relationships between the distributions of stressed and unstressed wetlands and the resulting likelihood of an arbitrarily selected wetland being stressed at a given value of . However, it is not a practical method for real-world application:

* It requires environmental status assessments for many hundreds or thousands of wetlands across a region – this is technically feasible, but very expensive;
* It requires long-term hydrograph measurements for the same large list of wetlands – this is beyond the staff and budget capabilities of any normal water management agency; and
* The use of histograms limits assessment of the effects of water level changes to relatively coarse changes because the minimum change that can be assessed is the difference between two adjacent class intervals in the distribution histograms (a difference of 0.5 ft. in the examples shown here) – and this interval is constrained by the requirement to keep the intervals broad enough to achieve a relatively smooth histogram fit with real-world data.

In the real world, we need to draw conclusions from smaller data sets based on representative samples derived from a relatively small fraction of the total population of wetlands. As shown in the following section, it is possible to achieve similar results by fitting continuous statistical distributions based on these smaller sampled data sets.

# A Statistical Approach Based on Representative Samples of Wetland Populations

Instead of measuring the occurrence of stress and the distribution of values in all wetlands, suppose that we selected a random representative sample of the wetlands, and measures the frequency of stress occurrence and the distribution of values in the random sample. So long as the sample is random and representative of the parent data set, we can assess the characteristics of the sampled population, and use this assessment to draw inferences about the whole population of wetlands.

Note that a random sample of the population of wetlands will yield two sample subsets: unstressed wetlands and stressed wetlands. The healthier the overall population of wetlands, the more these two subsets will be of unequal sizes, with the number of unstressed wetlands being substantially larger than the number of stressed wetlands. This can lead to difficulties in adequately characterizing the distribution of values in the stressed wetland subset if the number of stressed wetlands is too small to make an adequate estimate of the corresponding distribution of stressed values. In practice therefore, it may be more practical to work with two samples of the total wetland population:

1. A random sample of the total population that is used to characterize the overall frequency of occurrence of stress in the parent wetland population, with two subsets of wetlands (unstressed and stressed); and
2. A two random samples drawn from sample 1; one taken from the unstressed wetlands, and one from the stressed wetlands. Ideally, these two subsamples would yield approximately equal numbers of stressed and unstressed wetlands for which long-term water level hydrographs would be obtained so that the value distributions of unstressed and stressed wetlands can be determined with approximately equal accuracy. As we will see later, this helps to maximize the accuracy with which the overall risk of wetland stress at any selected value can be assessed.

Following Step 1 of the approach presented above, a random sample of a given type of wetland system will yield an estimate of the total fraction of unstressed and stressed wetlands in the parent population of wetlands:   
 (10)

(11)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The total fraction of unstressed wetlands observed in the sample |
|  | = | The total fraction of stressed wetlands observed in the sample |
|  | = | The total number of unstressed wetlands observed in the sample |
|  | = | The total number of stressed wetlands observed in the sample |
|  | = | The total number of wetlands (both stressed and unstressed) observed in the sample |

A tabulation of results for a hypothetical case is presented in Table 2.

**Table 2. Hypothetical Occurrence Frequency of Unstressed and Stressed Wetlands**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Total Number of Wetlands in Sample**  **()** | **Number of Unstressed Wetlands in Sample**  **()** | **Number of Stressed Wetlands in Sample**  **()** | **Total Fraction of Unstressed Wetlands in Sample**  **()** | **Total Fraction of Stressed Wetlands in Sample**  **()** |
| 270 | 221 | 49 | 81.9% | 18.1% |

Following Step 1 of the approach presented above, random sub-samples of the unstressed and stressed wetlands from the sample in Step 1 will yield mean and standard deviation values of from the long-term hydrographs of unstressed and stressed wetlands in the Step 2 sub-samples. These sample means and standard deviations can be used as estimates of the corresponding values from the parent population if the sub-sample sizes are large enough. An example of the probability density functions is shown in Figure 7 for a hypothetical case in which the means and standard deviations of the sub-sample values are presented in Table 3. The corresponding cumulative frequency distributions (CFDs) are shown in Figure 8.

**Table 3. Hypothetical Distribution Characteristics for Unstressed and Stressed Wetlands**

|  |  |  |  |
| --- | --- | --- | --- |
| **Wetland Stress Condition** | **Average Value of (ft.)** | **Std. Deviation of Values (ft.)** | **Is the Normal Distribution an Adequate Fit?** |
| Unstressed | 3.0 | 1.0 | Yes |
| Stressed | 5.0 | 2.0 | Yes |

For the case shown here, the normal distribution is considered to be an acceptable fit to the observed data. However, this is not a requirement of this statistical method. The method can be applied with any reasonable method for estimating the probability density functions of the observed values in the unstressed and stressed wetland sub-samples, including both parametric and non-parametric distributions and distribution fitting methods. In this case, we can calculate the following probability density values for unstressed and stressed wetlands at different values of :

|  |  |  |
| --- | --- | --- |
|  | = | The probability density of unstressed wetlands at a wetland hydrologic index value of (ft.) |
|  | = | The probability density of stressed wetlands at a wetland hydrologic index value of (ft.) |
|  | = | The normal distribution probability density function based on the distribution parameters listed below |
|  | = | The average of the observed values for the selected wetland sub-sample (i.e., either the unstressed or the stressed sub-sample, as appropriate) (ft.) |
|  | = | The variance of the observed values for the selected wetland sub-sample (i.e., either the unstressed or the stressed sub-sample, as appropriate) (ft.2) |
|  | = | The value of the wetland hydrologic index value at which the probability density is to be calculated (ft.) |

(12)

(13)

Where:

Stressed Wetlands

Unstressed Wetlands

Figure 7. Example Sample Probability Density Functions

Figure 8. Example Sample Cumulative Frequency Distributions

The probability density functions for the unstressed and unstressed wetlands each represent a fraction ( and , respectively), of the total probability density function for all wetlands. The contribution of each sub-set of wetlands (unstressed and stressed) to the total probability density function for all wetlands can be calculated as:

(14)

(15)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The population-weighted contribution of unstressed wetlands to the total population probability density of all wetlands at a wetland hydrologic index value of (ft.) |
|  | = | The population-weighted contribution of stressed wetlands to the total population probability density of all wetlands at a wetland hydrologic index value of (ft.) |
| Other terms | = | As previously defined |

The total population probability density function of all wetlands in the sample can be calculated from Equations 14 and 15 as:

(16)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The total population probability density of all wetlands in the sample evaluated at a wetland hydrologic index value of (ft.) |
| Other terms | = | As previously defined |

The resulting construction of the, and curves is shown in Figure 9.

Stressed Wetlands

Unstressed Wetlands

Figure 9. Weighted Example Sample Probability Density Functions

The cumulative frequency distribution for the total wetland population can be calculated similarly by summing the population-weighted individual CFDs of the unstressed and stressed wetland samples, as shown in Figure 10.

Figure 10. Example Sample Cumulative Frequency Distributions

For any randomly selected wetland at a given value of , the probability that the wetland will be stressed is the ratio of the population density of stressed wetlands to the population density of all wetlands. Similarly, the probability that any randomly selected wetland will be unstressed at a given value of is the ratio of the population density of unstressed wetlands to the population density of all wetlands.

(17)

(18)

(19)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The probability that any randomly selected wetland will be unstressed at a given value of (dimensionless) |
|  | = | The probability that any randomly selected wetland will be stressed at a given value of (dimensionless) |
| Other terms | = | As previously defined |

The resulting stress probability functions ( functions) are shown for the hypothetical example wetlands in Figure 11. Note that the functions are not probability density functions and .

Probability of a randomly selected wetland being unstressed,

Probability of a randomly selected wetland being stressed,

Figure 11. Example Sample Stress Probability Functions

The and functions represent the probabilities of a randomly selected wetland being found to be unstressed or stressed, respectively, at a specified value of the wetland hydrologic index,. In practice, we are frequently more interested in a different probability – the probability that a wetland of known initial stress condition and known initial wetland hydrologic index value,, will change its stress status when the wetland hydrologic index is altered to some different value of . The probabilities of a change in the wetland stress condition as a result of a change of wetland hydrologic index from an initial value of to a final value of is represented by the functions for adverse change from an unstressed to a stressed condition, and for a beneficial change from a stressed condition to an unstressed condition.

Changes in and are caused by:

* An imposed change in water levels resulting in a change of the hydrologic index value from to .
* A corresponding change of stress probability from to (and from to ).

The and functions are discontinuous. Consider the case of an unstressed wetland that is subjected to a change in the wetland hydrologic index, from an initial value of to a final value of . The corresponding probability of a wetland being unstressed under these conditions are and , respectively. If , the wetland has been moved to a condition that is less favorable for occurrence of unstressed wetlands, and we would therefore expect some risk of the wetland experiencing an adverse change of stress status. However, if , the wetland has been moved to a condition that is more favorable for occurrence of unstressed wetlands; since the wetland was already unstressed there is no reason to expect a change in stress status when it is subjected to more favorable conditions. Therefore, if , the probability of an adverse change of stress condition is considered to be zero. However, if , conditions have become less favorable for unstressed wetlands, and the probability of an adverse change from an unstressed condition to a stressed condition is greater than zero.

Consider a case where a large population of wetlands are found at an initial hydrologic index value of, and are subjected to a change which induces a final hydrologic index value of, such that so that an decrease in the fraction of unstressed wetlands is expected. The expected initial number of unstressed wetlands would be , and the expected final number of unstressed wetlands would be . Therefore the number of unstressed wetlands that changed status to a stressed condition would be , or . Therefore the probability of any randomly selected unstressed wetland in this population becoming stressed would be the number that changed from unstressed to stressed condition divided by the initial number of unstressed wetlands in the population: , which simplifies to .

Therefore, the risk of an adverse change in wetland stress status from an unstressed condition to a stressed condition can be calculated as:

If

(20)

If

(21)

Conversely, the probability of a beneficial change (recovery) from a stressed condition to an unstressed condition can be calculated as:

If ;

(22)

If ;

(23)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The probability of an adverse change in wetland status from an unstressed to a stressed condition, as a result of a change in the wetland hydrologic index from an initial value of to a final value of (dimensionless) |
|  | = | The probability of a beneficial change in wetland status from a stressed to an unstressed condition, as a result of a change in the wetland hydrologic index from an initial value of to a final value of (dimensionless) |
| Other terms | = | As previously defined |

The application ranges of the discontinuous probability functions for the probability of inducing a change in the stress status of wetlands by changing the wetland hydrologic index value are summarized in Table 4. Examples of the resulting probability functions for probability of an adverse change in wetland status from an unstressed to a stressed condition are shown in Figure 12 for multiple positive values of , and in Figure 13 for multiple negative values of , where.

***NOTE TO SELF, INSERT A REFERENCE HERE TO TWO ADDITIONAL FIGURES (14 & 15) ILLUSTRATING THE PROBABILITY OF A BENEFICIAL CHANGE IN WETLAND STATUS FROM A STRESSED TO AN UNSTRESSED CONDITION*** ***FOR MULTIPLE POSITIVE & NEGATIVE VALUES OF , AND INSERT THOSE FIGURES BELOW.***

**Table 4. Application Ranges of Discontinuous Functions for Calculation of the Probability of Inducing a Change in the Stress Status of Wetlands by Changing the Wetland Hydrologic Index Value**

|  |  |  |
| --- | --- | --- |
|  | Initial vs. Final Values of & | |
|  |  |
| Probability of **Adverse** Stress Change in Initially Unstressed Wetlands |  |  |
| Probability of **Beneficial** Stress Change (Recovery) in Initially Stressed Wetlands |  |  |

Row 1:

Probability of **Beneficial** Stress Change (Recovery) in Initially Stressed Wetlands

Probability of a Stressed Wetland Becoming Unstressed for Multiple Negative Values of , where for Plain and Ridge Wetlands

Row 2:

Probability of **Adverse** Stress Change in Initially Unstressed Wetlands

Probability of an Unstressed Wetland Becoming Stressed for Multiple Negative Values of , where for Plain and Ridge Wetlands

Row 3:

Probability of **Beneficial** Stress Change (Recovery) in Initially Stressed Wetlands

Probability of a Stressed Wetland Becoming Unstressed for Multiple Positive Values of , where

Probability of **Adverse** Stress Change in Initially Unstressed Wetlands

Probability of an Unstressed Wetland Becoming Stressed for Multiple Positive Values of , where

Figure 12:

|  |  |  |
| --- | --- | --- |
| **2018 Data** | **Probability of Inducing a Change in the Stress Status as the Wetland Hydrologic Index Value Changes** | |
| Negative Δθ | Plain | Ridge |
| Stressed to Not Stressed |  |  |
| Not Stressed to Stressed |  |  |
| Positive Δθ | Plain | Ridge |
| Stressed to Not Stressed |  |  |
| Not Stressed to Stressed |  |  |

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\\ad.sfwmd.gov\dfsroot\data\wsd\SUP\proj\CFWI\_WetlandStress\Update2018\ZetaCalcIntegrals.R

For most wetlands, we do not have the observations of water levels that allow calculation of an initial value of the wetland hydrologic index, . However, The weighted average risk of unstressed wetlands becoming stressed () due to an imposed change of hydrologic index () can be calculated from the *pdf* () for occurrence of unstressed wetlands as a function of hydrologic index value (), and the risk function for occurrence of stress in initially unstressed wetlands as a function of the initial hydrologic index value () and the imposed change of hydrologic index value ():

(24)

By definition, the integral of the probability density function across the full range of has a value of one:

(25)

Therefore Equation 24 can be simplified to:

(26)

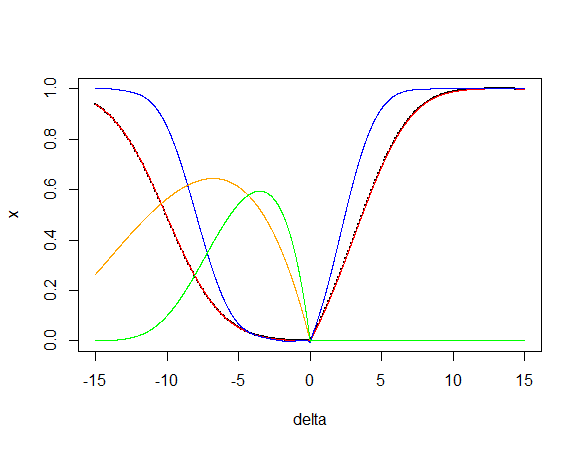
Similarly, the population-weighted average probability of stressed wetlands becoming unstressed for a specific imposed change of hydrologic index value () can be calculated as:

(27)

Where:

|  |  |  |
| --- | --- | --- |
|  | = | The population-weighted average probability of an adverse change in wetland status from an unstressed to a stressed condition, as a result of an imposed change of hydrologic index value () from an unknown initial value of . |
|  | = | The population-weighted average probability of a beneficial change in wetland status from a stressed to an unstressed condition, as a result of an imposed change of hydrologic index value () from an unknown initial value of . |
| Other terms | = | As previously defined |

[\\ad.sfwmd.gov\dfsroot\data\wsd\SUP\proj\CFWI\_WetlandStress\New\_Poly\_UsedinCalcs\_for\_SFWMD\_2019.xlsx](file:///\\ad.sfwmd.gov\dfsroot\data\wsd\SUP\proj\CFWI_WetlandStress\New_Poly_UsedinCalcs_for_SFWMD_2019.xlsx)



# Definitions

| **Variable** | **Units** | **Definition** |
| --- | --- | --- |
|  | ft. NGVD29 | Wetland edge reference elevation. |
|  | dimensionless | The fraction of stressed wetlands in the class interval of values, expressed as a percentage. |
|  | dimensionless | The fraction of unstressed wetlands in the class interval of values, expressed as a percentage. |
|  | dimensionless | The total fraction of stressed wetlands observed in the sample. |
|  | dimensionless | The total fraction of unstressed wetlands observed in the sample. |
|  | dimensionless | A subscript index counter for tabulation of class intervals. |
|  | dimensionless | A value representing the maximum observed number of the subscript index counter. |
|  | dimensionless | The total number of stressed wetlands observed in the class interval of values. |
|  | dimensionless | The total number of unstressed wetlands observed in the class interval of values. |
|  | dimensionless | The total number (sum) of wetlands (both stressed and unstressed) observed in all the class intervals of values (Section 3), or in a whole sample set (Section 4). |
|  | dimensionless | The total number (sum) of stressed wetlands observed in all the class intervals of values (Section 3), or in a whole sample set (Section 4). |
|  | dimensionless | The total number (sum) of unstressed wetlands observed in all the class intervals of values (Section 3), or in a whole sample set (Section 4). |
|  | dimensionless | The normal distribution probability density function based on the distribution parameters listed in the parentheses. |
|  | dimensionless | The probability density at a particular value the hydrologic index, , derived from the distribution characteristics of the probability density function fitted to all observed values of in a sample of stressed wetlands.  A function of . |
|  | dimensionless | The probability density at a particular value of the hydrologic index, , derived from the distribution characteristics of the probability density function fitted to all observed values of in a sample of unstressed wetlands.  A function of . |
|  | dimensionless | The total population probability density of all wetlands (unstressed and stressed) in the sample evaluated at a wetland hydrologic index value of .  A function of . |
|  | dimensionless | The population-weighted contribution of stressed wetlands to the total population probability density of all wetlands at a wetland hydrologic index value of .  A function of . |
|  | dimensionless | The population-weighted contribution of unstressed wetlands to the total population probability density of all wetlands at a wetland hydrologic index value of .  A function of . |
|  | ft. NGVD29 | The 5th percentile low water elevation (i.e., the water level is higher than this elevation 5 percent of the time). |
|  | ft. NGVD29 | The 80th percentile low water elevation (i.e., the water level is higher than this elevation 80 percent of the time). |
|  | ft.2 | The variance of the observed values for a selected wetland sub-sample (i.e., either the unstressed or the stressed sub-sample, as appropriate). The standard deviation of the observed values is . |
|  |  |  |
|  | ft. | A change of wetland hydrologic index value (). |
|  | dimensionless | The probability of a stressed wetland becoming unstressed (recovery) due to an imposed change of hydrologic index ().  A function of: , (where . |
|  | dimensionless | The risk (probability) of an unstressed wetland becoming stressed due to an imposed change of hydrologic index ().  A function of: , (where . |
|  | dimensionless | The population-weighted average probability of stressed wetlands becoming unstressed (recovery) due to an imposed change of hydrologic index ().  A function of . |
|  | dimensionless | The population-weighted average risk (probability) of unstressed wetlands becoming stressed due to an imposed change of hydrologic index ().  A function of . |
|  | ft. | Wetland hydrologic index value equal to the elevation of the wetland edge minus the P80 water elevation. |
|  | ft. | Initial value of the wetland hydrologic index before an imposed hydrologic change. |
|  | ft. | Final value of the wetland hydrologic index after an imposed hydrologic change. |
|  | ft. NGVD29 | The average of the observed values for the selected wetland sub-sample (i.e., either the unstressed or the stressed sub-sample, as appropriate) (ft.) |
|  | dimensionless | Initial value of when .  A function of . |
|  | dimensionless | Final value of when .  A function of . |
|  | dimensionless | Probability that a randomly selected wetland at a specific value of will be stressed.  A function of . |
|  | dimensionless | Initial value of when .  A function of . |
|  | dimensionless | Final value of when .  A function of . |
|  | dimensionless | Probability that a randomly selected wetland at a specific value of will be unstressed.  A function of . |
|  |  |  |