# Indices of Tidal Marsh Integrity and Resiliency:

# Marsh indices and optimizing tidal marsh conservation value

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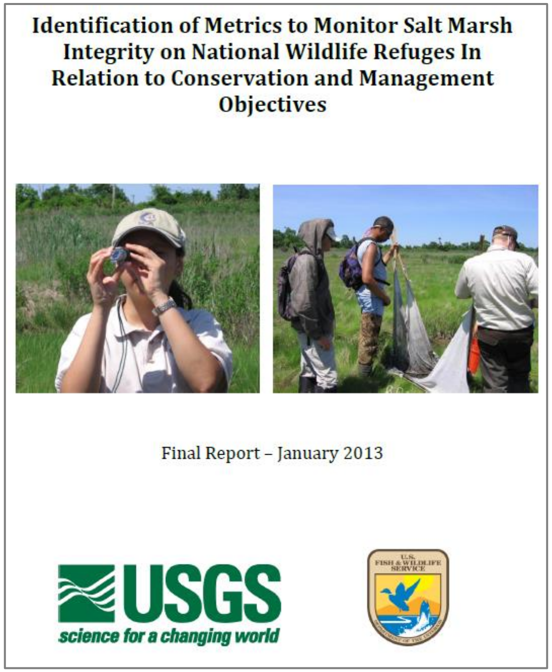
Hurricane Sandy Tidal Marsh Resiliency Coordination Workshop
USFWS Northeast Regional Office
Hadley, Massachusetts
December 8-9, 2014



Identification of Metrics to Monitor Salt Marsh Integrity on National Wildlife Refuges In Relation to Conservation and Management Objectives

Final Report – January 2013

USGS science for a changing world

U.S. Fish & Wildlife Service

**<u>28 metrics total</u>**

Landscape = 10 metrics

Hydrologic / abiotic = 4 metrics

Vegetation = 9 metrics

Nekton = 3 metrics

Breeding birds = 2 metrics

| Metric | Definition |
|---|---|
| *Historical condition and geomorphic setting* | |
| Landscape position | Landscape position: marine, middle-estuary, or upper-estuary |
| Shape | Marsh shape: expansive meadow or narrow fringing marsh |
| Fill fragmentation | Degree of fill/fragmentation: no, low, moderate, or severe |
| Tidal flushing | Degree of tidal flushing: well flushed, moderately flushed, or poorly flushed |
| Aquatic edge | Degree of aquatic edge: low, moderate, or high amount |
| *Ditch density* | |
| Ditch density | Ordinal ranking of ditch density: no, low, moderate, or severe |
| *Surrounding land-use* | |
| Ag relative | % agricultural land in 150 m buffer * (area of buffer/area of unit) |
| Natural 150m relative | % natural land in 150 m buffer * (area of buffer/area of unit) |
| Natural 1km relative | % natural land in 1 km buffer * (area of buffer/area of unit) |
| *Ratio of open water area : vegetation area* | |
| OW Veg withinUnit | Ratio of open water to emergent herbaceous wetlands within unit |
| *Marsh surface elevation* | |
| Elevation | Elevation referenced to NAVD88 |
| *Tidal range/groundwater level* | |
| % flooded | % of time marsh surface was flooded during datalogger deployment |
| Mean Flood Depth | Mean Flood Depth (cm) during datalogger deployment |
| *Salinity* | |
| Rapid Salinity (surface water) | Salinity measured in surface water |
| *Vegetation community* | |
| Rapid Veg SpRich | Vegetation species richness using rapid point-intercept method in survey plots |
| Brack Terr Border | % cover of Brackish Terrestrial Border community (rapid survey plot method) |
| Open Water | % cover of Open Water (rapid survey plot method) |
| Pannes Pools Creeks | % cover of Pannes, Pools, & Creeks (rapid survey plot method) |
| High Marsh | % cover of High Marsh community (rapid survey plot method) |
| Low Marsh | % cover of Low Marsh community (rapid survey plot method) |
| Salt Marsh Terr Border | % cover of Salt Marsh Terrestrial Border community (rapid survey plot method) |
| Upland | % cover of Upland community (rapid survey plot method) |
| *Invasive species abundance* | |
| Invasives | % cover of Invasive Plant Species (rapid survey plot method) |
| *Nekton community* | |
| Nekton Density | Nekton density (ind $m^{-2}$) using throw traps and ditch nets |
| Nekton SpRich | Nekton species richness using throw traps and ditch nets |
| Fundulus Length | *Fundulus heteroclitus* length (mm) captured in throw traps and ditch nets |
| *Breeding bird community* | |
| Willet Abundance | Abundance of Willets counted per point during standard call-broadcast surveys |
| TMO Abundance | Sum abundance of tidal marsh obligate species per point during standard call-broadcast surveys: Clapper Rail, Willet, Saltmarsh Sparrow, Seaside Sparrow |

# Bird Community Integrity



Table 2. Bird species attributes (Poole and Gill 1999) and scoring criteria used to develop Index of Marsh Bird Community Integrity (IMBCI) scores.

| Species attributes | Score: Generalist → Specialist | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 2.5 | 3 | 4 |
| Foraging habitat | habitat generalist | | marsh facultative | | marsh obligate |
| Nesting substrate | non-marsh nesters | | marsh vegetation | | marsh ground nester |
| Migratory status | resident | | short distance/temperate | | Neotropical |
| Breeding range | North America | North America—east of Rocky Mts. | | coastal North America | North America—east coast only |

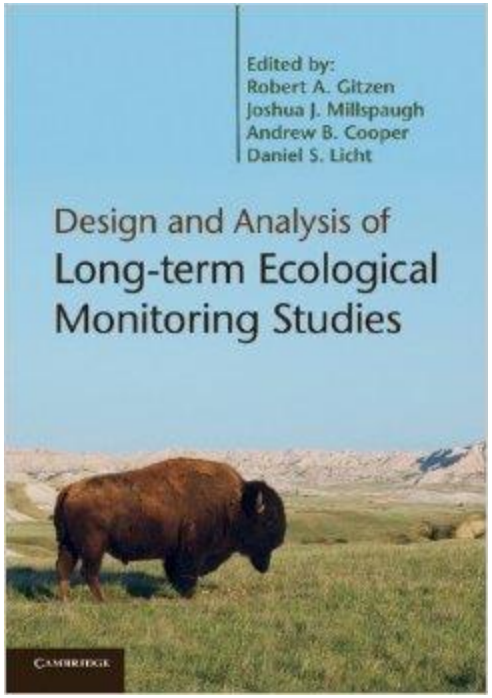
$$W_{IMBCI} = \left[\left(\sum S_{IMBCI}/S_N\right) + MO_N\right]$$

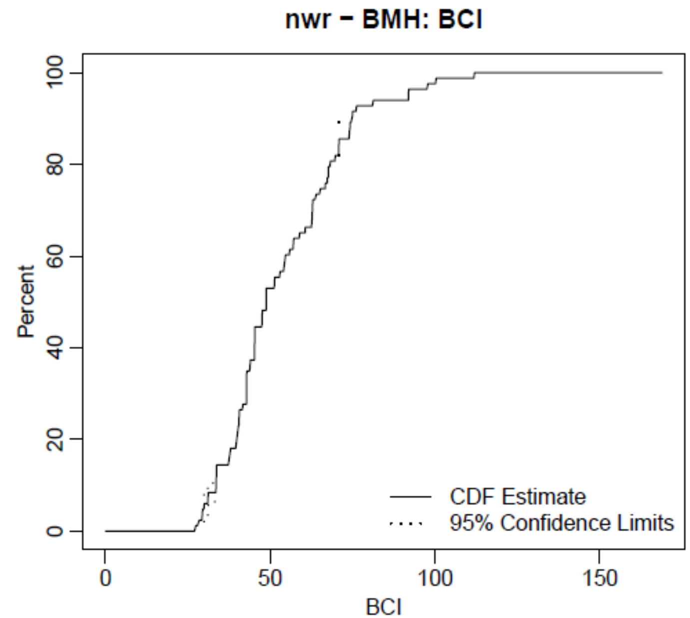
$W_{IMBCI}$ = wetland bird community integrity score
$S_{IMBCI}$ = Ind. Species scores
$S_N$ = number species detected in the unit
$MO_N$ = number of marsh obligate species detected in the unit

DeLuca, W. V., C. E. Studds, L. L. Rockwood, and P. P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of the Chesapeake Bay, USA. Wetlands 24:837–847.

| Species | Scientific Name | Foraging habitat | Nesting substrate | Migratory status | Breeding range | $S_{BCI}$ score |
|---|---|---|---|---|---|---|
| American Kestrel | *(Falco sparverius)* | 1 | 1 | 2.5 | 1 | 5.5 |
| Northern Bobwhite | *(Colinus virginianus)* | 1 | 1 | 1 | 1.5 | 4.5 |
| Clapper Rail* | *(Rallus longirostris)* | 4 | 4 | 1 | 3 | 12 |
| Virginia Rail | *(Rallus limicola)* | 4 | 4 | 2.5 | 1 | 11.5 |
| Sora | *(Porzana carolina)* | 4 | 4 | 4 | 1 | 13 |
| Black Rail | *(Laterallus jamaicensis)* | 4 | 4 | 2.5 | 1 | 11.5 |

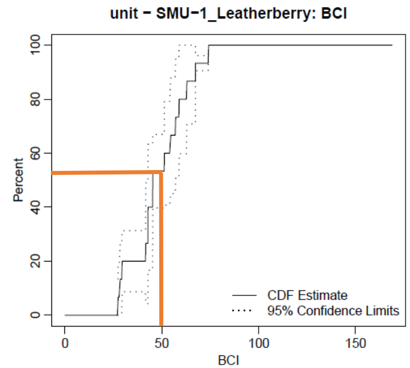
# Cumulative Distribution Functions

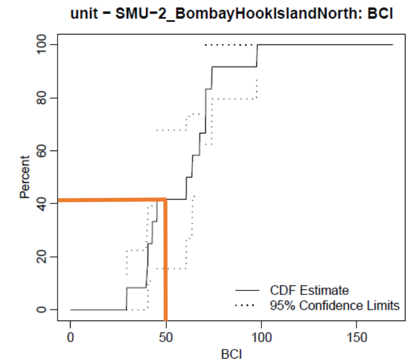


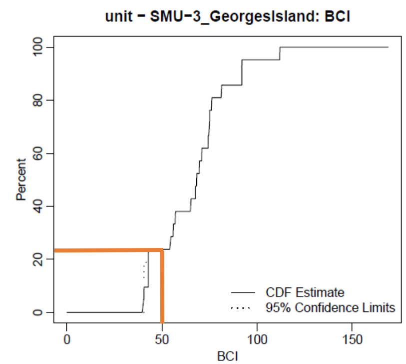



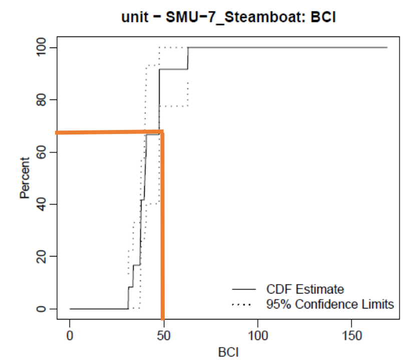

**Section III Data analysis**

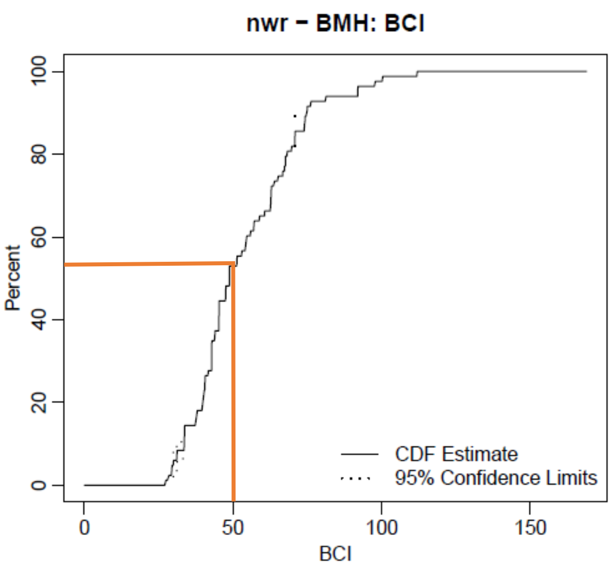
# Bombay Hook NWR - Bird Community Integrity

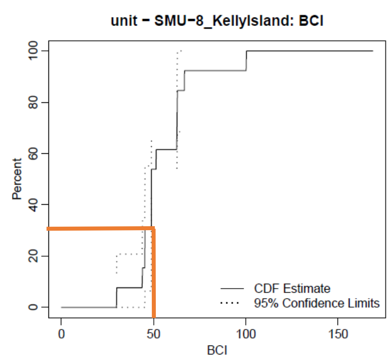



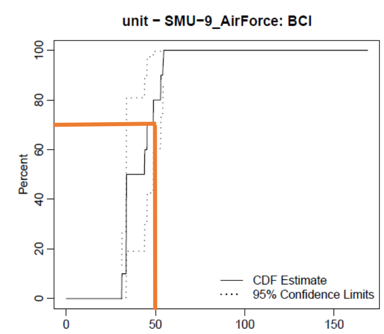



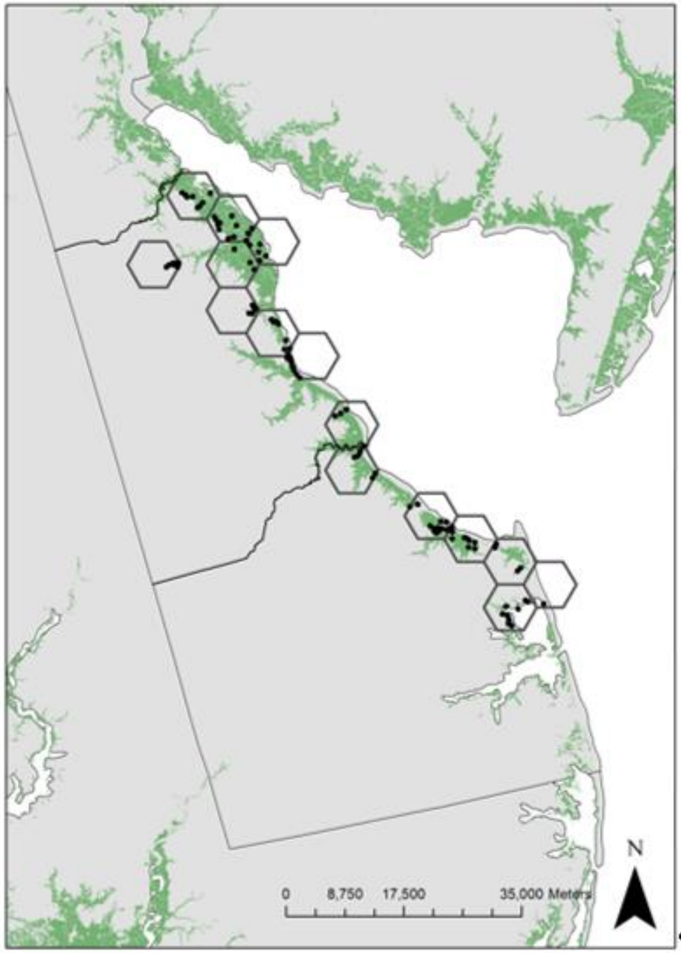



# Optimizing Tidal Marsh Conservation Value

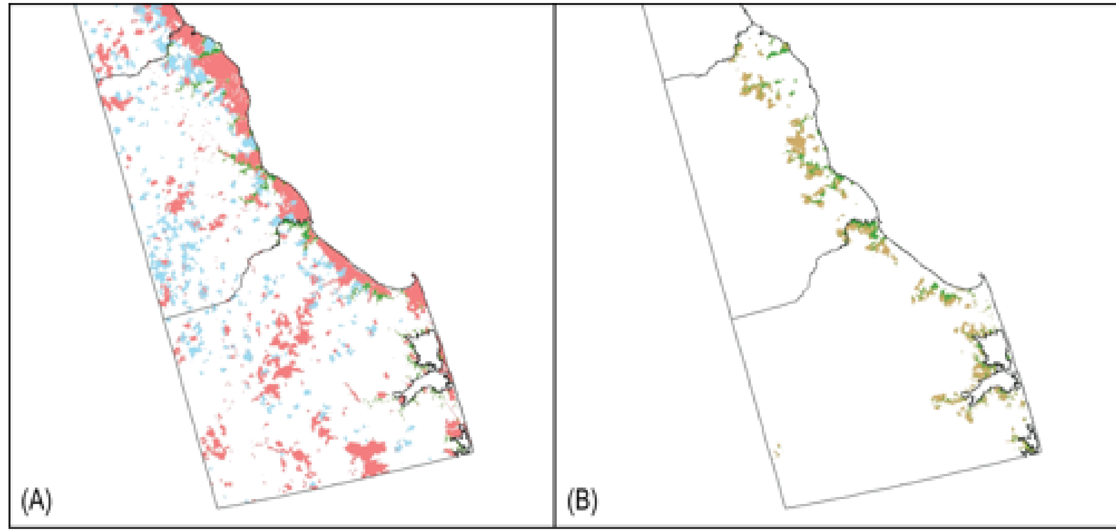
## Case Study: Kent and Sussex Counties, Delaware

Bird Survey Locations




Protected Areas/Easements

Unprotected Marsh Parcels




| County | Unprotected marsh (ha) | Unprotected parcels |
|---|---|---|
| Kent | 2,587 | 947 |
| Sussex | 3,542 | 2,318 |
| Total | 6,129 | 3,265 |

Wiest, W. A., W. G. Shriver, and K. D. Messer. 2014. Incorporating climate change with conservation planning: a case study for tidal marsh bird conservation in Delaware, USA. Journal of Conservation Planning 10:25–42.

## Maximizing our Conservation Benefit

How do we achieve the "biggest conservation bang for the buck" ?

parcel bird abundance + parcel easement value


**Benefit Targeting**

1. Parcels listed in descending order of benefit value
2. The parcel with the highest benefit score (i.e., highest bird abundance) is acquired first, and the process continues until the budget is exhausted.

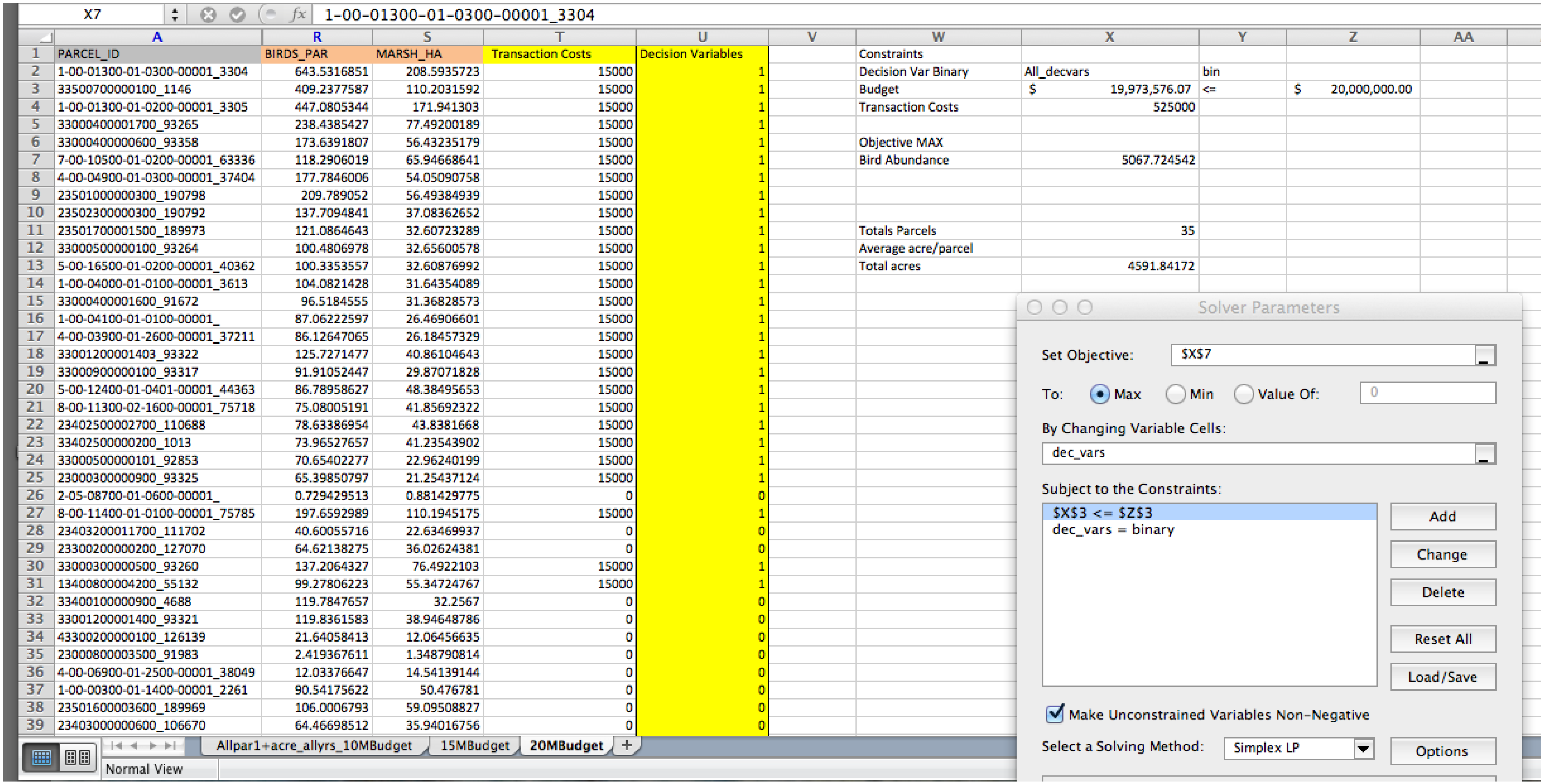
**Optimization -** Binary linear programming optimization model (Solver)

1. Evaluates the conservation benefits and costs of the entire parcel pool.
2. Selects parcels that contribute to achieving the maximum total conservation benefit possible within the apportioned budget.

**OBJECTIVE:** maximize bird abundance within a budget constraint

$$\max(X) = \sum_{i=1}^{I} X_i A_i \qquad \sum_{i=1}^{I} C_i X_i \leq B$$

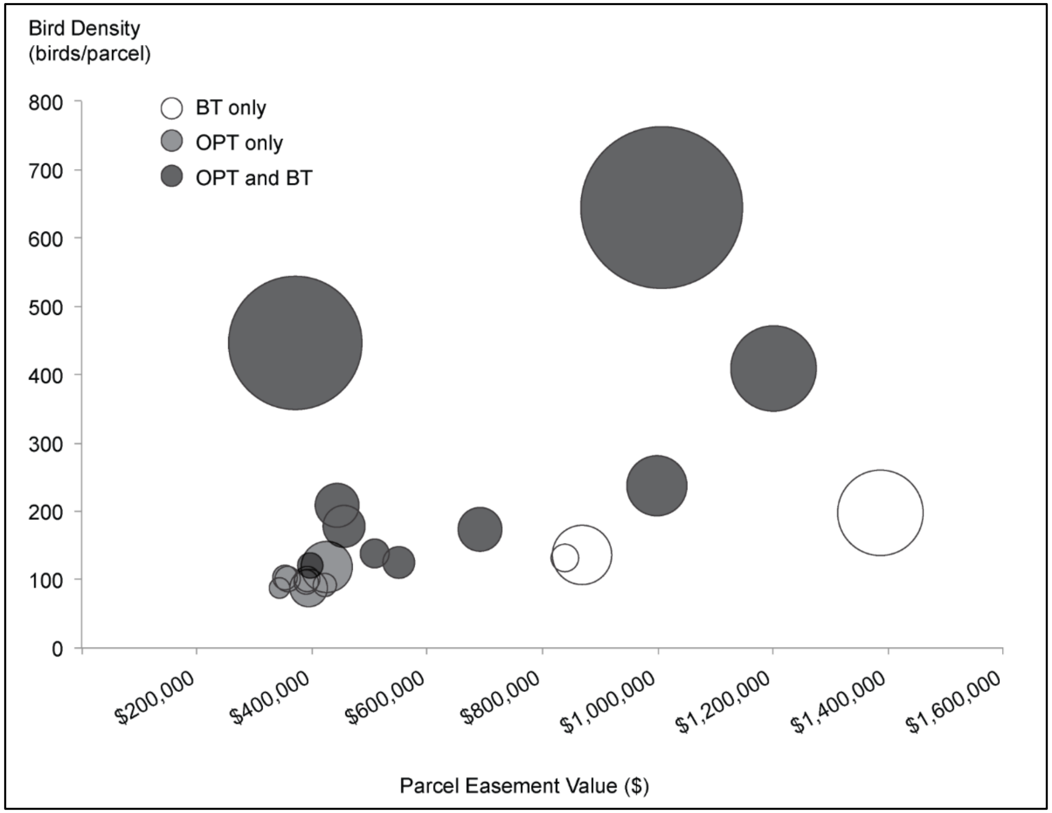
# Solver in Excel

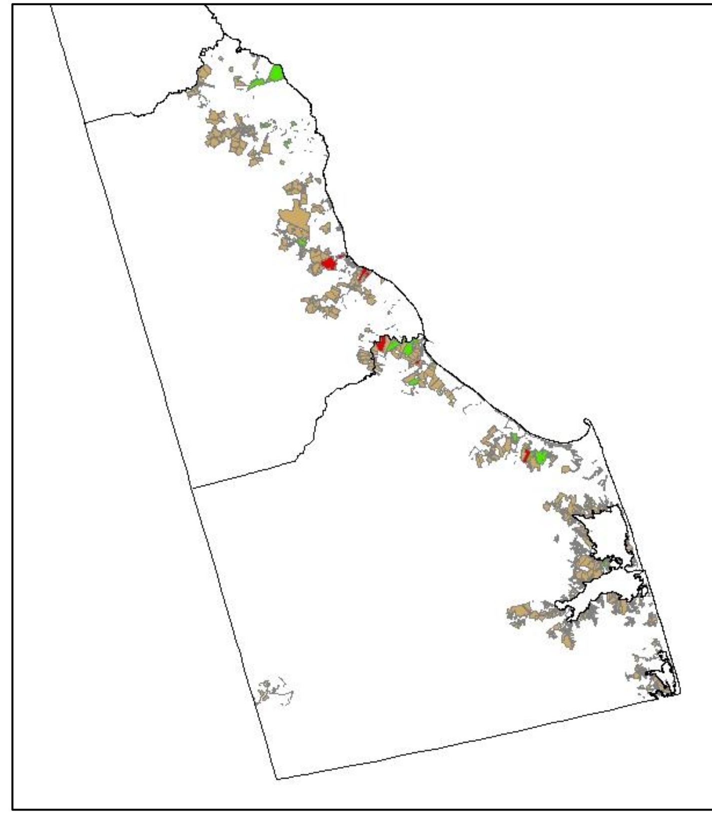


X7 | 1-00-01300-01-0300-00001_3304

| | A | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PARCEL_ID | BIRDS_PAR | MARSH_HA | Transaction Costs | Decision Variables | | Constraints | | | |
| 2 | 1-00-01300-01-0300-00001_3304 | 643.5316851 | 208.5935723 | 15000 | 1 | | Decision Var Binary | All_decvars | bin | |
| 3 | 33500700000100_1146 | 409.2377587 | 110.2031592 | 15000 | 1 | | Budget | $ 19,973,576.07 | <= | $ 20,000,000.00 |
| 4 | 1-00-01300-01-0200-00001_3305 | 447.0805344 | 171.941303 | 15000 | 1 | | Transaction Costs | 525000 | | |
| 5 | 33000400001700_93265 | 238.4385427 | 77.49200189 | 15000 | 1 | | | | | |
| 6 | 33000400000600_93358 | 173.6391807 | 56.43235179 | 15000 | 1 | | Objective MAX | | | |
| 7 | 7-00-10500-01-0200-00001_63336 | 118.2906019 | 65.94668641 | 15000 | 1 | | Bird Abundance | 5067.724542 | | |
| 8 | 4-00-04900-01-0300-00001_37404 | 177.7846006 | 54.05090758 | 15000 | 1 | | | | | |
| 9 | 23501000000300_190798 | 209.789052 | 56.49384939 | 15000 | 1 | | | | | |
| 10 | 23502300000300_190792 | 137.7094841 | 37.08362652 | 15000 | 1 | | | | | |
| 11 | 23501700001500_189973 | 121.0864643 | 32.60723289 | 15000 | 1 | | Totals Parcels | 35 | | |
| 12 | 33000500000100_93264 | 100.4806978 | 32.65600578 | 15000 | 1 | | Average acre/parcel | | | |
| 13 | 5-00-16500-01-0200-00001_40362 | 100.3353557 | 32.60876992 | 15000 | 1 | | Total acres | 4591.84172 | | |
| 14 | 1-00-04000-01-0100-00001_3613 | 104.0821428 | 31.64354089 | 15000 | 1 | | | | | |
| 15 | 33000400001600_91672 | 96.5184555 | 31.36828573 | 15000 | 1 | | | | | |
| 16 | 1-00-04100-01-0100-00001_ | 87.06222597 | 26.46906601 | 15000 | 1 | | | | | |
| 17 | 4-00-03900-01-2600-00001_37211 | 86.12647065 | 26.18457329 | 15000 | 1 | | | | | |
| 18 | 33001200001403_93322 | 125.7271477 | 40.86104643 | 15000 | 1 | | | | | |
| 19 | 33000900000100_93317 | 91.91052447 | 29.87071828 | 15000 | 1 | | | | | |
| 20 | 5-00-12400-01-0401-00001_44363 | 86.78958627 | 48.38495653 | 15000 | 1 | | | | | |
| 21 | 8-00-11300-02-1600-00001_75718 | 75.08005191 | 41.85692322 | 15000 | 1 | | | | | |
| 22 | 23402500002700_110688 | 78.63386954 | 43.8381668 | 15000 | 1 | | | | | |
| 23 | 33402500000200_1013 | 73.96527657 | 41.23543902 | 15000 | 1 | | | | | |
| 24 | 33000500000101_92853 | 70.65402277 | 22.96240199 | 15000 | 1 | | | | | |
| 25 | 23000300000900_93325 | 65.39850797 | 21.25437124 | 15000 | 1 | | | | | |
| 26 | 2-05-08700-01-0600-00001_ | 0.729429513 | 0.881429775 | 0 | 0 | | | | | |
| 27 | 8-00-11400-01-0100-00001_75785 | 197.6592989 | 110.1945175 | 15000 | 1 | | | | | |
| 28 | 23403200011700_111702 | 40.60055716 | 22.63469937 | 0 | 0 | | | | | |
| 29 | 23300200000200_127070 | 64.62138275 | 36.02624381 | 0 | 0 | | | | | |
| 30 | 33000300000500_93260 | 137.2064327 | 76.4922103 | 15000 | 1 | | | | | |
| 31 | 13400800004200_55132 | 99.27806223 | 55.34724767 | 15000 | 1 | | | | | |
| 32 | 33400100000900_4688 | 119.7847657 | 32.2567 | 0 | 0 | | | | | |
| 33 | 33001200001400_93321 | 119.8361583 | 38.94648786 | 0 | 0 | | | | | |
| 34 | 43300200000100_126139 | 21.64058413 | 12.06456635 | 0 | 0 | | | | | |
| 35 | 23000800003500_91983 | 2.419367611 | 1.348790814 | 0 | 0 | | | | | |
| 36 | 4-00-06900-01-2500-00001_38049 | 12.03376647 | 14.54139144 | 0 | 0 | | | | | |
| 37 | 1-00-00300-01-1400-00001_2261 | 90.54175622 | 50.476781 | 0 | 0 | | | | | |
| 38 | 23501600003600_189969 | 106.0006793 | 59.09508827 | 0 | 0 | | | | | |
| 39 | 23403000000600_106670 | 64.46698512 | 35.94016756 | 0 | 0 | | | | | |

# Results : $10 million budget

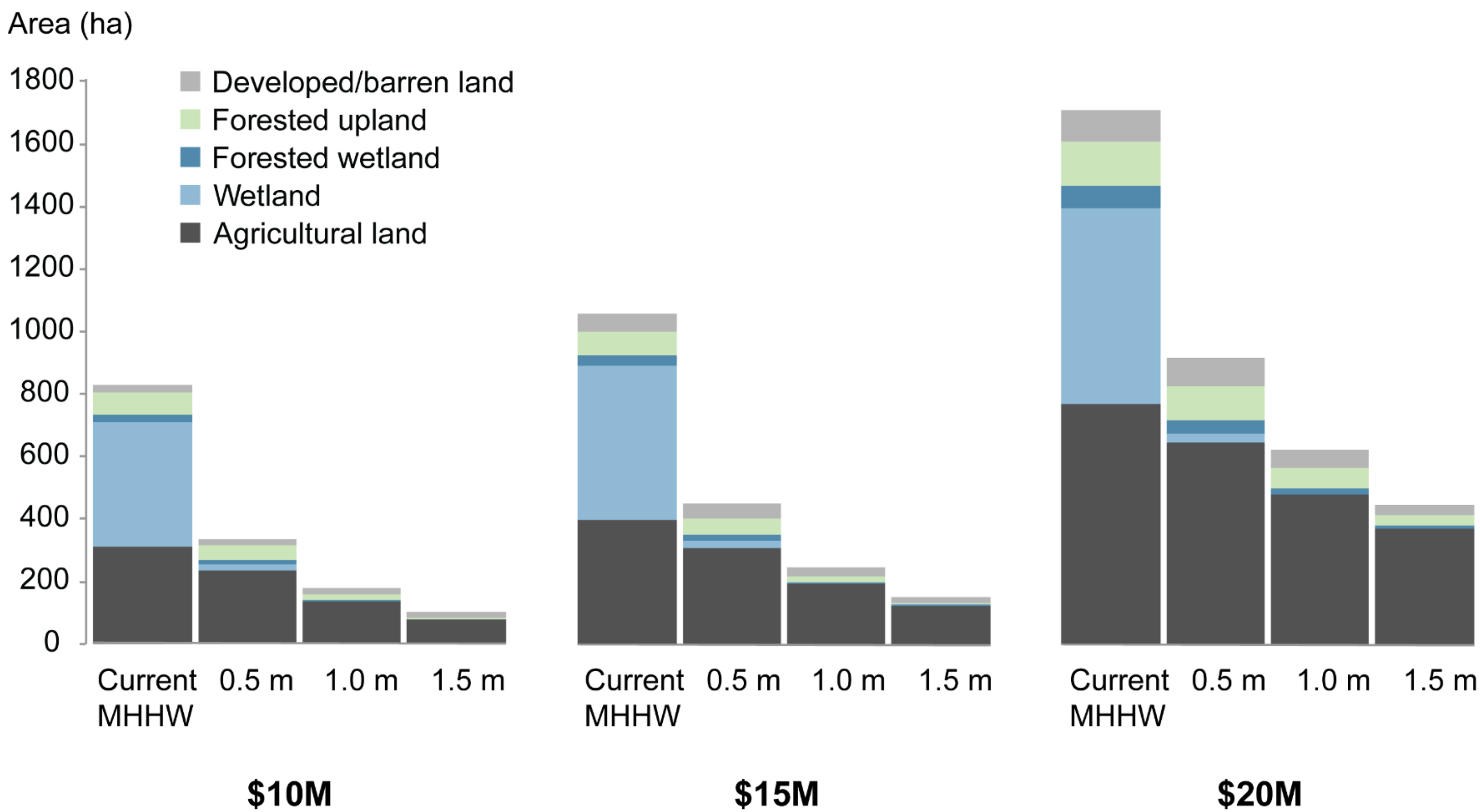


Conservation benefit (bird density) by parcel easement value for parcels selected in the $10M budget scenario.

Bubbles are color-coded by selection method (benefit targeting [BT], optimization [OPT]) and bubble size represents parcel unprotected marsh area.

# Results : Land cover and sea level rise




Area (ha) of land cover types present on optimized parcels under current mean higher high water (MHHW) and three future sea level rise scenarios (0.5 m, 1.0 m, and 1.5 m), grouped by budget scenario.

## Future Optimization Possibilities…

### Goal Programming

Specify multiple goals or targets. Minimize the deviations from not achieving each goal.

Multiple conservation benefits - examples

Achieve Maximum #:

1. Bird abundance (bird abundance x probability of SLR [coastal response probability?])
2. Proportion of high marsh
3. Sites with marsh migration potential
4. Carbon storage

Achieve Minimum #:

1. saltmarsh sparrow abundance in specific area (e.g., X # birds in each state in breeding range)
2. At least 50% of selected parcels with low probability of SLR/permanent inundation, etc.

*Whose objective function do we want to model?* - - -
i.e., *Who has the funds for conservation and what do they want?*

-NAWCA Standard Grants Program