***Introduction***

Coastal salt marshes are among of the world's rarest ecosystems, accounting for a mere ~0.3% of total surface area. Despite their limited extent, a healthy salt marsh is rich in biodiversity and rivals tropical rain forests in primary and secondary production per acre (Valiela et al., 2005). They are also of great ecological and economic importance, providing benefits to adjacent upland and nearshore landscapes in multiple ways. For example, coastal marshes filter and sequester nutrient runoff in benthic sediments (Odum, 2005). They are carbon sinks with a sequestration capacity on par with that of terrestrial forests (Laffoley, D., & Grimsditch, G., 2009). They function as a coastal buffer, protecting shorelines from storm surges and erosion (Sun & Carson, 2020). And they provide critical nursery habitat for juvenile fishes (Teal & Howes, 2005).

Despite their import, the ecological integrity of coastal marshes continues to be threatened by a variety of factors. Chief among them are sea level rise and coastline modification resulting from human development (Smith et al., 2022). The degradation of coastal marsh habitat places many species at risk, especially salt marsh obligates. Among salt marsh avifauna, no species faces greater risk than the saltmarsh sparrow (*Ammospiza caudacutus*). After declining ~9.0% annually between 1998 and 2012, the species faces a high probability of extinction within 50 years if current trends continue (Correll et al., 2017). Saltmarsh sparrows depend upon the availability of high-quality, high marsh habitat, above the mean high-water line. Their nests are constructed on the ground there, typically among *Spartina* grasses. This strategy leaves the nest vulnerable to flooding and predation, with the result that nest failure is the leading cause of population decline (Shriver, 2002). While nesting is not a concern in the non-breeding season, saltmarsh sparrows also demonstrate a strong affinity for high marsh vegetation on their wintering grounds. Working to ensure access to high marsh habitat throughout the species' range is critical. Strategies include conserving existing high-quality habitat and working to restore degraded habitat through interventions such as elevation enhancement, restoration of sediment supply, ditch remediation, and draining pools and impoundments caused by ditching.

***This project aims to identify unprotected potential saltmarsh sparrow habitat areas in southeast Virginia.*** By focusing on this area, special attention was be given to the identification of non-breeding habitat. This region will become increasingly important for wintering saltmarsh sparrows as climate change shifts their wintering range northward and habitat to the south is lost to anticipated sea-level rise.

***Methods***

This prioritization of potential habitat area was carried out through a classification of land parcels. Using a vector data layer with polygons mapped to every land parcel in Virginia, those parcels that met three specific criteria were extracted to create a new featureclass and assigned a habitat suitability score based four habitat indicator variables. To be considered for habitat suitability a parcel had to a) *fall within the saltmarsh sparrow's winter range*, b) *contain coastal* *salt marsh*, and c) *not fall within an already protected area*, i.e., an area with an existing conservation or biodiversity mandate.

Parcels within the wintering range of saltmarsh sparrow were identified using a data layer from the U.S. Geological Survey (USGS) containing the species range of saltmarsh sparrow. The polygon representing the species' winter range was selected to create a new layer and intersected with Virginia land parcel data. Next, the overlap of parcels with protected areas was determined by intersecting candidate parcels with a USGS data layer from the Protected Area Database (PAD). All PAD polygons have a GAP status code between 1 and 4 assigned to them. Status codes 1-3 indicate some degree of conservation/biodiversity mandate, while GAP status code 4 indicates that an area has no known mandate for protection. Any parcel that intersected a PAD polygon with a GAP status code of 1-3 was removed from consideration. Finally, the presence of coastal salt marsh within parcels was determined by intersecting candidate parcels with a polygon data layer representing global salt marsh distribution.

Once parcels meeting the requisite criteria were identified, a habitat suitability index (HSI) score was calculated for each parcel based on the following four indicators.

*(i)* *proximity to known saltmarsh sparrow habitat* ($I_P$)

$I_P$ was determined by calculating the distances between candidate parcels and the closest known observations of saltmarsh sparrow over the last twenty years, between the months of November and March. A score between 0 and 5 was then assigned to each parcel based on proximity, measured in meters. (*5* = ≤ 250, *4* = > 250 and ≤ 400, *3* = > 400 and ≤ 600, *2* = > 600 and ≤ 800, *1* = > 800 and ≤ 1200, *0* = > 1200). Saltmarsh sparrow observation data was retrieved from eBird (Cornell Lab of Ornithology).

*(ii)* *extent of high marsh* ($I_{HM}$)

The total area of high marsh within a given parcel was calculated using raster data representing the elevation of coastal lands relative to tidal ranges within the conterminous United States at a resolution of 30m. Relative tidal elevations ($Z^*$, where $Z^*$= (orthometric elevation - mean sea level) / (mean high water - mean sea level)) greater than 0 were considered as high marsh for the purpose of analysis. Cells with a value greater than 0 were first extracted to create a new data layer. That data was further refined by extracting only cells that intersected with coastal marsh. Zonal statistics were then used to calculate the total area of high marsh within each parcel. A score between 0 and 5, $I_{HM}$, was assigned to each parcel based on total area of high marsh, measured in $m^2$. (*5* = > 50000, *4* = ≤ 50000 and > 20000 *3* = ≤ 20000 and >10000, *2* = ≤ 10000 and > 4000, *1* = ≤ 4000 and > 1800, *0* = ≤ 1800)

*(iii)* *potential impact of tidal restrictions* ($I_{TR}$)

Using a raster data layer representing the potential upstream effects of tidal restrictions ranging from 0 (no effect) to 1 (severe effect), a mean effect value was calculated for the salt marsh patches within each land parcel polygon. The value represents an estimate of the proportion of salt marsh lost due to the tidal restriction. Tidal restrictions include undersized culverts and bridges, tide gates, dikes, and other structures that impede the ability of an estuarine system to carry out normal tidal flushing.

*(iv) extent of impervious cover within corresponding 12-digit hydrologic unit* ($I_I$)

Impervious surfaces are unable to absorb and filter water, and instead increase both the volume and speed at which runoff moves down an elevation gradient. This often results in excessive influxes of water into wetland areas as well as concentrated inputs of pollutants and fertilizer that can have a deleterious effect on wetland ecosystem health. An impervious cover score was calculated for each parcel by determining the percentage of impervious surface cover within the sixth order (12-digit) hydrologic unit (the smallest unit available for analysis) corresponding to each parcel. The resulting percentage associated with each parcel equated to a score between 0 and 1. Hydrologic unit data was obtained from the USGS Watershed Boundary dataset, while impervious surface data was available through the National Land Cover Database (NLCD).

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A HSI score was calculated by assigning the following weights to each indicator: $I_P$ = 1; $I_{HM}$ = 2; $I_{TM}$ = 1; $I_I$ = 0.5. The formula below was then used to determine the final HSI score.

$$0.4(I_P) + 0.8(I_{HM}) - 2(I_{TR}) - I_I$$

Multiplying each score by the above factors normalized the values in relation to one another and achieved the target relative weight for each indicator. The maximum scores for each indicator are, $I_P$ = 2; $I_{HM}$ = 4; $I_{TM}$ = 2; $I_I$ = 1. Possible HSI scores range between a maximum of 6.0 and a minimum of -3.0. A score of 5.0 and above earned a parcel designation as “excellent candidate for saltmarsh sparrow winter habitat preservation”.

## ***Results and Discussion***

Following the initial screening of land parcels, 1,513 were determined to meet the three criteria and evaluated based on the four indicators. Candidate parcels were principally clustered in four zones within southeast Virginia: around Mathews on the southeastern tip of the Middle Peninsula (Fig. 1); along the eastern edge of the Virginia Peninsula (Fig. 2); in Portsmouth and Suffolk, on either side of the Nansemond River as it empties into Hampton Roads (Fig. 3); and in the extreme southeast corner of the state, effectively ringing Back Bay, and along the eastern edge of the North Landing River (Fig. 4).

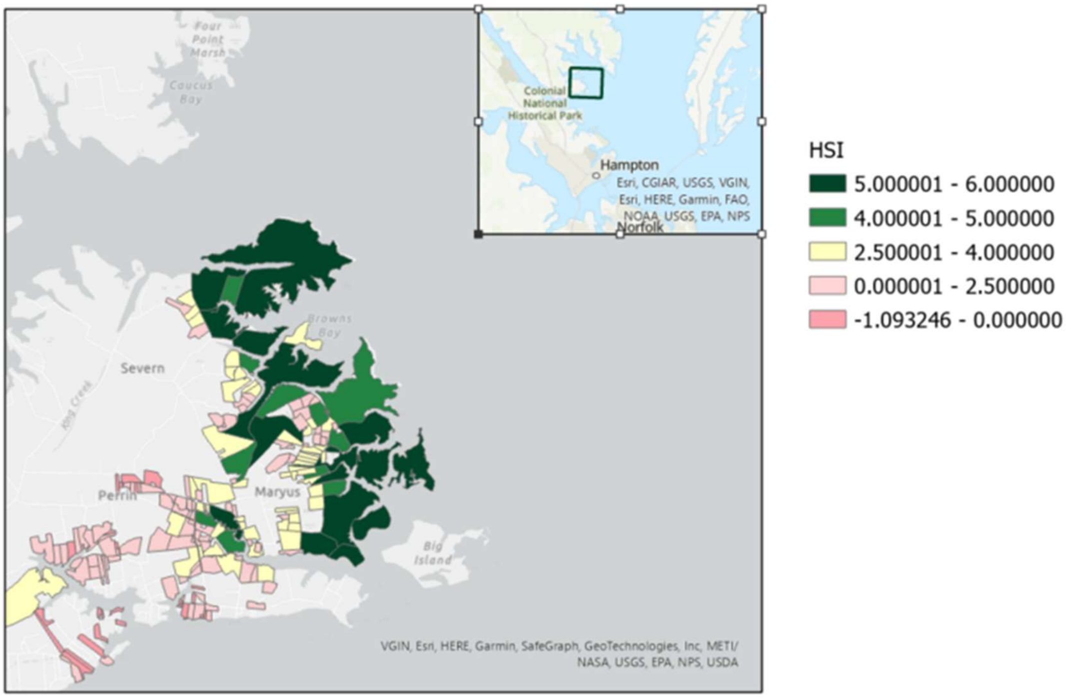



*Fig. 1. Mathews area, Middle Peninsula*

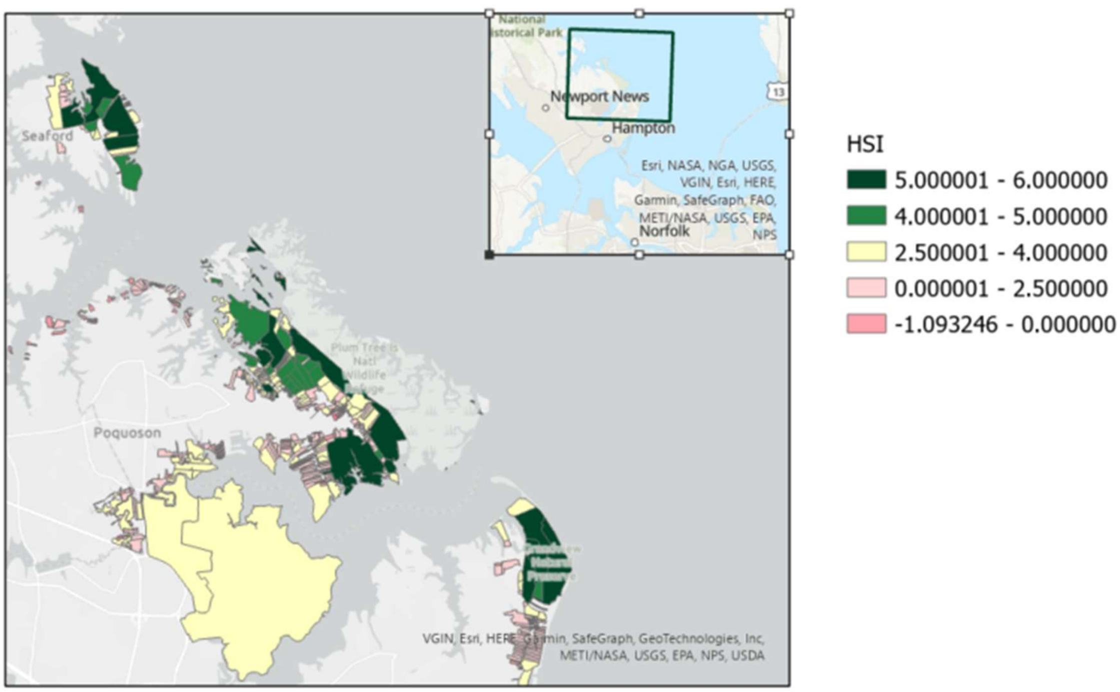



*Fig. 2. East side of Virginia Peninsula*

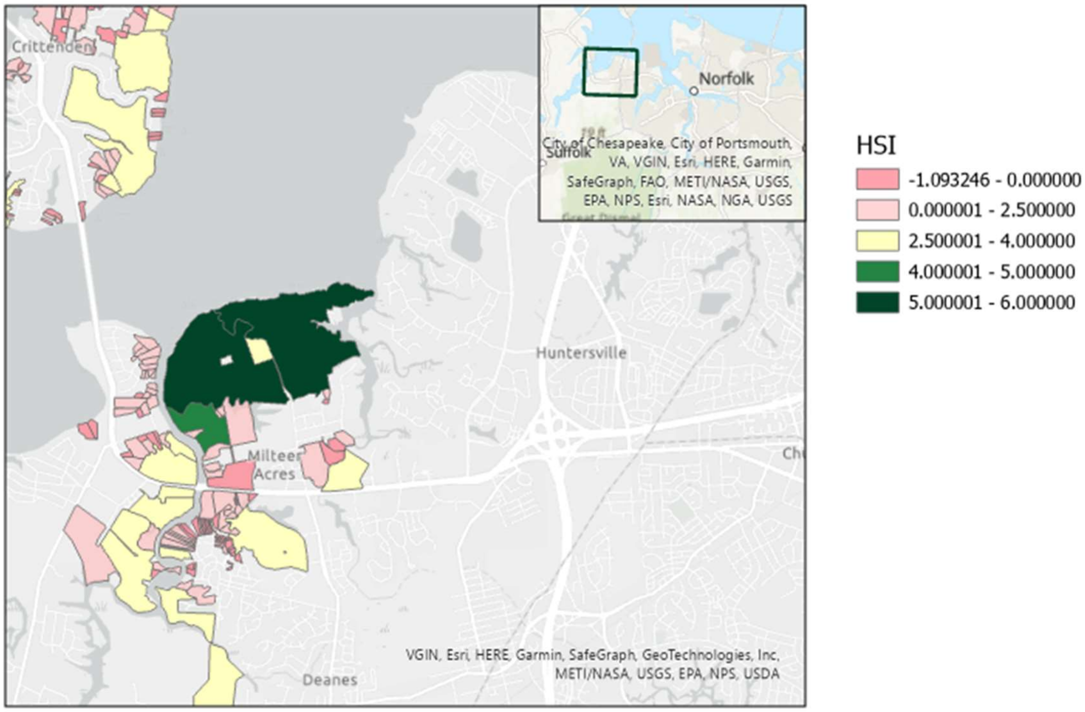



*Fig. 3. West Portsmouth*

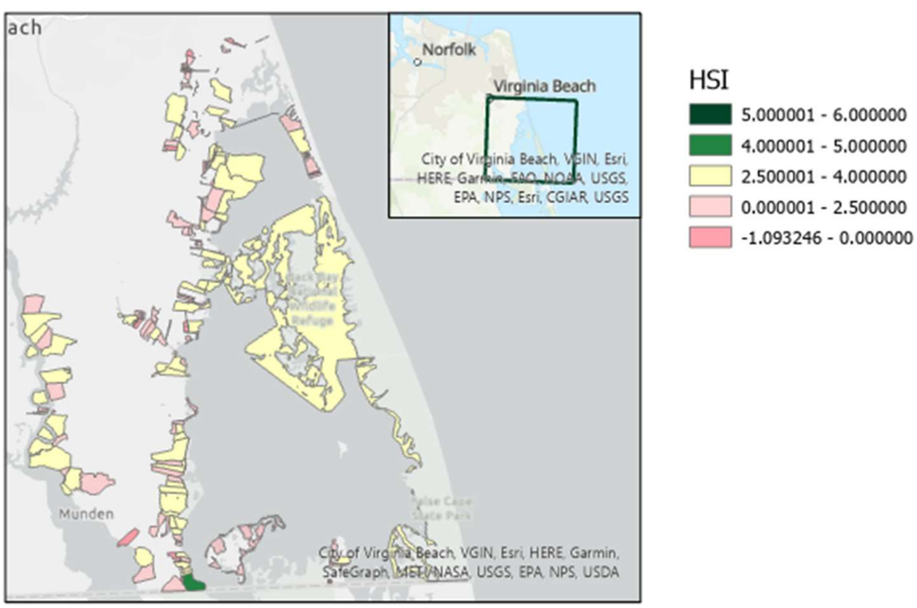
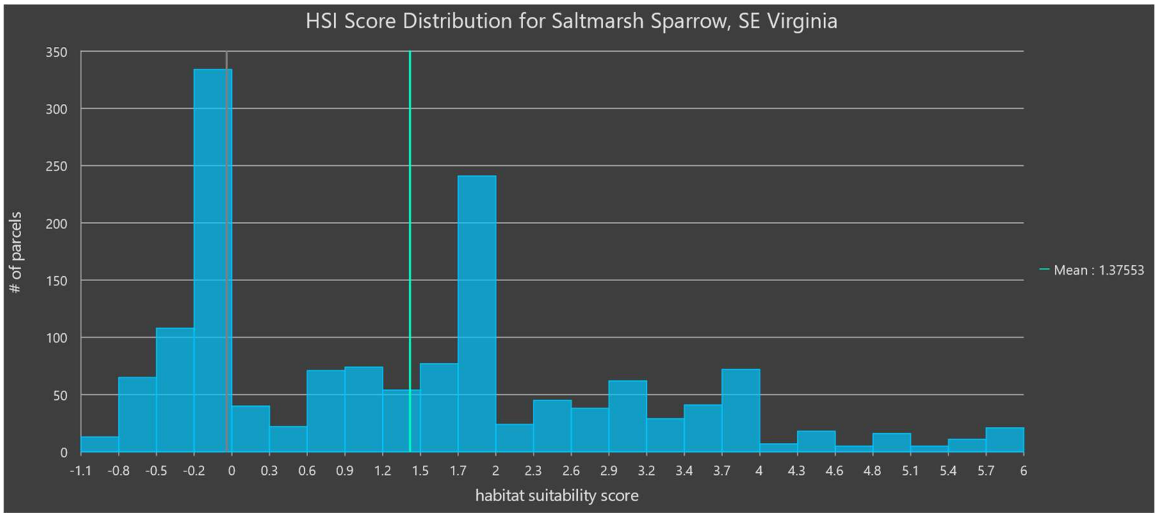



*Fig. 4. Back Bay area*

The mean score of all candidate parcels was 1.375, with a bimodal distribution around -0.2 and 1.7. By a significant margin, most parcels are unworthy of further consideration for conservation or restoration. Only 42 parcels scored 5.0 or better and should be seriously explored as candidates for potential conservation action.




In the Back Bay area, though many parcels scored well on high marsh distribution (≥ 3), the area is subject to significant effects from tidal restrictions ($\mu$ = 0.32). More importantly, there are simply no recorded observations from the area over the last twenty years that are indicative of an overwintering individual as opposed to a bird in migration (Fig 5).

Two large parcels containing the Bennett's Creek Marsh in western Portsmouth at the mouth of Nansemond River are strong candidates for further review. Both received HSI scores > 5.95 and contain, between the two of them, 2.78 km$^2$ of potential high marsh. Additionally, a dozen overwintering birds were observed at this location within the last decade.

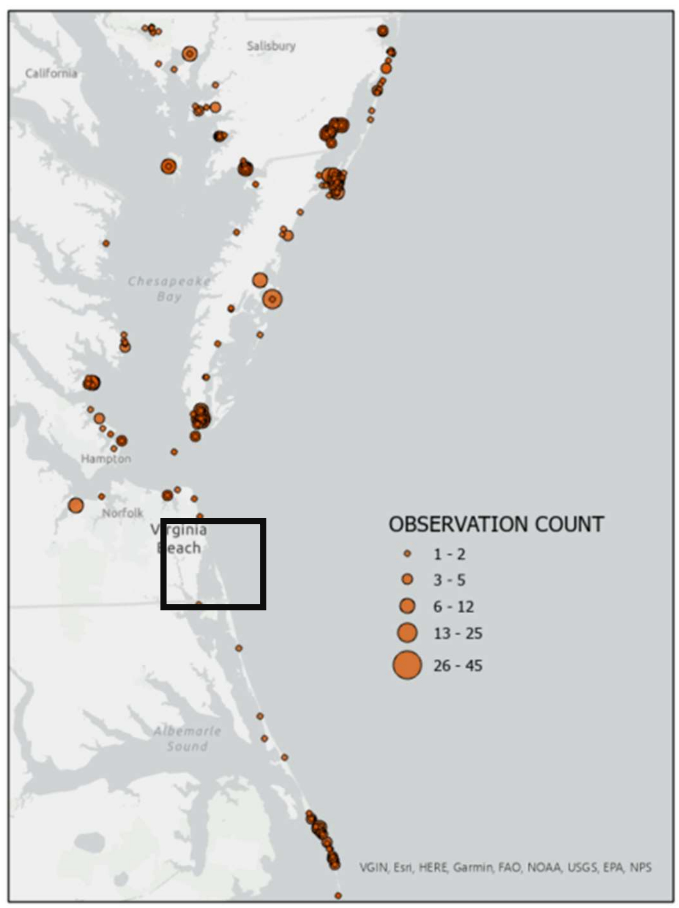



*Fig. 5. Observations of saltmarsh sparrow since 2012, Nov.-Mar.*

Based on the analysis carried out in this project, the vast majority of excellent candidate parcels (HSI ≥ 5.0) for saltmarsh sparrow winter habitat preservation are located on the Virginia Peninsula and southeastern tip of the Middle Peninsula (Fig. 6). These areas have robust historical observation records of overwintering birds, and the parcels identified within them demonstrate relatively high levels of extant high marsh, almost no impact from tidal restriction ($\mu$ = 0.001), and very low levels of impervious surface cover within their corresponding sixth order hydrologic units ($\mu$ = 0.07%).

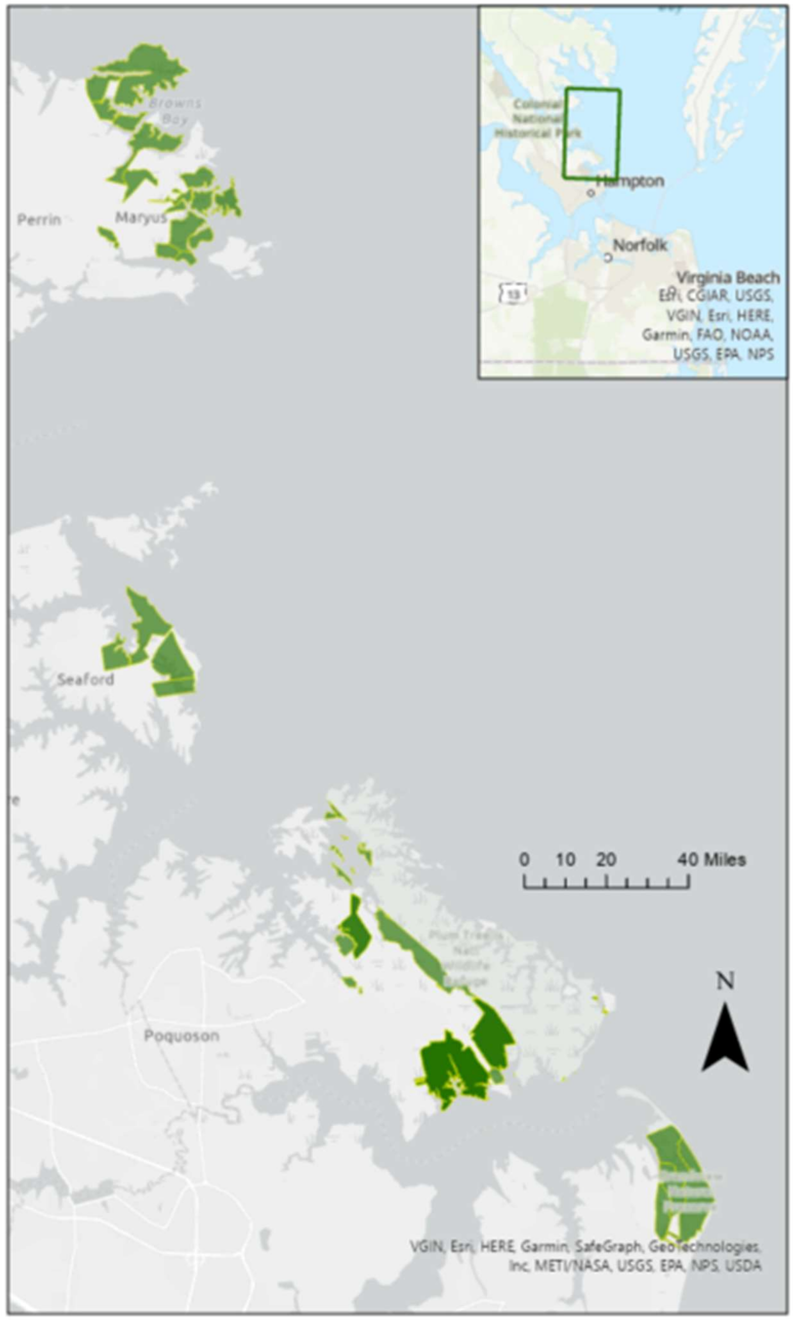



*Fig. 6. "Excellent" candidate parcels on the Virginia and Middle Peninsulas*

The map in Figure 6 represents a first step towards preserving critical wintering habitat for the saltmarsh sparrow. The map should be used to identify and screen sites worthy of further consideration for restoration and/or conservation. Once target sites are identified, next steps would involve conducting field visits to assess other key habitat features, such as openness and angle to the horizon[1], as well as determining which restoration and management methods would yield maximal benefit for the patch under consideration.

**References**

[1] Habitat openness (vs. area or distance to marsh edge) has been identified as a primary predictor of species abundance [11], though it is not clear to me that such a characteristic can be measured without visiting sites individually and collecting field data.

Correll, M. D., Wiest, W. A., Hodgman, T. P., Shriver, W. G., Elphick, C. S., McGill, B. J., O'Brien, K. M., & Olsen, B. J. (2017). Predictors of specialist avifaunal decline in coastal marshes. *Conservation Biology*, *31*(1). https://doi.org/10.1111/cobi.12797

Laffoley, D., & Grimsditch, G. (Eds.). (2009). *The Management of Natural Coastal Carbon Sinks*

Odum, E. P. (2005). Tidal Marshes as Outwelling/Pulsing Systems. In *Concepts and Controversies in Tidal Marsh Ecology*. https://doi.org/10.1007/0-306-47534-0_1

Shriver, W.G. (2002). *Conservation Ecology of Salt Marsh Birds in New England* (Doctoral dissertation, SUNY College of Environmental Science and Forestry).

Smith, J. A. M., Adamowicz, S. C., Wilson, G. M., & Rochlin, I. (2022). "Waffle" pools in ditched salt marshes: assessment, potential causes, and management. *Wetlands Ecology and Management*, *30*(5). https://doi.org/10.1007/s11273-021-09835-3

Sun, F., & Carson, R. T. (2020). Coastal wetlands reduce property damage during tropical cyclones. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(11). https://doi.org/10.1073/pnas.1915169117

Teal, J. M., & Howes, B. L. (2005). Salt Marsh Values: Retrospection from the end of the Century. In *Concepts and Controversies in Tidal Marsh Ecology*. https://doi.org/10.1007/0-306-47534-0_2

Valiela, I., Cole, M. L., Mcclelland, J., Hauxwell, J., Cebrian, J., & Joye, S. B. (2005). Role of Salt Marshes as Part of Coastal Landscapes. In *Concepts and Controversies in Tidal Marsh Ecology*. https://doi.org/10.1007/0-306-47534-0_3

## Data Sources

**Virginia land parcels.** Virginia Department of Conservation & Recreation, 2014. Virginia Wetlands Catalog, Conservation Summary by Parcel. https://www.dcr.virginia.gov/natural-heritage/wetlandscat

**Global Distribution of Saltmarsh.** Mcowen C, Weatherdon LV, Bochove J, Sullivan E, Blyth S, Zockler C, Stanwell-Smith D, Kingston N, Martin CS, Spalding M, Fletcher S, 2017. A global map of saltmarshes (v6.1). Biodiversity Data Journal 5: e11764. Paper DOI: https://doi.org/10.3897/BDJ.5.e11764. Data DOI: https://doi.org/10.34892/07vk-ws51

**Protected Area Database (VA).** U.S. Geological Survey (USGS) Gap Analysis Project (GAP), 2021, Protected Areas Database of the United States (PAD-US), Version 2.1: U.S. Geological Survey data release, https://doi.org/10.5066/P9Q9LQ4B .

**USGS Species Data.** U.S. Geological Survey - Gap Analysis Project, 2018. Saltmarsh Sharp-tailed Sparrow (Ammodramus caudacutus) bSSTSx_CONUS_2001v1 Range Map. U.S. Geological Survey. https://doi.org/10.5066/F78G8JTB

**Relative Tidal Elevation.** Holmquist, J.R., and L. Windham-Myers. 2021. Relative Tidal Marsh Elevation Maps with Uncertainty for Conterminous USA, 2010. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1844

**Saltmarsh Sparrow observations.** eBird Basic Dataset. Version: EBD_relAug-2022. Cornell Lab of Ornithology, Ithaca, New York. Aug 2022.

**Hydrologic Cataloging Unit (12 digit HUC).** (ESRI, ArcGIS Online)

**USA NLCD Impervious Surface Time Series.** (ArcGIS Online)

## Appendix

WORKFLOW

## Part I: Identification of land parcels that meet established criteria for receiving a ranking/score as potential habitat.

1. Add necessary layers (Virginia land parcels, global saltmarsh distribution, species data, and Virginia PAD data). Select by Location all parcels within the winter range of the species distribution and create a new layer based on the selection.

2. Using parcels selection from step 1, again Select By Location to identify all remaining parcels that intersect with coastal saltmarsh.

3. Using the layer from 2, Select By Attributes to isolate all parcels with a Conservation Score of 3 or higher (High, Very High, Outstanding) and generate a new layer.

4. From the resulting PAD data layer, select all polygons that are coded with a GAP Status of 1, 2, or 3. The resulting layer will be used to exclude all parcels that intersect with it. This way parcels will only be permitted to intersect with GAP Status Code 4 areas (which have no biodiversity or conservation mandate)

5. Using the Erase tool, remove any parcel that intersects with a PAD polygon with GAP status of 1, 2, or 3. All remaining polygons contain saltmarsh and have no biodiversity or conservation mandate → "Parcels_noMandate". This layer represents all possible candidate polygons for potential unprotected winter habitat.

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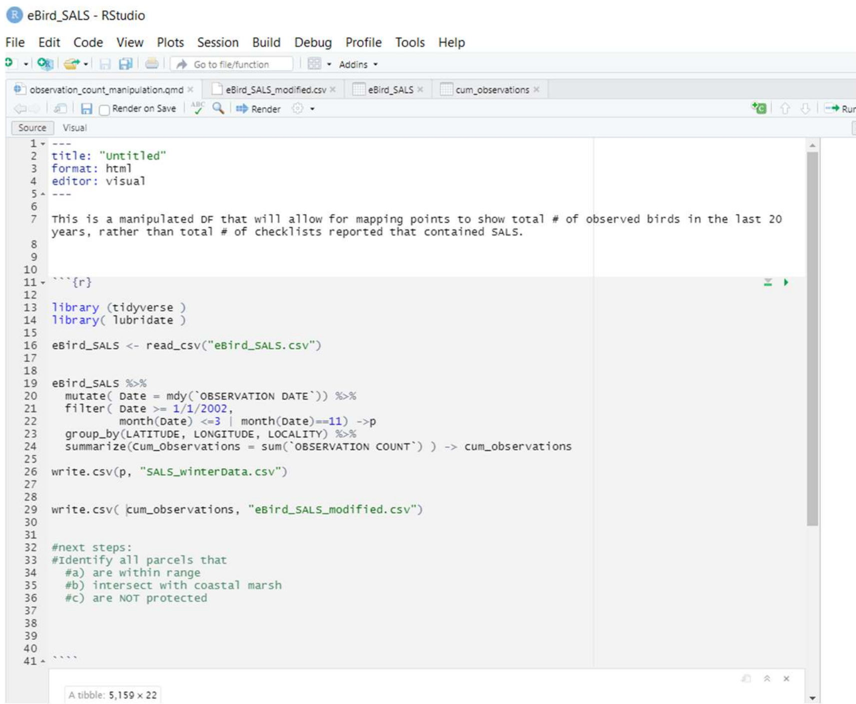
## Part 2: Calculation of scores for habitat suitability index (HSI) components

*(i)* proximity to known saltmarsh sparrow habitat ($I_P$)

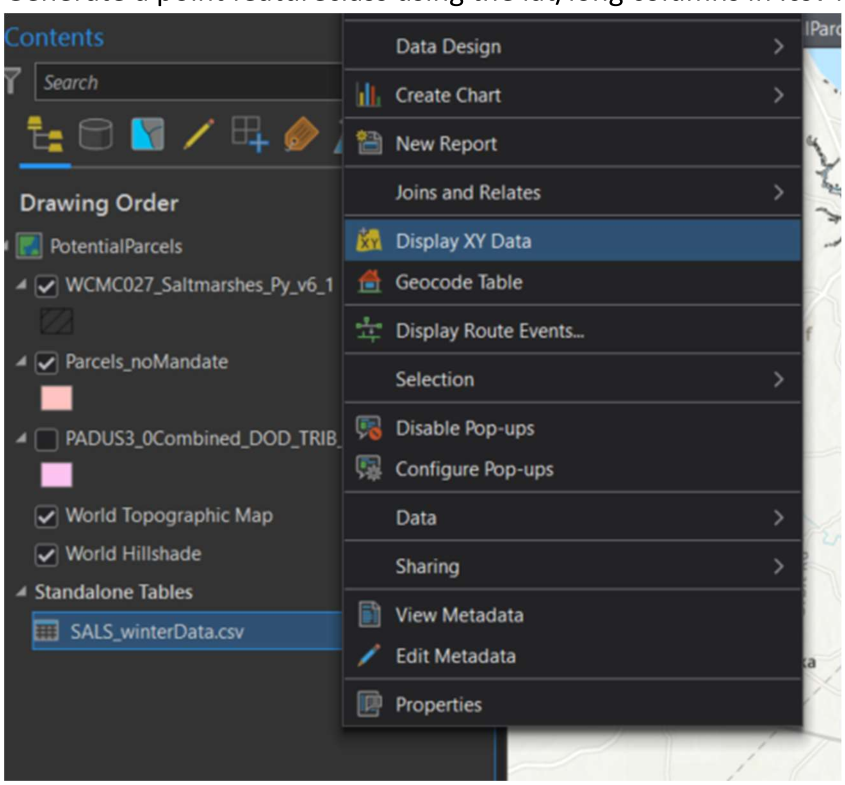
This was determined with a Near analysis of the land parcels data layer and a layer containing presence data for *Ammospiza caudacutus*. Data source: Cornell Lab of Ornithology (eBird).

1. Manipulate eBird to select for sightings in the last 20 years, within winter range and between and November and March.




2. Import .csv file into ArcGIS Pro.

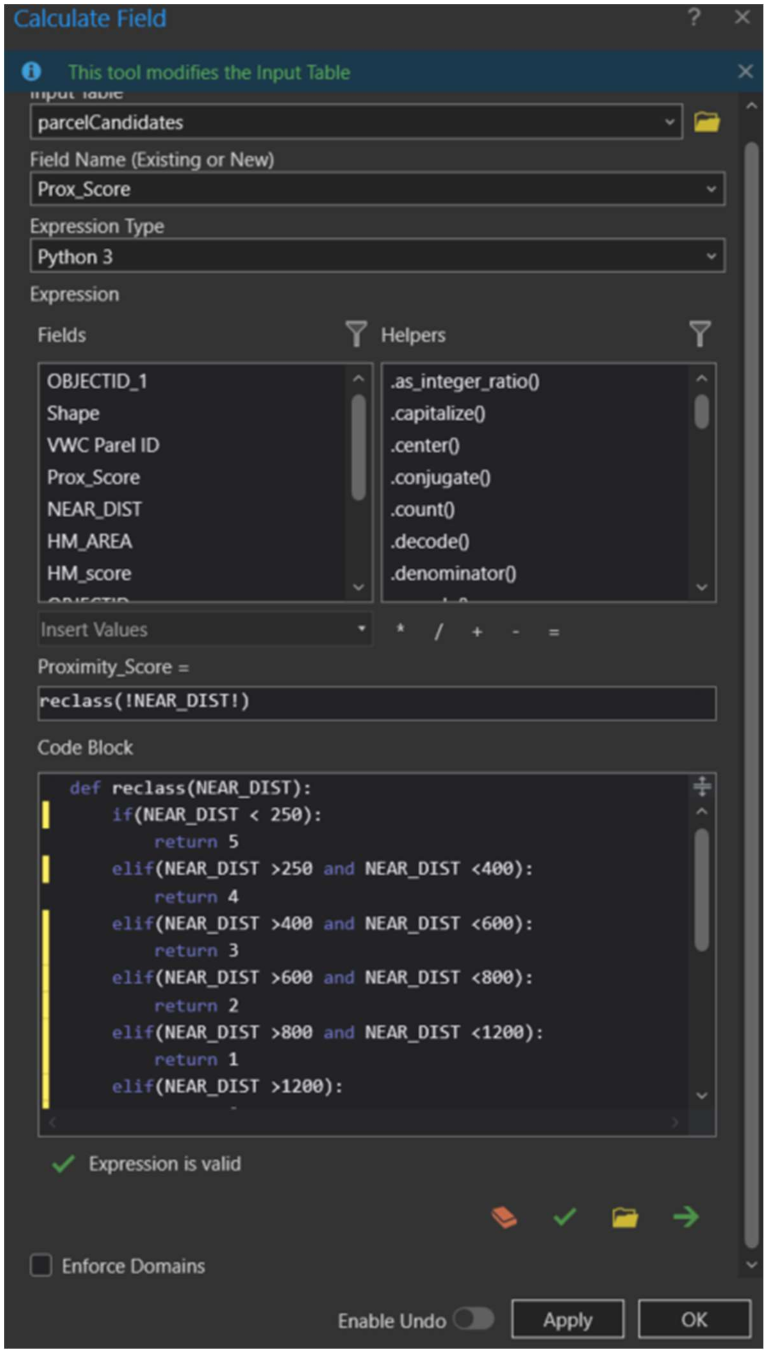
3. Generate a point featureclass using the lat/long columns in .csv file




4. Use the Near tool to calculate distances between candidate parcels and recorded saltmarsh sparrow observations.

5. Data Design → Fields → Create a new field, "Proximity Score"

6. Calculate Field for newly created field using the script below, thereby assigning a score of 0 (worst) to 5 (best) depending on distance from known observations of saltmarsh sparrow.

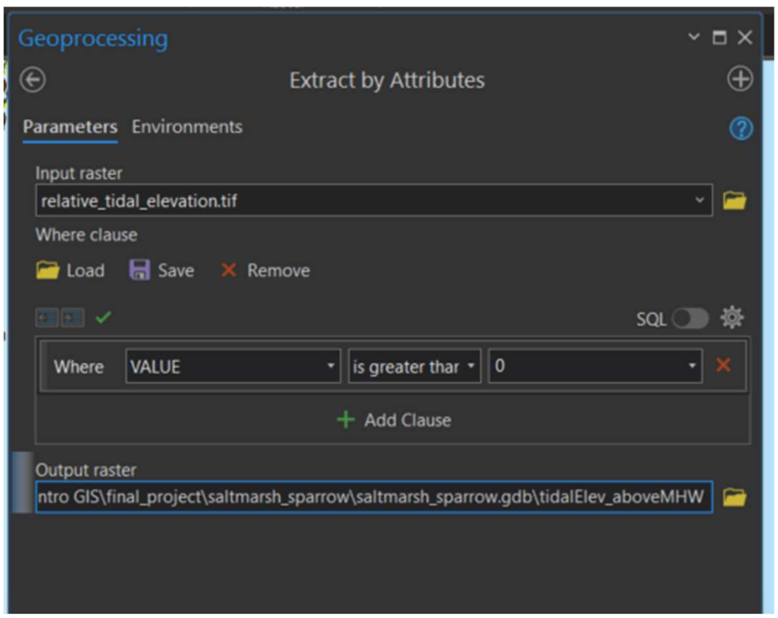


***(ii)*** availability of high marsh ($I_{HM}$)

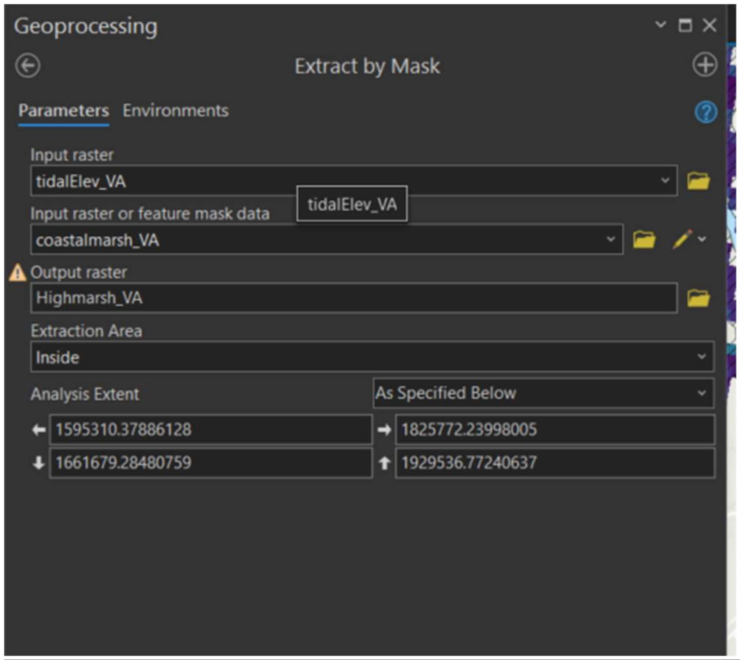
The total area of high marsh within a given parcel was calculated using relative tidal elevation as a proxy. Relative tidal elevations > 0 were considered as high marsh (Relative tidal elevation ($Z^*$), elevation normalized to the tidal range. $Z^*$ = (orthometric elevation - mean sea level) / (mean high water - mean sea level).

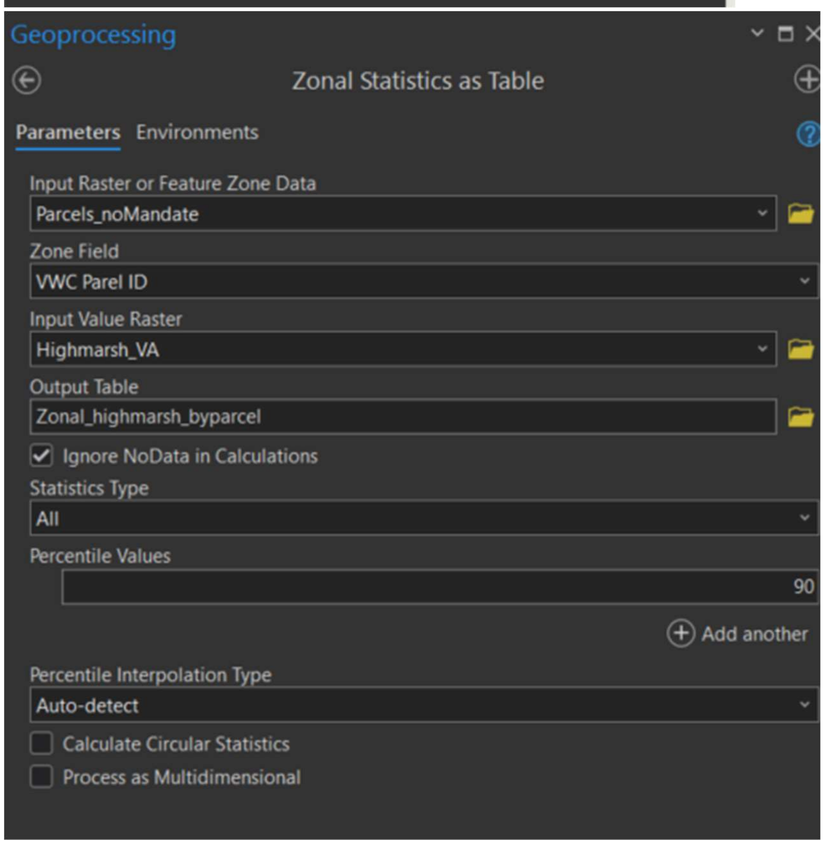
Preliminary: For ease of subsequent data manipulation, clip tidal elevation and saltmarsh layers using VA state boundary as the extent.

1. Extract by Attributes (Spatial Analyst Tools) to create a layer containing only coastal land with a relative elevation above 0.

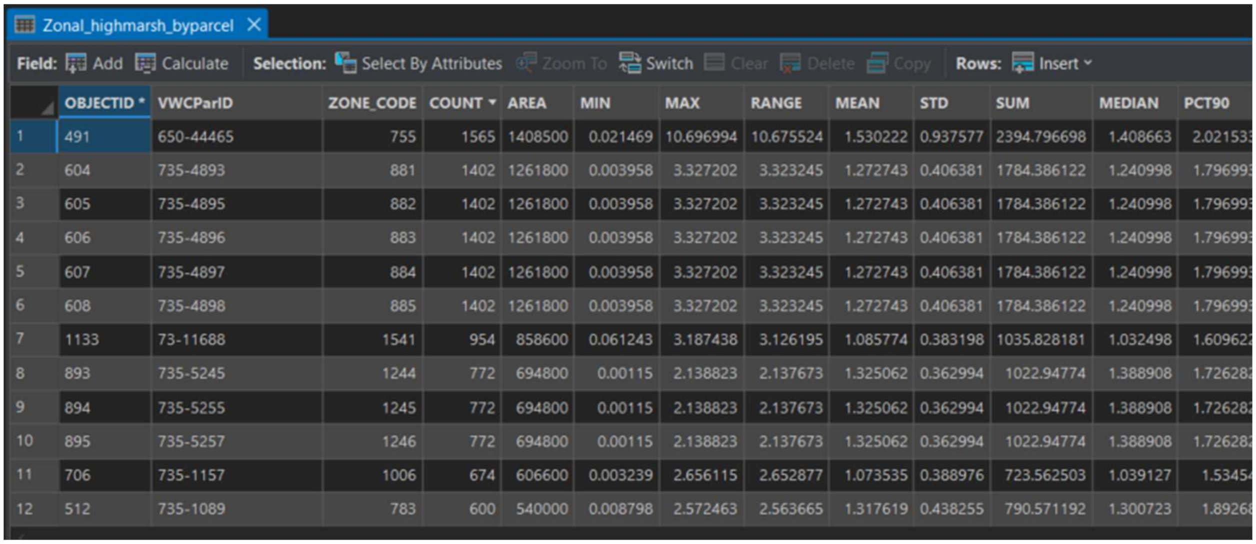



2. Only a subset of cells with a value > 0 are found within coastal marsh. Using Extract by Mask, clip the raster using the coastal saltmarsh layer as output extent.




3. 

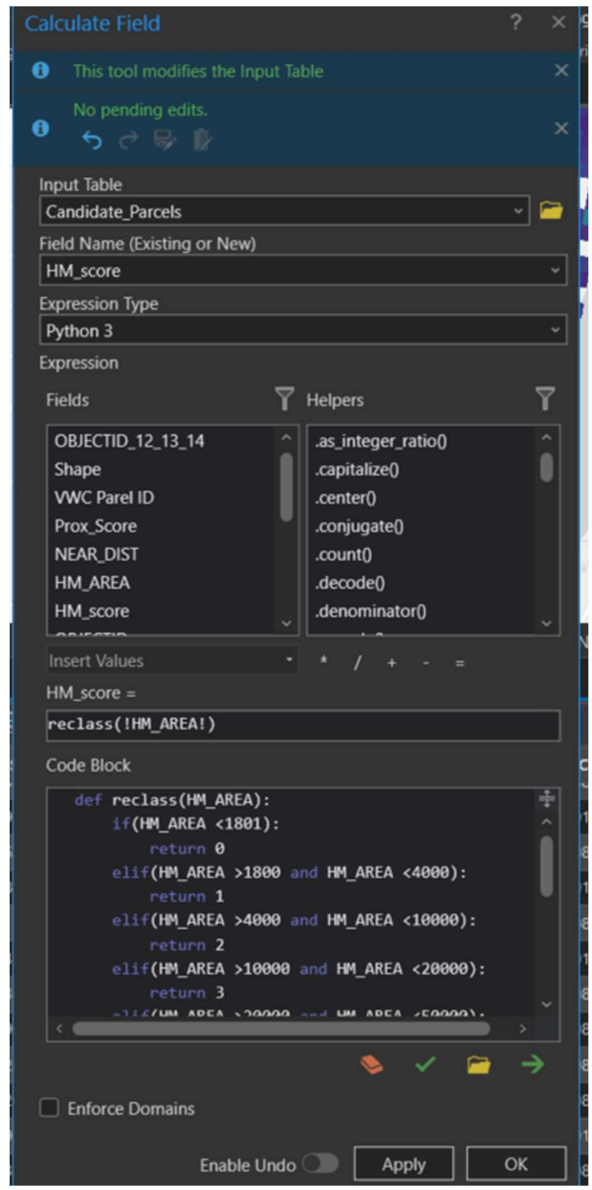

Resulting table below (1 cell = 30mx30m):





| | OBJECTID * | VWCParID | ZONE_CODE | COUNT | AREA | MIN | MAX | RANGE | MEAN | STD | SUM | MEDIAN | PCT90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 491 | 650-44465 | 755 | 1565 | 1408500 | 0.021469 | 10.696994 | 10.675524 | 1.530222 | 0.937577 | 2394.796698 | 1.408663 | 2.02153 |
| 2 | 604 | 735-4893 | 881 | 1402 | 1261800 | 0.003958 | 3.327202 | 3.323245 | 1.272743 | 0.406381 | 1784.386122 | 1.240998 | 1.79699 |
| 3 | 605 | 735-4895 | 882 | 1402 | 1261800 | 0.003958 | 3.327202 | 3.323245 | 1.272743 | 0.406381 | 1784.386122 | 1.240998 | 1.79699 |
| 4 | 606 | 735-4896 | 883 | 1402 | 1261800 | 0.003958 | 3.327202 | 3.323245 | 1.272743 | 0.406381 | 1784.386122 | 1.240998 | 1.79699 |
| 5 | 607 | 735-4897 | 884 | 1402 | 1261800 | 0.003958 | 3.327202 | 3.323245 | 1.272743 | 0.406381 | 1784.386122 | 1.240998 | 1.79699 |
| 6 | 608 | 735-4898 | 885 | 1402 | 1261800 | 0.003958 | 3.327202 | 3.323245 | 1.272743 | 0.406381 | 1784.386122 | 1.240998 | 1.79699 |
| 7 | 1133 | 73-11688 | 1541 | 954 | 858600 | 0.061243 | 3.187438 | 3.126195 | 1.085774 | 0.383198 | 1035.828181 | 1.032498 | 1.60962 |
| 8 | 893 | 735-5245 | 1244 | 772 | 694800 | 0.00115 | 2.138823 | 2.137673 | 1.325062 | 0.362994 | 1022.94774 | 1.388908 | 1.72628 |
| 9 | 894 | 735-5255 | 1245 | 772 | 694800 | 0.00115 | 2.138823 | 2.137673 | 1.325062 | 0.362994 | 1022.94774 | 1.388908 | 1.72628 |
| 10 | 895 | 735-5257 | 1246 | 772 | 694800 | 0.00115 | 2.138823 | 2.137673 | 1.325062 | 0.362994 | 1022.94774 | 1.388908 | 1.72628 |
| 11 | 706 | 735-1157 | 1006 | 674 | 606600 | 0.003239 | 2.656115 | 2.652877 | 1.073535 | 0.388976 | 723.562503 | 1.039127 | 1.53454 |
| 12 | 512 | 735-1089 | 783 | 600 | 540000 | 0.008798 | 2.572463 | 2.563665 | 1.317619 | 0.438255 | 790.571192 | 1.300723 | 1.89268 |

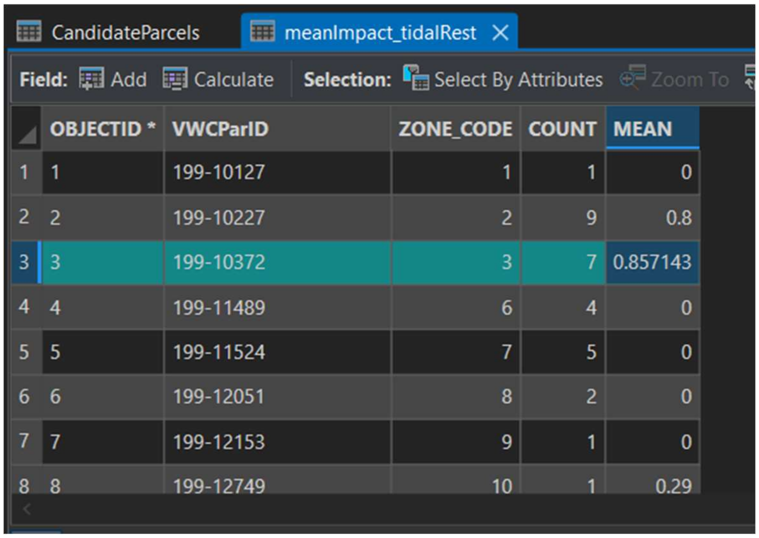
4. Delete all fields but COUNT, AREA, and VWCParID. Join to Parcels_noMandate. Select and remove all entries with a <Null> value for high marsh area.
5. Assign a high marsh score (HM_score) using a series of if/then statements in Python and applying the *reclass*() function with HM_AREA as argument.



*(iii)* potential impact of tidal restrictions ($I_{TR}$)

Using a raster data layer representing the potential effects of tidal restrictions ranging from 0 (no effect) to 1 (severe effect), a mean effect value was calculated for the salt marsh patches within each land parcel polygon. Data source: [Northeast Conservation Planning Atlas](#).

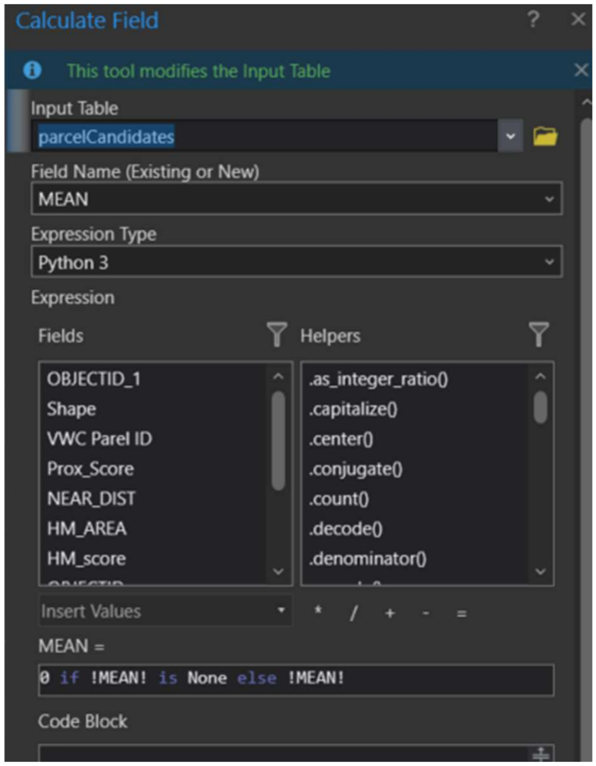
1. Create zonal statistic table to determine mean tidal impact per parcel. Values will be between 0 and 1, with 0 = no impact, 1 = most severe impact.




| | OBJECTID * | VWCParID | ZONE_CODE | COUNT | MEAN |
|---|---|---|---|---|---|
| 1 | 1 | 199-10127 | 1 | 1 | 0 |
| 2 | 2 | 199-10227 | 2 | 9 | 0.8 |
| 3 | 3 | 199-10372 | 3 | 7 | 0.857143 |
| 4 | 4 | 199-11489 | 6 | 4 | 0 |
| 5 | 5 | 199-11524 | 7 | 5 | 0 |
| 6 | 6 | 199-12051 | 8 | 2 | 0 |
| 7 | 7 | 199-12153 | 9 | 1 | 0 |
| 8 | 8 | 199-12749 | 10 | 1 | 0.29 |

2. Join table to candidate parcel layer. Export join as its own featureclass, and use newly created featureclass as primary "candidate parcel" layer moving forward.

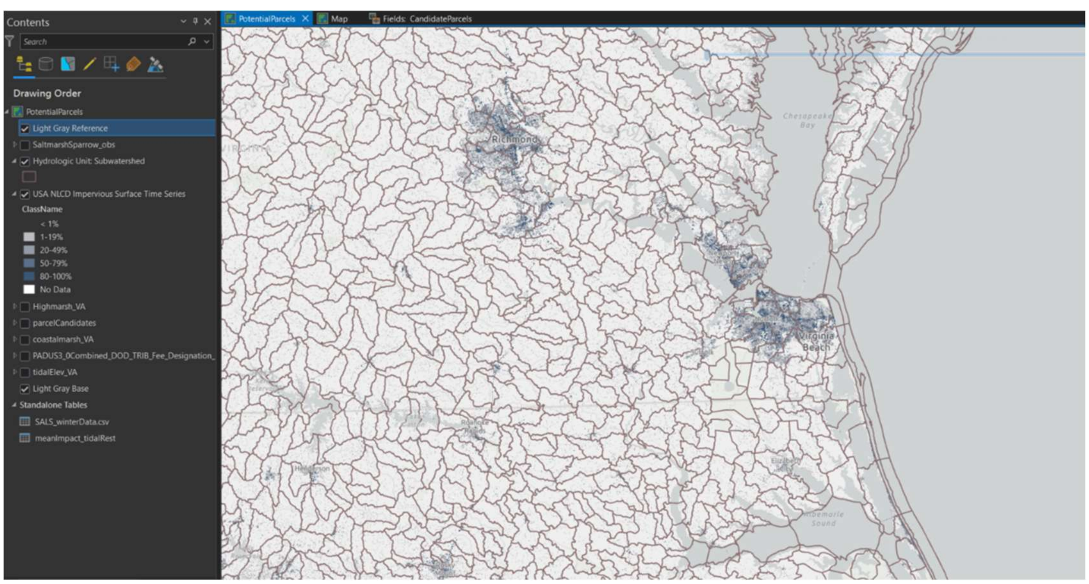
3. Replace all <Null> values with 0




4. Let MEAN tidal impact represent tidal impact score and subtract the value from other indicator scores when calculating final HSI.

*(iv)* degree of impervious cover within corresponding 12-digit hydrologic unit ($I_I$)

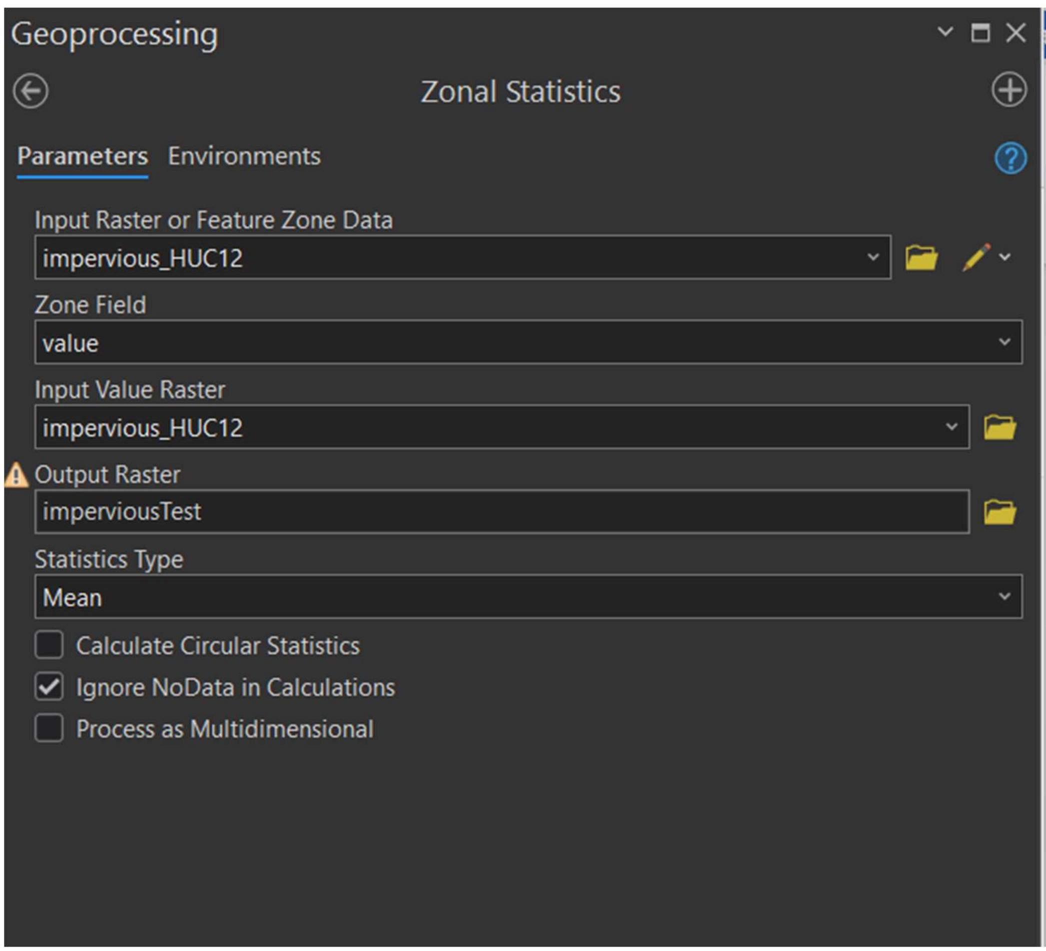
1. Add hydrologic unit boundaries (12 digit) and NLCD imperviousness layers to map




2. Clip HUC12 boundaries and imperviousness raster cells to VA state boundary for ease of geoprocessing.

3. Using Zonal Statistics tool (NOT "...as Table"), create a new raster layer based on the existing impervious raster layer. Use "value" as the zone field. The newly created raster should have only one attribute associated with it, stretch.pixel value. Each value representing % of impervious cover within a given cell. This allowsfor accurate calculation of the average % impervious cover by HUC12 boundary when generating zonal statistics as table.

   Calculation of zonal statistics as table using the original imperviousness raster layer consistently produced mean values of 2 for all cells for some reason. The additional step outlined above circumvents this problem.




4. Calculate zonal statistics as a table using the new raster layer. "Mean" field will represent average impervious cover per HUC12 as a percentage.

| OBJECTID * | HUC12 | ZONE_CODE | COUNT | AREA | MIN | MAX | RANGE | MEAN | STD | SUM | MEDIAN | PCT90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 020700100307 | 1 | 39306 | 35375400 | 0 | 100 | 100 | 24.016511 | 24.470075 | 943993 | 19 | 62 |
| 2 | 020700100103 | 2 | 67001 | 60300900 | 0 | 100 | 100 | 30.350129 | 27.931034 | 2033489 | 25 | 75 |
| 3 | 020700100301 | 3 | 56709 | 51038100 | 0 | 100 | 100 | 42.805445 | 27.681061 | 2427454 | 42 | 83 |
| 4 | 051301010102 | 4 | 42 | 37800 | 0 | 55 | 55 | 5.666667 | 11.143366 | 238 | 2 | 14.7 |
| 5 | 051301010103 | 5 | 610 | 549000 | 0 | 35 | 35 | 0.216393 | 2.076187 | 132 | 0 | 0 |
| 6 | 051301010104 | 6 | 186 | 167400 | 0 | 46 | 46 | 0.494624 | 4.056387 | 92 | 0 | 0 |
| 7 | 051301010105 | 7 | 28 | 25200 | 0 | 29 | 29 | 2.214286 | 7.052645 | 62 | 0 | 2.4 |
| 8 | 051301010202 | 8 | 312 | 280800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

5. Divide "Mean" field by 100 to generate a value between 0 and 1.

6. Delete all fields except for HUC12 and MEAN. Join table to HUC12_VA data layer.

7. Export features to create a new layer that can also be joined and edited.

8. "Add Spatial Join" to primary parcelCandidates layer. Export features to create new layer and delete all unnecessary fields related to HUC12 data.

The resulting table now includes the four indicators to be used to calculate a habitat suitability score for each parcel.

| OBJECTID_12_13_14 * | Shape * | VWC Parel ID | Prox_Score | NEAR_DIST | HM_AREA | HM_score | OBJECTID | COUNT | TIDALRES_IMPACT | HUC12 | NAME | MEAN | Shape_Length | Shape_Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Polygon | 199-10127 | 0 | 4501.78542 | 900 | 1 | 1 | 1 | 0 | 020801080101 | Poquoson River-Lower... | [illegible] | 477.548197 | 10745.328043 |
| 2 | Polygon | 199-10227 | 0 | 4604.673047 | 2700 | 1 | 2 | 9 | 0.8 | 020801080101 | Poquoson River-Lower... | 0.08176 | 1087.510937 | 27510.070761 |
| 3 | Polygon | 199-10372 | 0 | 3470.870053 | 900 | 1 | 3 | 7 | 0.857143 | 020801080101 | Poquoson River-Lower... | 0.08176 | 1017.280342 | 63910.050276 |
| 4 | Polygon | 199-10381 | 0 | 3369.077751 | 900 | 1 | <Null> | <Null> | 0 | 020801080101 | Poquoson River-Lower... | 0.08176 | 769.512208 | 13473.262483 |
| 5 | Polygon | 199-10540 | 0 | 2927.768692 | 1800 | 1 | <Null> | <Null> | 0 | 020801080101 | Poquoson River-Lower... | 0.08176 | 811.426807 | 25042.603717 |
| 6 | Polygon | 199-11489 | 0 | 4886.210699 | 900 | 1 | 4 | 4 | 0 | 020801080101 | Poquoson River-Lower... | 0.08176 | 913.563587 | 40605.429163 |
| 7 | Polygon | 199-11524 | 0 | 6143.357659 | 1800 | 1 | 5 | 5 | 0 | 020801080101 | Poquoson River-Lower... | 0.08176 | 633.274506 | 10550.135994 |
| 8 | Polygon | 199-12051 | 0 | 2161.752136 | 900 | 1 | 6 | 2 | 0 | 020801080101 | Poquoson River-Lower... | 0.08176 | 409.903565 | 7378.367523 |
| 9 | Polygon | 199-12153 | 0 | 1786.228414 | 900 | 1 | 7 | 1 | 0 | 020801080101 | Poquoson River-Lower... | 0.08176 | 190.334203 | 1720.092116 |
| 10 | Polygon | 199-12749 | 0 | 5298.146568 | 900 | 1 | 8 | 1 | 0.29 | 020801080102 | Northwest Branch Back... | 0.205008 | 239.361517 | 2847.89004 |
| 11 | Polygon | 199-12756 | 0 | 5106.482973 | 17100 | 4 | 9 | 16 | 0.29 | 020801080102 | Northwest Branch Back... | 0.205008 | 1824.46605 | 33604.841916 |
| 12 | Polygon | 199-13003 | 0 | 5236.998341 | 3600 | 2 | 10 | 1 | 0.29 | 020801080102 | Northwest Branch Back... | 0.205008 | 695.279791 | 7876.414336 |
| 13 | Polygon | 199-13613 | 0 | 4686.307415 | 900 | 1 | 11 | 1 | 0 | 020801080101 | Poquoson River-Lower... | 0.08176 | 905.80722 | 25590.582815 |

## Part III: Calculate HSI scores by parcel

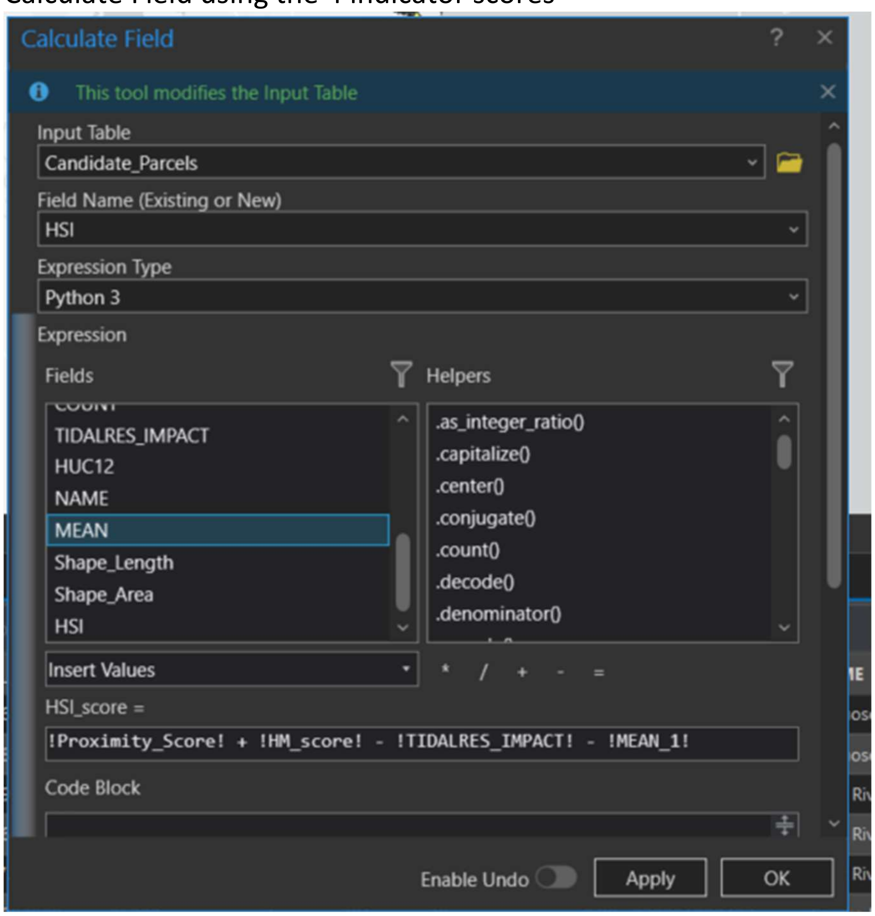
1. The two positive indicators (proximity to observed SALS and high marsh area) are currently scored on a 0-5 point scale, while the negative indicators (tidal restriction impact and imperviousness) are scored between 0 and 1.

2. Weights for indicators to be calculated as follows:
    - Proximity to observation sites, x1
    - Area of high marsh within parcel, x2
    - Tidal restriction impact, x1
    - Imperviousness of HUC12, x0.5

3. All values must be normalized relative to one another by recalculating fields
    - Multiply Prox_Score by 0.4 to yield a value range between 0 and 2
    - Multiply HM_score by 0.8 to yield a value range between 0 and 4
    - Multiply TIDALRES_IMPACT by 2 to yield a value range between 0 and 2
    - MEAN (= % impervious cover) does not need to be recalculated.

4. Create a new field, HSI_score.

5. Calculate Field using the 4 indicator scores




All candidate parcels now have a HIS score, with a maximum value of 6 and a minimum value of -3.