Quantifying ecosystem services associated with BMPs: Wetland Creation & Restoration

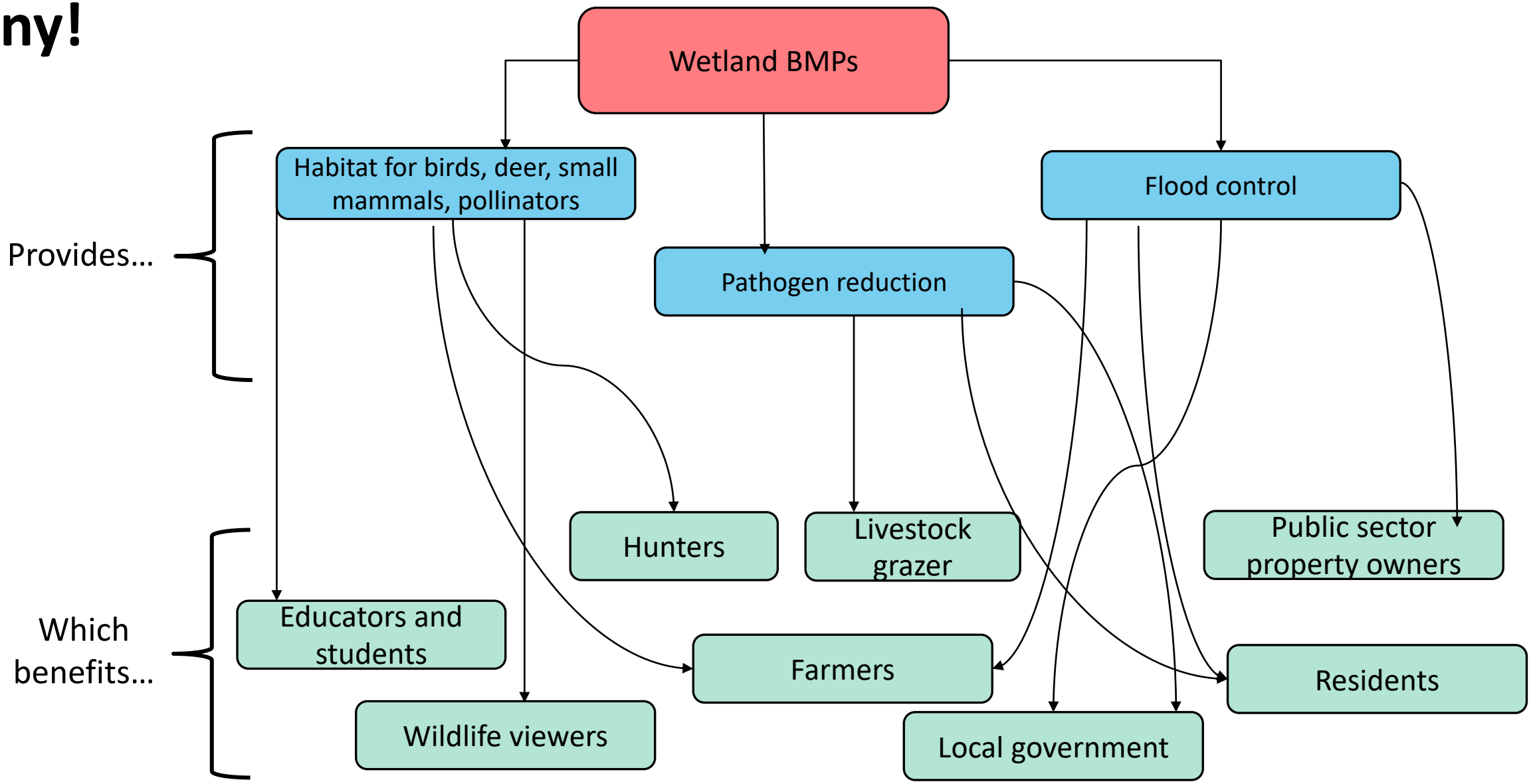
RYANN ROSSI[1], CARIN BISLAND[2], LEAH SHARPE[3], EMILY TRENTACOSTE[2], VANESSA VAN NOTE[2], BO WILLIAMS[2], SUSAN YEE[3]

1 OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION, U.S. ENVIRONMENTAL PROTECTION AGENCY, GULF BREEZE, FL, USA

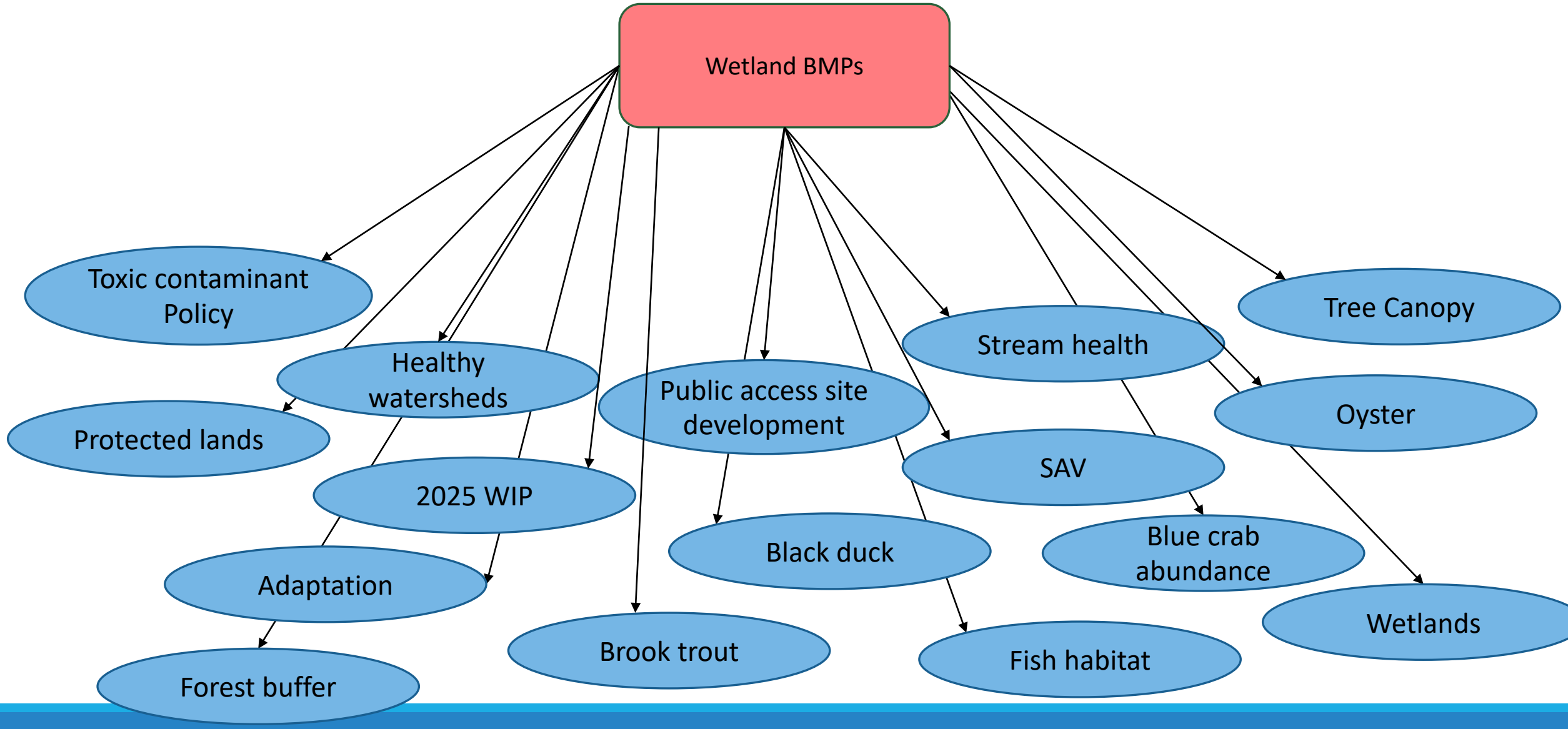
2 CHESAPEAKE BAY PROGRAM OFFICE, U.S. ENVIRONMENTAL PROTECTION AGENCY, ANNAPOLIS, MD, USA

3 GULF ECOSYSTEM MEASUREMENT AND MODELING DIVISION, U.S. ENVIRONMENTAL PROTECTION AGENCY, GULF BREEZE, FL, USA

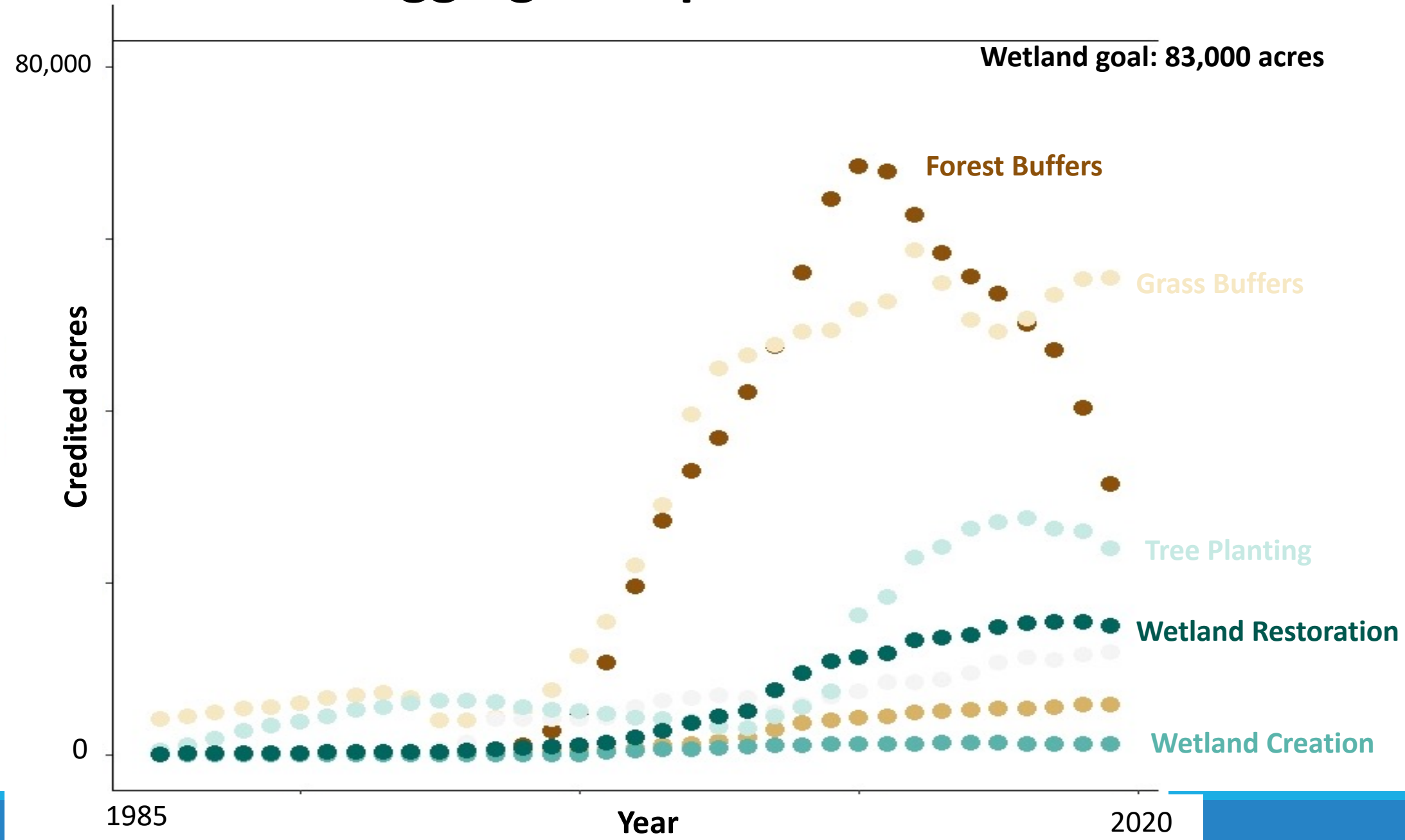
Wetland BMPs provide many ecosystem services & benefit many!



Wetland BMPs are connected to many Outcomes!



Yet wetland BMPs are lagging in implementation



Project Background

Goal: Describe how ecosystem services may change as BMPs are implemented to restore the watershed

We focused on BMPs:

- Lagging in implementation
- Associated with a Watershed Agreement goal
- Related to habitat or restoration
- Relevant for upstream communities

We focused on the following BMPs:

- Forest Buffers
- Grass Buffers
- Impervious Surface Reduction
- Urban Forest Buffer
- Urban Forest Planting
- Urban Tree Planting
- **Wetland Creation**
- **Wetland Restoration**

Approach: The Ecosystem Services Gradient

This project covers these steps.

Ecosystem Services Gradient Framework	Generic Process
What ecosystem services (ES) are relevant?	Identify and prioritize ES with stakeholders
How will we measure them?	Identify ES metrics and indicators, and the biophysical attributes that provide them
What ES could we have?	Establish potential availability under a range of bio-physical conditions
What ES do we have now?	Measuring, mapping, and ecological production functions (EPFs)
What ES do we want?	Evaluate co-benefits and tradeoffs
How do we get there?	Identify impacts of management actions
What are the social and economic consequences?	*Conduct and communicate benefits assessment using ecological benefit functions (EBFs)*

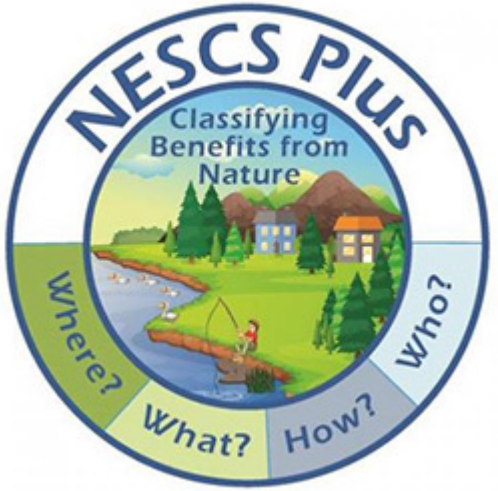
Yee et al, 2020

Identify potential ecosystem services & beneficiaries associated with BMPs

- Use classification systems such as NESCS Plus to identify general ecosystem services (ES)

- Mine Chesapeake Bay Program (CBP) documents and reports for ecosystem services and add to list

- Share laundry list of ES with CBP partners for feedback on most important ES and any missing ES



https://www.epa.gov/eco-research/national-ecosystem-services-classification-system-nescs-plus

Best Management Practice	Forest Buffers	Additional Co-Benefits					
		Habitat Biodiversity	Brook Trout	Stream Health	Fish Habitat	Healthy Watersheds	Tree Canopy
Agricultural Forest Buffer	5	4	4.5	4	4.5	4	4.5
Forest Conservation	3.5	5	4	4	4	5	5
Forest Harvesting Practices	3.5	2	2	4	3	3	2
Narrow Forest Buffer	5	2.5	3.5	2	3.5	2	5
Streamside Forest Buffers	5	4	4.5	3	4.5	3	5
Urban Forest Buffers	5	5	5	4	4	3.5	4.5

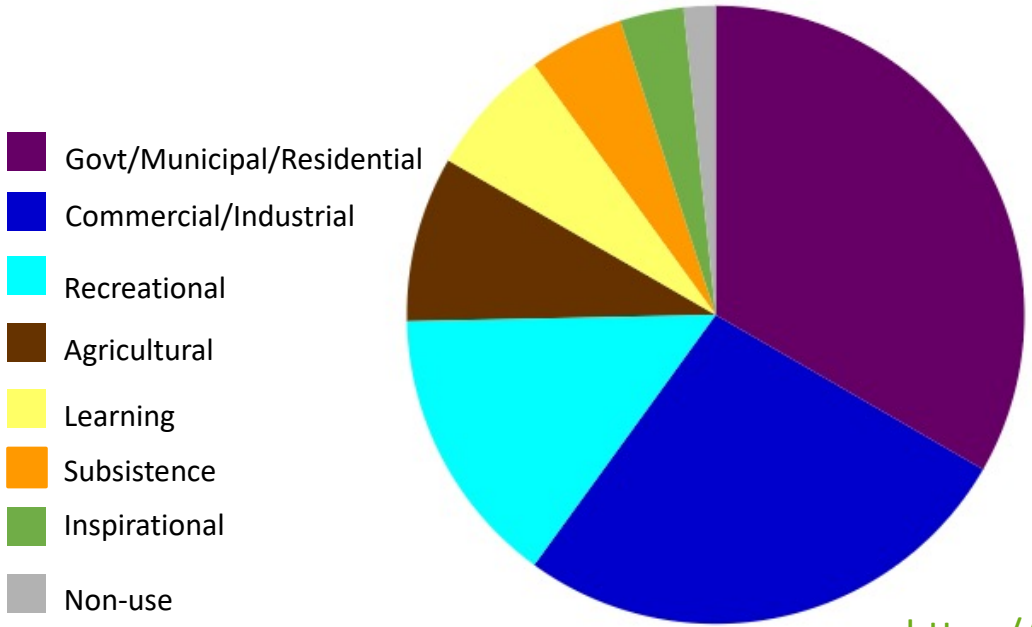
Tetra Tech Co-Benefits Report

Prioritize potential ecosystem services & beneficiaries associated with BMPs

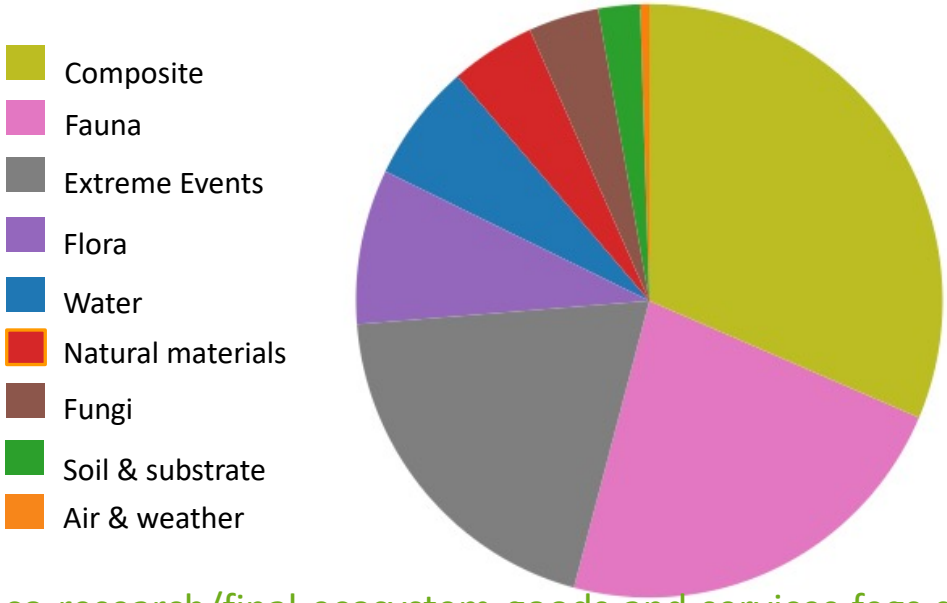
Use FEGS Scoping Tool to prioritize ecosystem services based on feedback and CBP documents

- ES and beneficiaries identified in feedback and documents get more weight than those from base list

Beneficiaries



General ecosystem service relative priority



https://www.epa.gov/eco-research/final-ecosystem-goods-and-services-fegs-scoping-tool

Scoped list of Ecosystem Services:

Ecosystem Service (ES)
Air quality
Edible flora
Carbon sequestration*
Habitat quality for birds
Heat risk
Soil quality
Open space
Pest predator/depredator fauna
Pollinator supply
Flood control
Water clarity
Water quality- nutrients
Pathogen reduction
Water quantity

Identify Metrics to quantify Ecosystem Services

Ecosystem Service (ES)	Short list of metrics	Source
Air quality	concentration of CO, NO2, O3, PM 10, PM 2.5, SO2	iTree (Nowak 2020)
Edible flora	plant diversity, cover of edible species	EnviroAtlas (Pickard et al. 2015)
Habitat quality	habitat suitability for species of interest	inVEST; Smith et al 2017 (Smith et al. 2017, Sharp et al. 2020)
Heat risk	daytime and nighttime temperature reduction	EnviroAtlas (Pickard et al. 2015)
Soil quality	soil C content, N fixation, pH, salinity, type, percent sand, bulk density, organic matter	NESP; Smith et al, 2017 (Russell et al. 2013, Olander et al. 2017, Smith et al. 2017)
Open space	open space access index; distance to open space	EnviroAtlas; NESP (Russell et al. 2013, Pickard et al. 2015, Olander et al. 2017)
Pest predator/depredator fauna	density of certain pest predators (e.g., ladybugs)	ESML (US EPA 2020)
Pollinator supply	area of wild pollinator habitat; ratio of pollinator habitat to pollinator dependent crops	EnviroAtlas; inVEST (Pickard et al. 2015, Sharp et al. 2020, Warnell et al. 2020)
Flood control	flood depth, duration, extent and frequency; maximum retained rainwater; soil precipitation retention; surface water runoff; wave attenuation	EnviroAtlas; inVEST; EPA H2O; ESML (Russell et al. 2013, Pickard et al. 2015, Sharp et al. 2020)
Water clarity	mean sediment retention; secchi depth; turbidity	Angradi et al. (2018)
Water quality- nutrients	concentration of nitrates in groundwater	Terziotti et al. (2018)
Pathogen reduction	concentration of harmful bacteria (e.g., fecal coliform)	Yee et al. (2021)
Water quantity	water availability	inVEST (Sharp et al. 2020)

What did we quantify for wetland BMPs?

Ecosystem Service (ES)	Short list of metrics	Source
C sequestration	C sequestration estimates	Literature search
Habitat quality- for birds	habitat suitability for species of interest	inVEST; Smith et al 2017 (Smith et al. 2017, Sharp et al. 2020)
Soil quality	soil C content, N fixation, pH, salinity, type, percent sand, bulk density, organic matter	NESP; Smith et al, 2017 (Russell et al. 2013, Olander et al. 2017, Smith et al. 2017)
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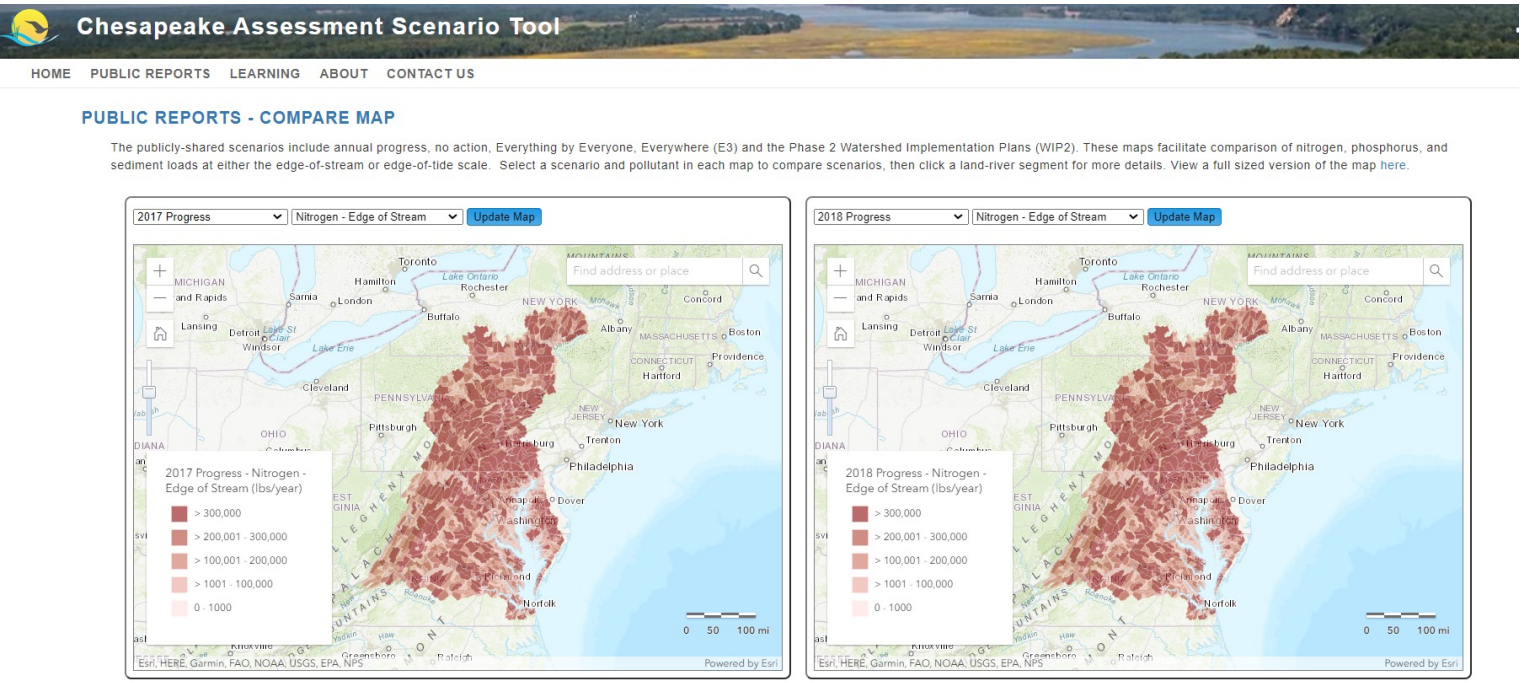
Pathogen reduction	concentration of harmful bacteria (e.g., fecal coliform); % FIB removal	Yee et al. (2021)
Water quantity	water availability	inVEST (Sharp et al. 2020)

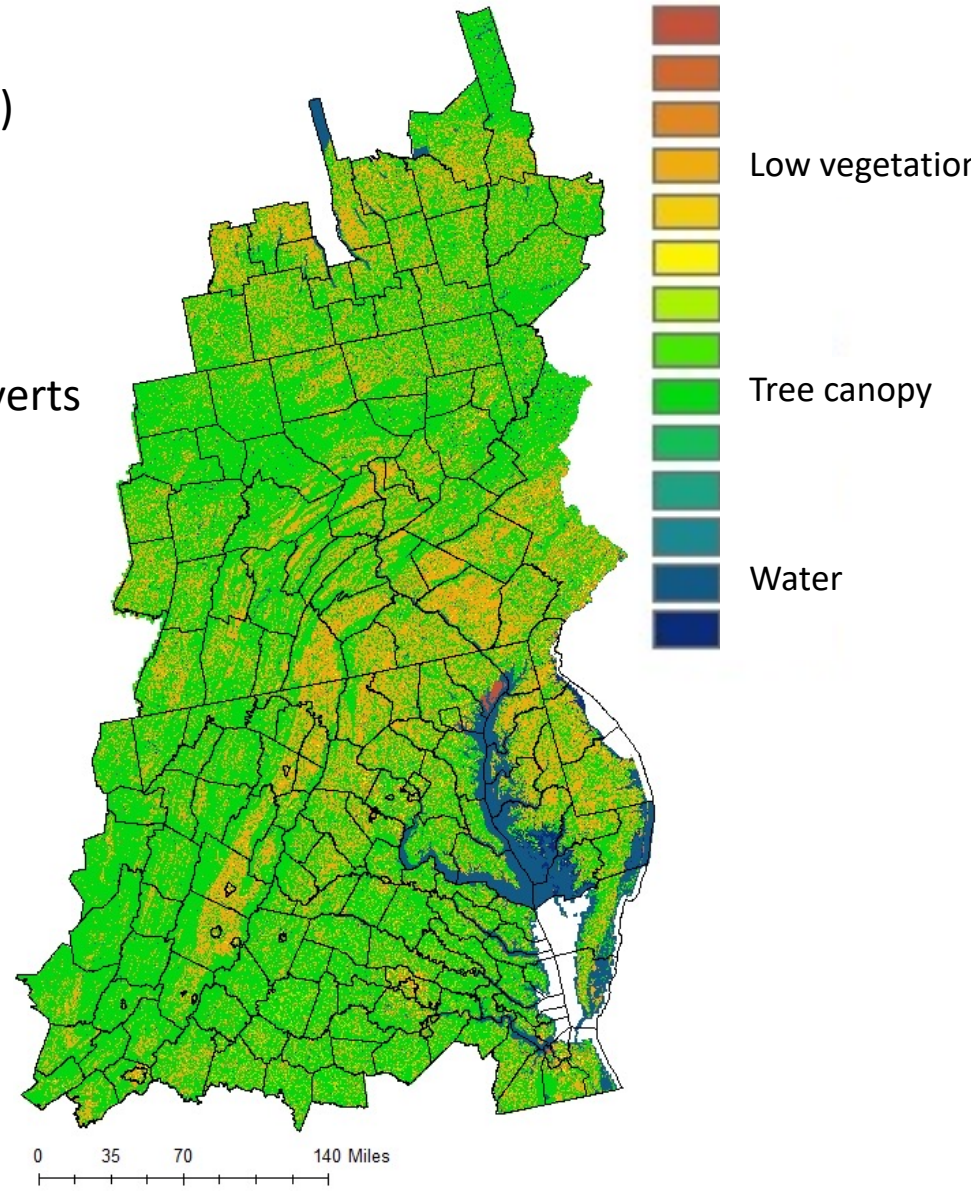
ES Quantification: General methods

- Methods rely on remotely sensed land cover land use data
  - We assume BMPs match land covers (e.g., Wetland restoration= wetland)

- We assume the BMP is mature
  - E.g., Estimates are based on a fully functional wetland

- END GOAL: 1 multiplier/equation per BMP for the land use that the BMP converts to (e.g., forest buffers convert to forest)



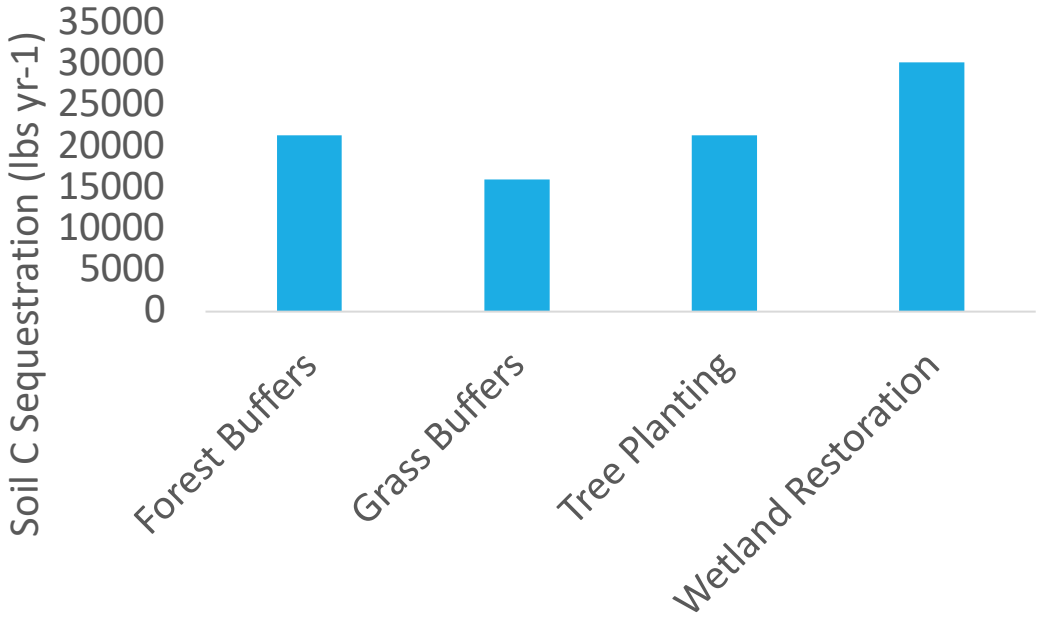


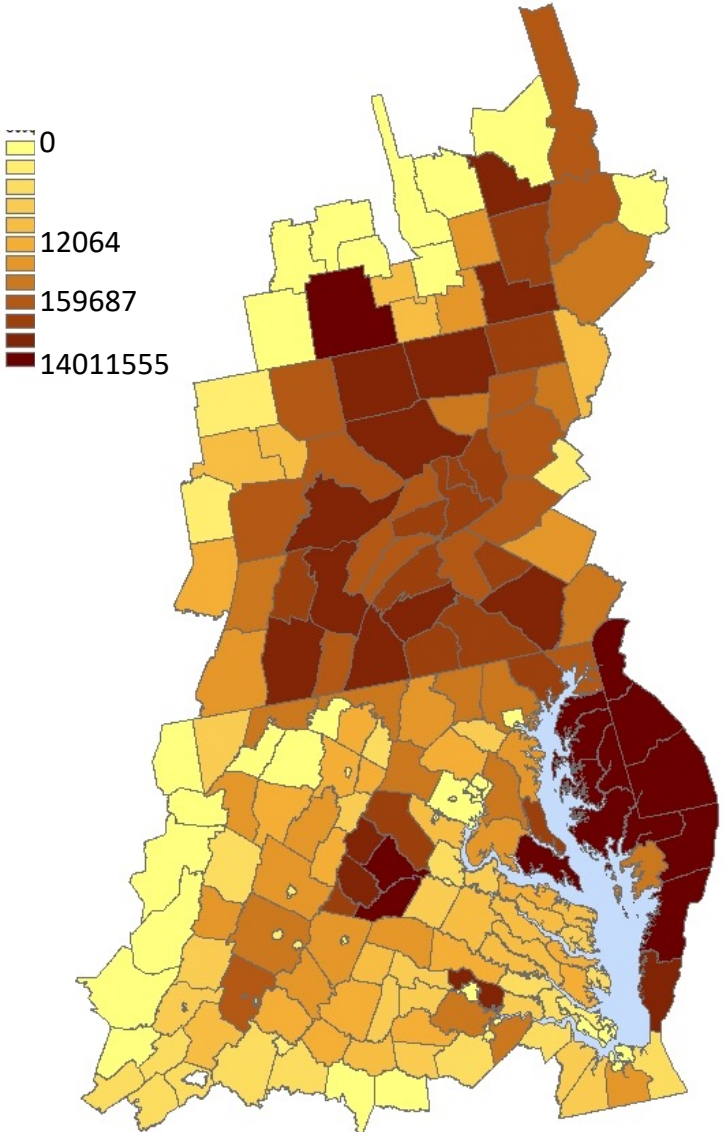
ES Quantification results: C sequestration

Metric: Soil Carbon sequestration

Approach:

- Literature search of soil C sequestration estimates for wetlands in the Chesapeake Bay watershed
- Took average of all values for our purposes





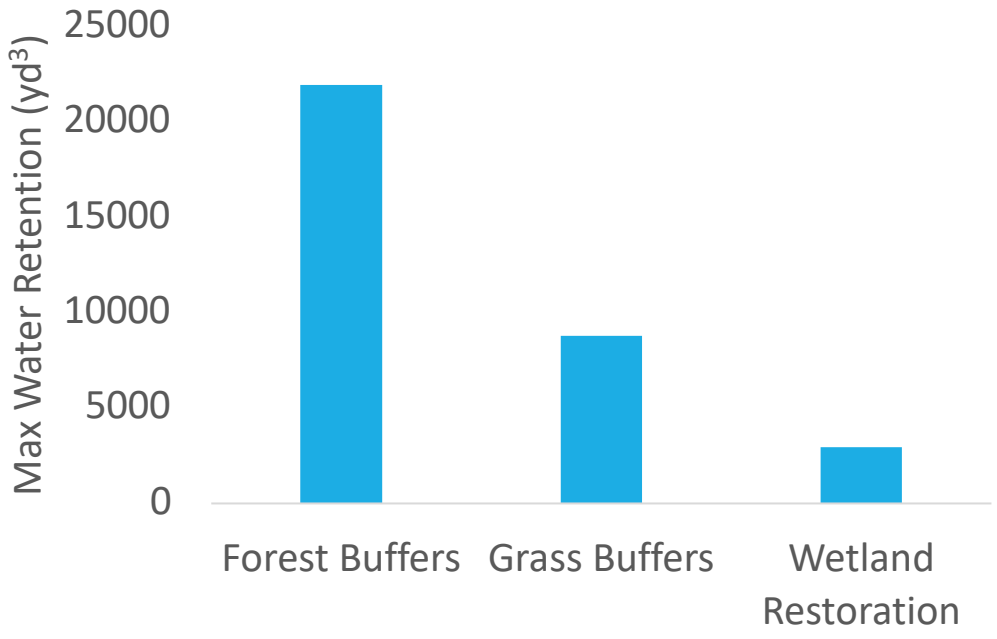
Estimated soil C sequestration due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

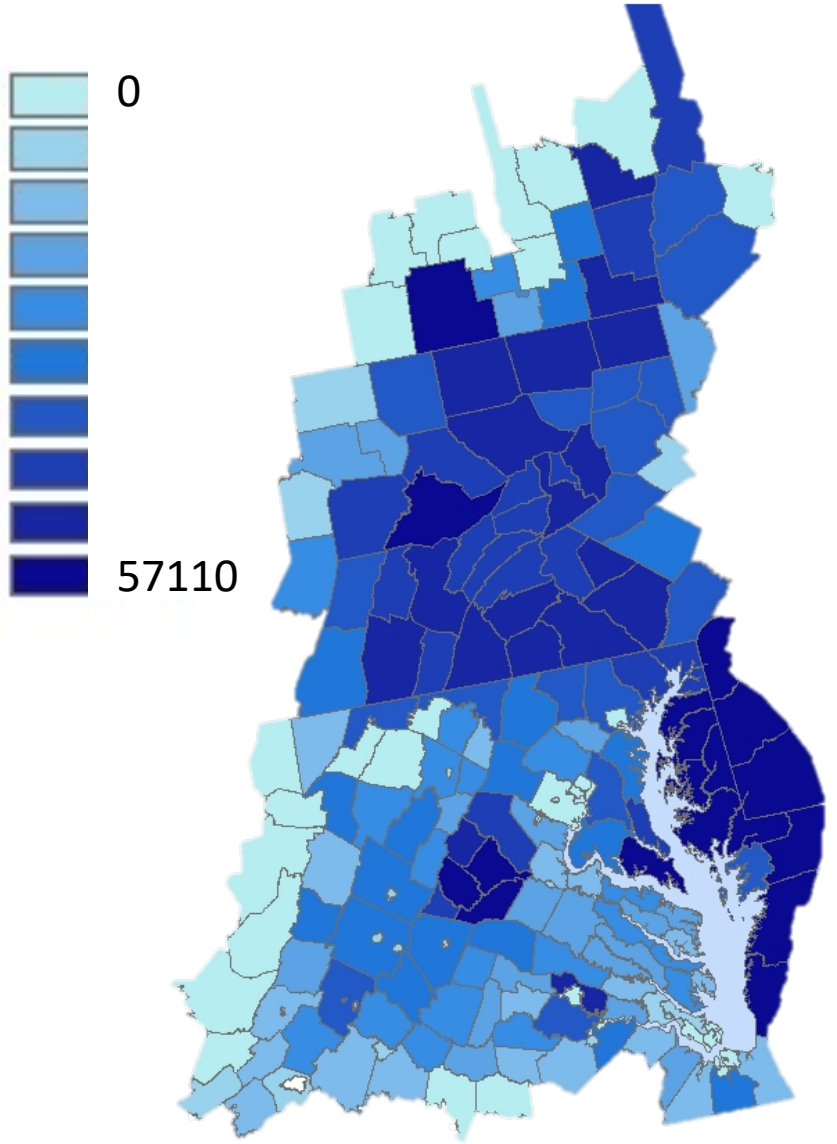
ES Quantification results: Flood control

Metric: Max water retention

Approach:
Curve number method:

- Relies on LULC and soil hydrologic group



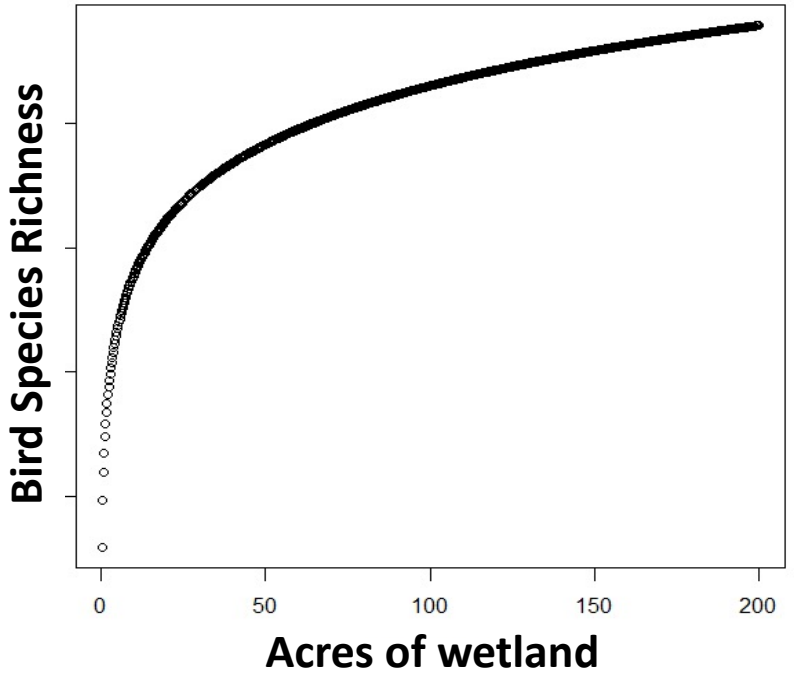


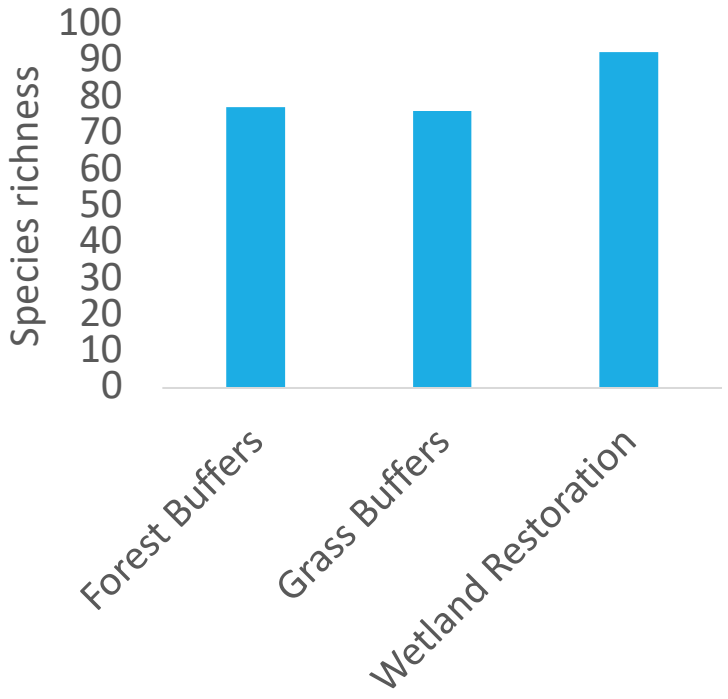
Estimated max retention of water (yd³) due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

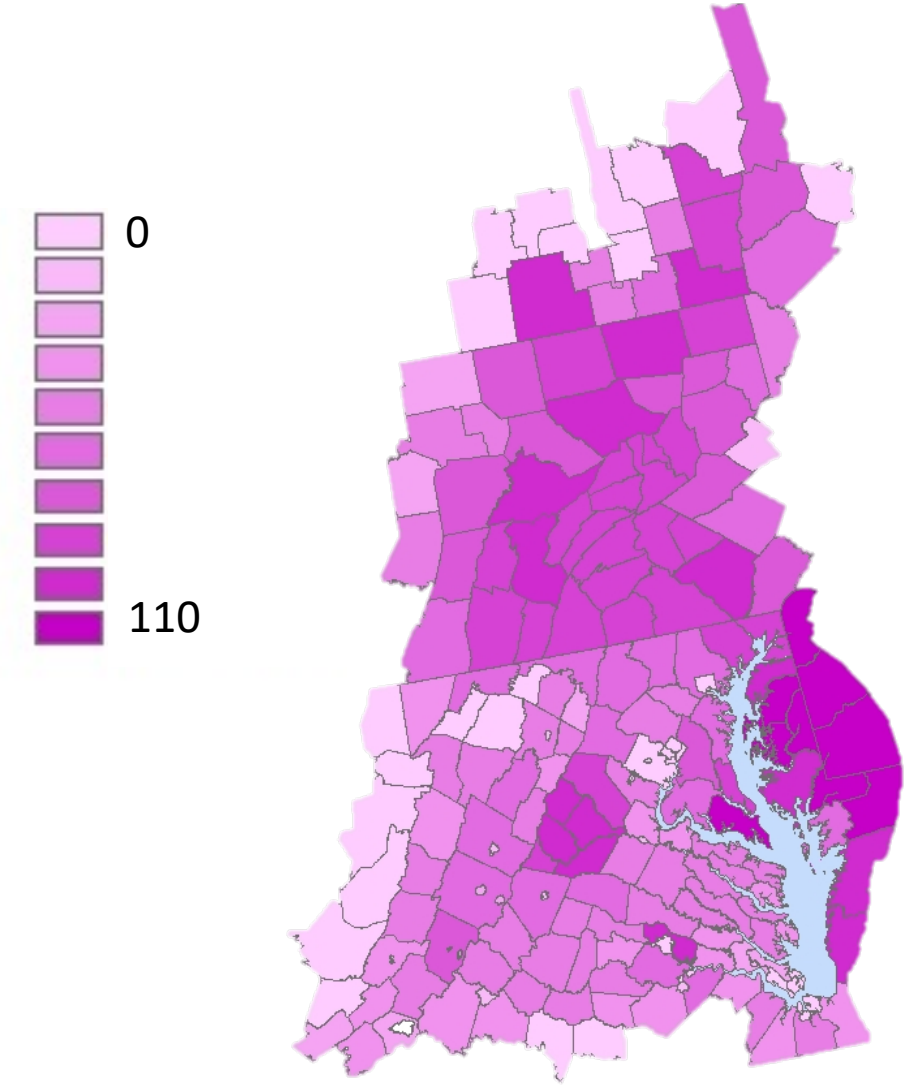
ES Quantification results: Habitat quality

Metric: Bird Species Richness

Approach:
Use species are curve concept and USGS species GAP data to estimate species richness in different areas of different land uses.







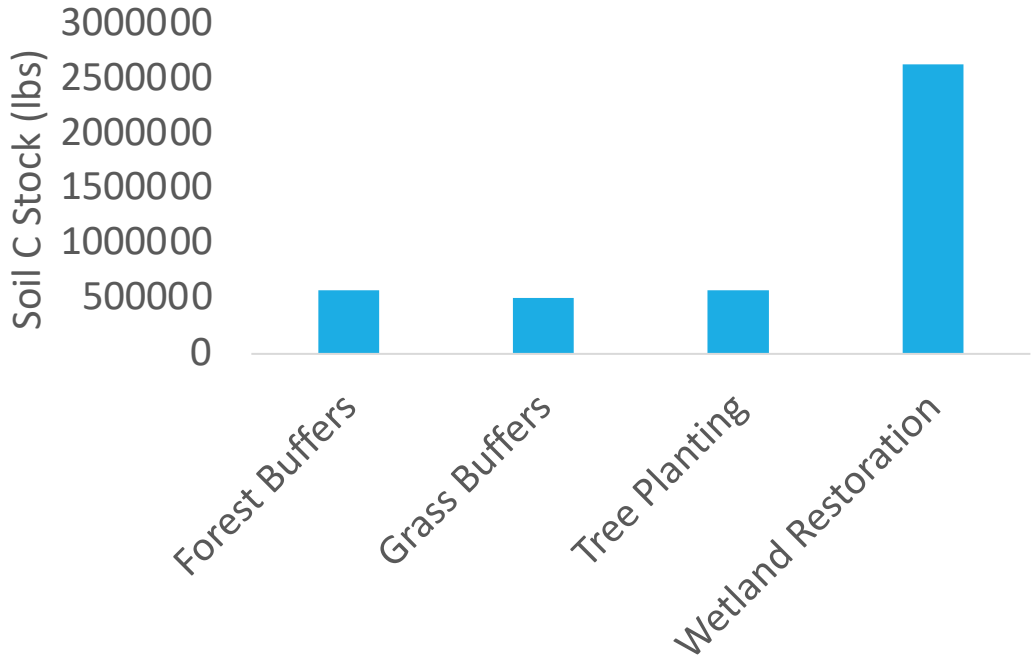
Estimated bird species richness due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

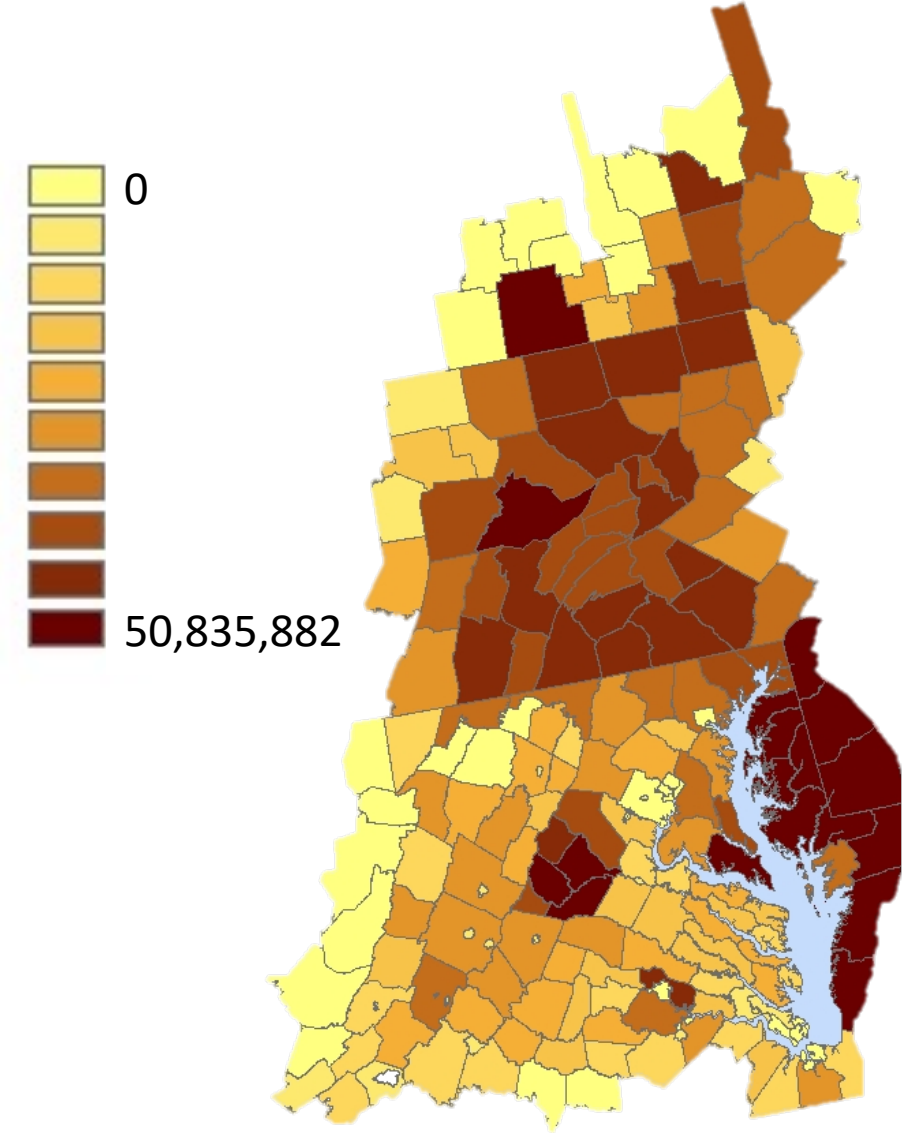
ES Quantification results: Soil quality

Metric: Soil Carbon Stock

Approach:

- Literature search for soil C stock estimates for wetland types found in the Chesapeake Bay Watershed
- Took average of all values for our purposes





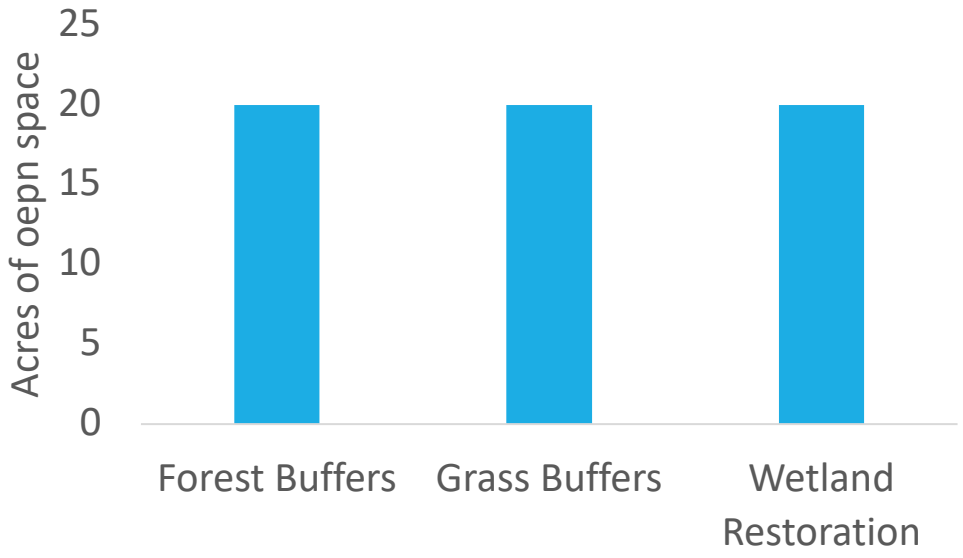
Estimated soil C stock due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

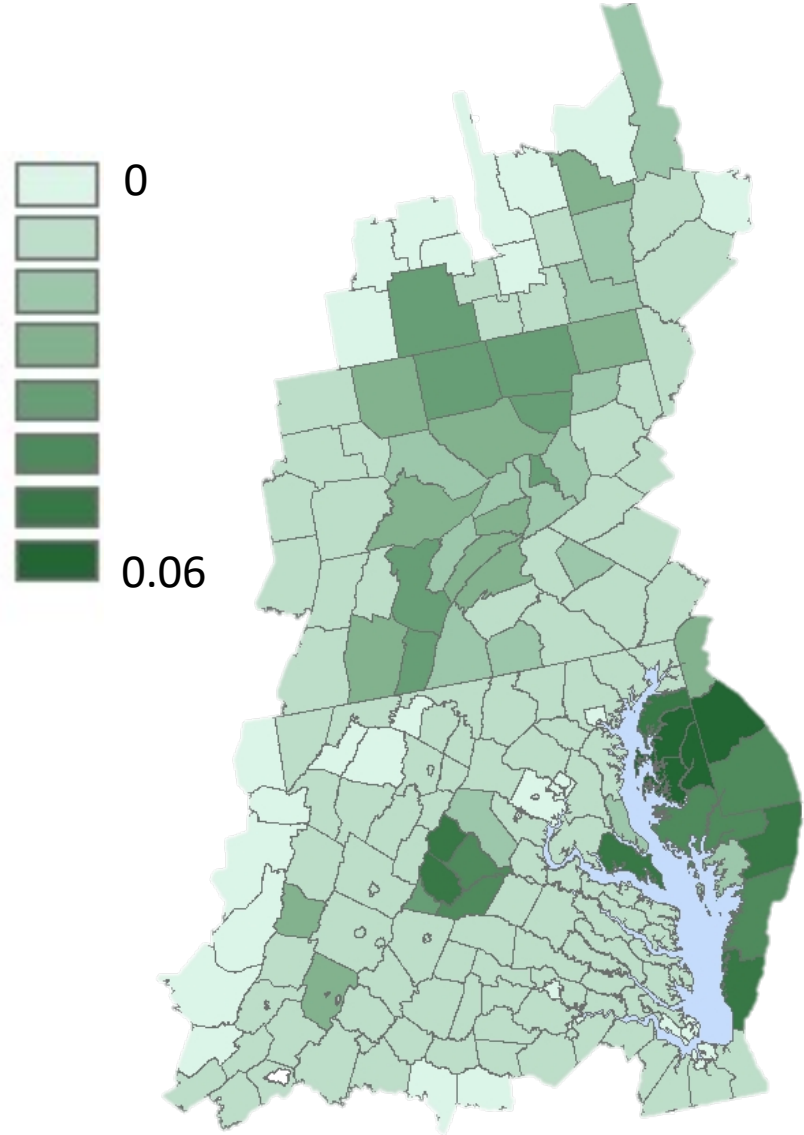
ES Quantification results: Open Space

Metric: Open space per capita

Approach:

- As wetland area is added, potential open space per capita increases.
- Assumes all wetlands are open to people





Estimated open space per capita due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

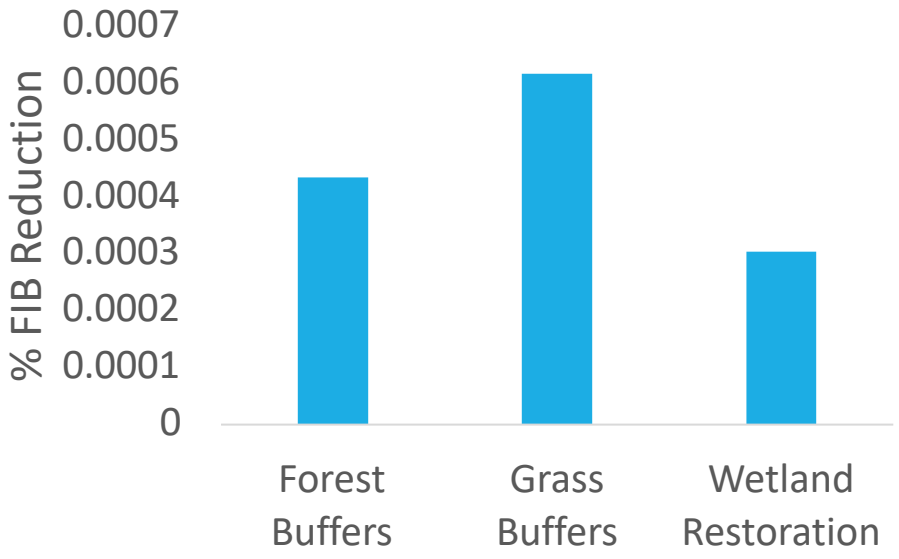
ES Quantification results: Pathogen Reduction

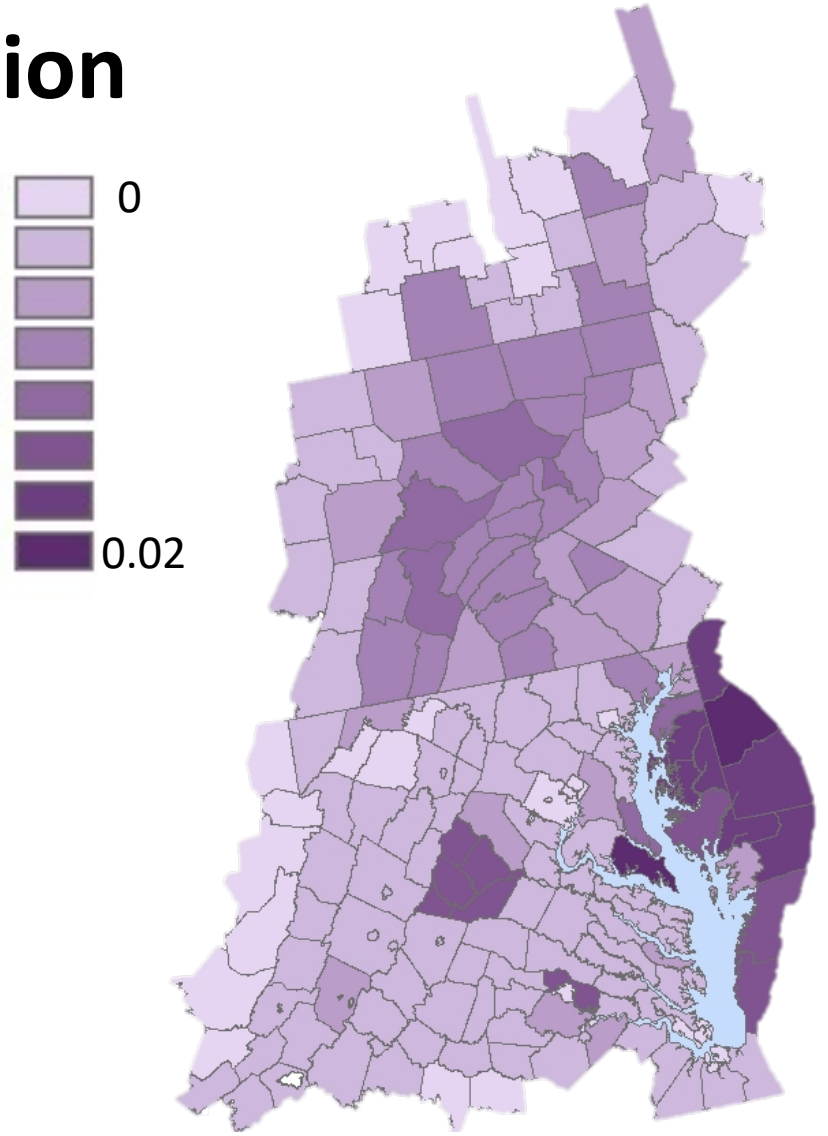
Metric: % Fecal Indicator Bacteria (FIB) reduction

Approach:
Adpated from Wainger et al 2016 & Richkus et al 2016:

- Use literature to determine FIB removal efficiencies of BMPs

% FIB Reduction = $\frac{Credited\ BMP\ acres}{Total\ land\ use\ acres\ the\ BMP\ was\ implemented\ on} * \%\ FIB\ efficiency$





Estimated % FIB reduction due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

ES Quantification results: Pollinator supply

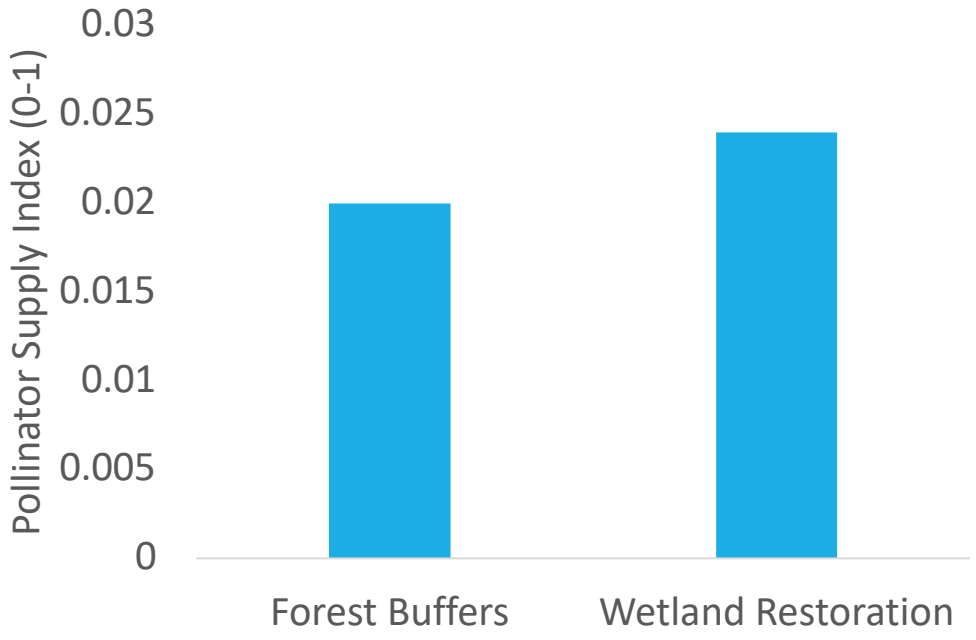
Metric:

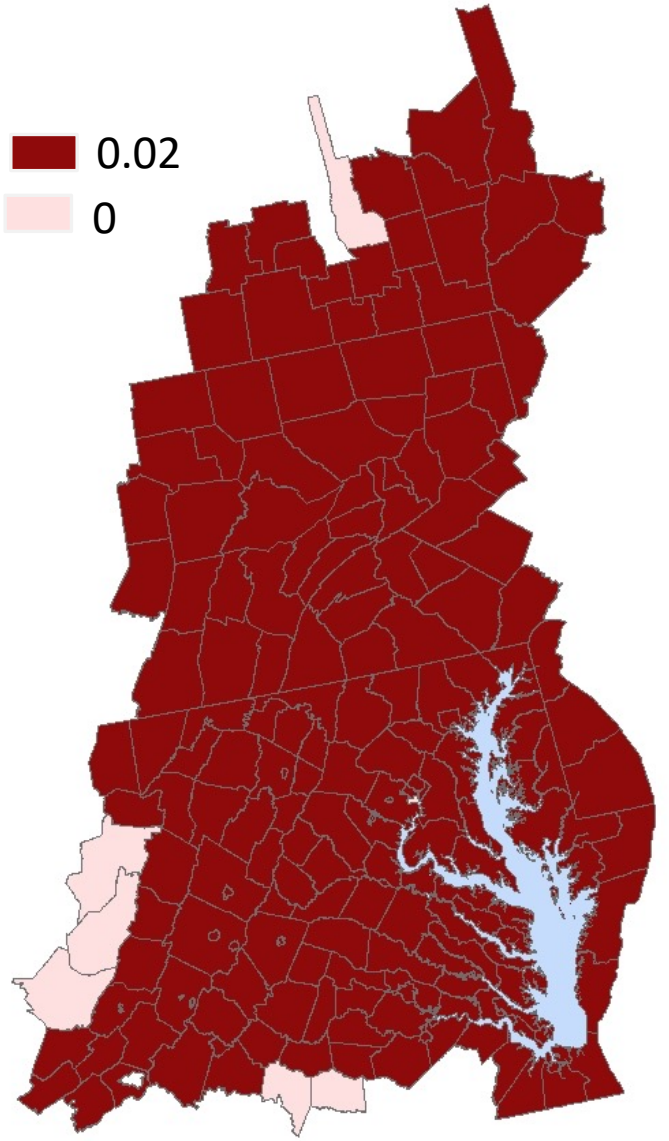
Habitat suitability for certain pollinator species (e.g., Bumblebee)

Approach:

- Use InVEST pollinator supply model to estimate relative species abundance which ranges from 0-1 (very much like habitat suitability)
  - This is dependent upon floral resources and nesting habitat.

Species	Habitat suitability (0-1)
bumblebee	0.024
blue sweat bee	0.008
orchard bee	0.008
bicolor sweat bee	0.008





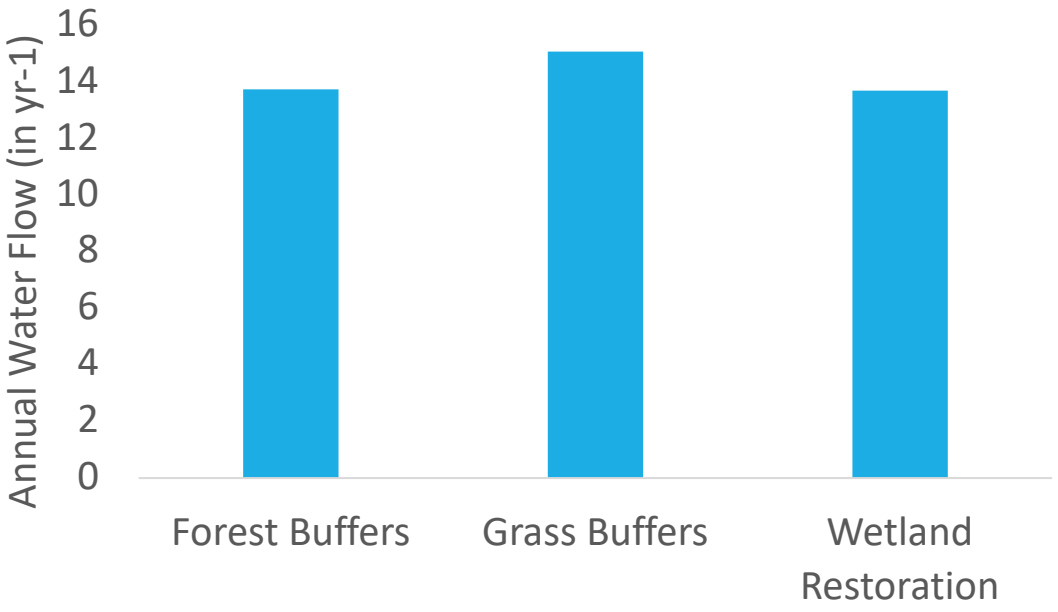
Estimated supply of Bumblebees due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

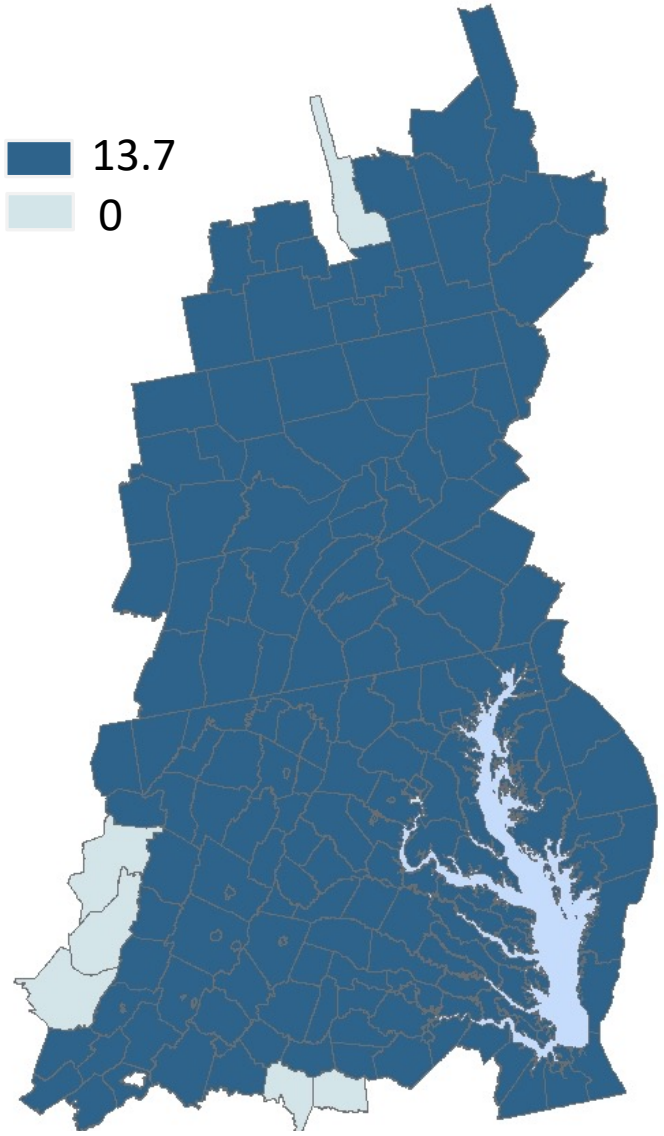
ES Quantification results: Water quantity

Metric: Surface water flow

Approach:

- Use annual flow as an estimate for potential supply of water on the landscape.
  - This approach does not account for groundwater.
  - Data from CAST model





Estimated annual flow (in yr^{-1})due to wetland BMPs based on WIP3 Targets for each county (obtained from CAST).

How will we share these results?

1. **EPA style report:**
   - Composed of individual fact sheets that CBP and CBP partners can adapt for their needs

2. **Integrate with CAST:**
   - Developed methods that can be used to determine a per acre estimate of an ecosystem service
   - Work with CAST on a visual tool that displays connections between BMPs, ES, and Watershed Outcomes

3. **Integrate with other tools**
   - Targeting dashboard
   - Diversity dashboard
   - Data dashboard

EPA report fact sheet example:

BMP: Wetland creation

What is Wetland creation?

Wetland creation is the manipulation of the physical, chemical, or biological characteristics present to develop a wetland that did not previously exist at a site. Wetland creation can be done in tidal and non-tidal wetland areas (Chesapeake Bay Program, 2018). The maximum acres of wetland creation implemented in the watershed is about 330 acres in Queen Anne, MD (Fig 28).

What are the additional benefits of implementing a wetland creation BMP?

Wetland creation help reduce N, P and sediment loads while also providing additional ecosystem services. For example, creating a wetland may provide flood control which would benefit nearby residents, farms, and businesses (Fig 29,30). In total, we identified 34 potential ecosystem services provided by wetland creation that would benefit 43 potential user groups.

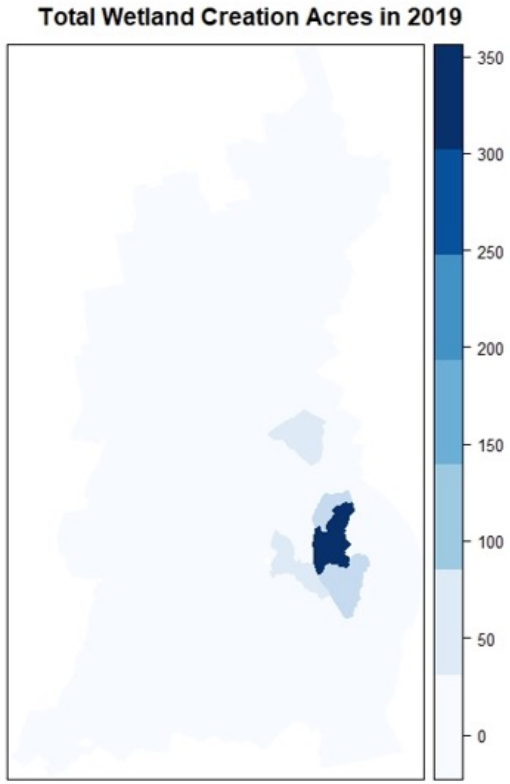


Figure 28 Total wetland creation acres by county.

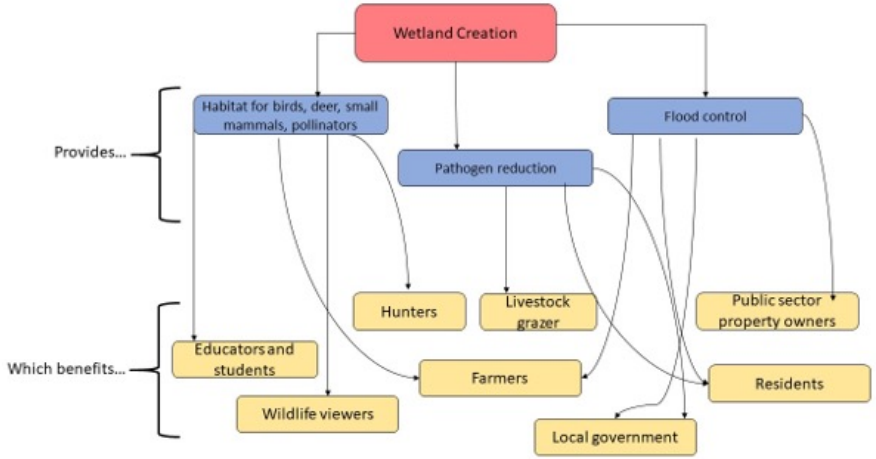


Figure 29 BMPs (red box) provide ecosystem services (blue box) which benefit different user groups (yellow box). For example, wetland creation provides flood control services which benefits property owners, local governments, farmers and residents.

What Watershed Outcomes may benefit from Wetland creation?

We identified a direct connection between wetland creation and 16 of the 31 outcomes. The outcomes we identified are listed below:

2025 WIP
Adaptation
Black Duck
Blue Crab Abundance
Brook Trout
Fish Habitat
Forest Buffer
Healthy Watersheds
Oyster
Protected Lands
Public Access Site Development
Stream Health
Submerged Aquatic Vegetation (SAV)
Toxic Contaminants Policy and Prevention
Tree Canopy Outcome
Wetlands

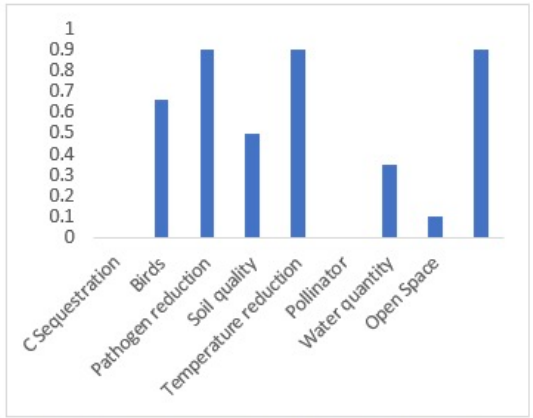


Figure 30 Relative provisioning of FES for wetland creation BMPs. Missing values due to lack of data to quantify that FES.

EPA report fact sheet example:

4.3 Bird Species

Why are bird species important?

Many people enjoy birdwatching, especially for some of the more well known, or large birds. Additionally, the presence or absence of bird species may be a useful indicator for habitat quality.

Who is impacted by bird species?

There are many beneficiaries, or users of an ecosystem, that benefit from birds. Some beneficiaries to consider are: artists , experiences and viewers (e.g., birdwatchers), hunters, farmers , food and medical subsisters, resource dependent businesses

How do we quantify bird species?

Identify a metric that may be modeled, measured, or monitored that corresponds to a FEGS or ES. For bird species, we have chosen to use bird species richness (no. of birds/acre). Briefly, we used species area curves to determine the relationship between habitat area and bird species richness for every different land use in the watershed. Then we used each curve to estimate how many bird species may be in a certain area of each land use.

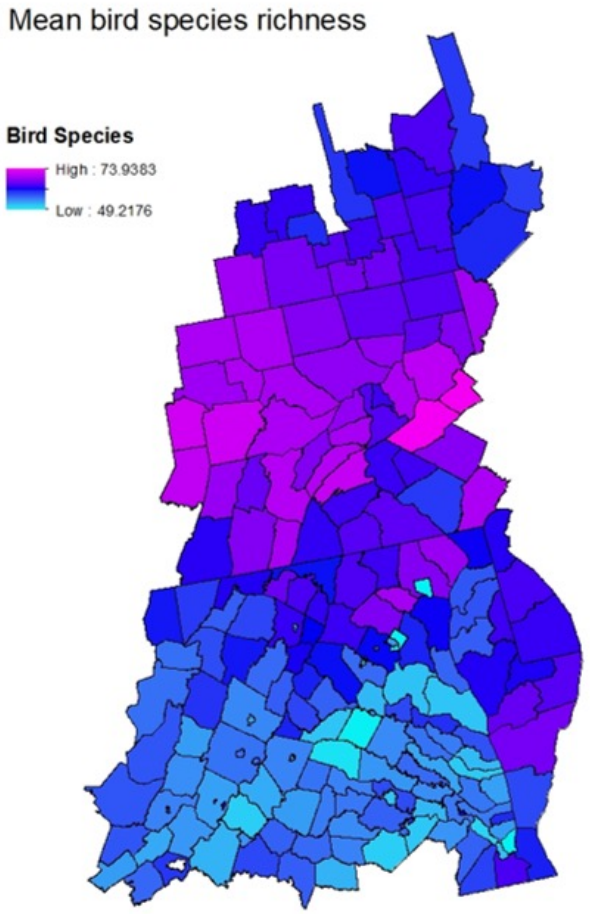


Figure 36 Estimated number of bird species in each county in Chesapeake Bay Watershed based on USGS GAP data.

Limitations

USGS GAP species richness data is based on modeling predicted habitat based on the 2001 NLCD land cover dataset, as a result, these estimates may not be as accurate due to land use land cover change that has likely occurred since 2001.

How can this information be used?

Users can explore the current estimate of bird species richness for their county and then explore the relationships between different landuses and bird species richness to determine if there are certain land

- Healthy watersheds
- Public access site development

What Watershed Agreement Outcomes may directly help improve bird species?

- Wetlands
- Black duck
- Forest buffers
- Tree canopy

What best management practices (BMPs) may help improve from bird species?

Some best management practices may help improve bird species richness. BMPs that increase habitat used by birds are especially important. We quantified how BMPs that increase potential bird habitat contribute to changes in bird species richness. The table below shows estimates for bird species richness for different BMPs based on 20 acres of BMP implementation. Units are birds/acre.

BMP NAME	POTENTIAL BIRD SPECIES RICHNESS
FOREST BUFFERS	77
GRASS BUFFERS	76
IMPERVIOUS SURFACE REDUCTION	76
WETLAND CREATION/RESTORATION	92

Estimates of maximum and mean bird species richness for 900m² areas of each land use.

LAND USE LAND COVER CLASS	MAX BIRD SPECIES RICHNESS	MEAN BIRD SPECIES RICHNESS
WATER	114	40.9
EMERGENT WETLAND	113	81.7
TREE CANOPY	114	65.9
SHRUBLAND	114	58.8
LOW VEG	114	63.5
BARREN	114	56.8
STRUCTURE	111	57.7
IMP SURFACES	114	57.3
IMP ROADS	113	63.6
TC OVER STRUCTURE	107	68.5
TC OVER IMP SURF	113	66.2
TC OVER IMP ROADS	108	68.4

Additional resources:

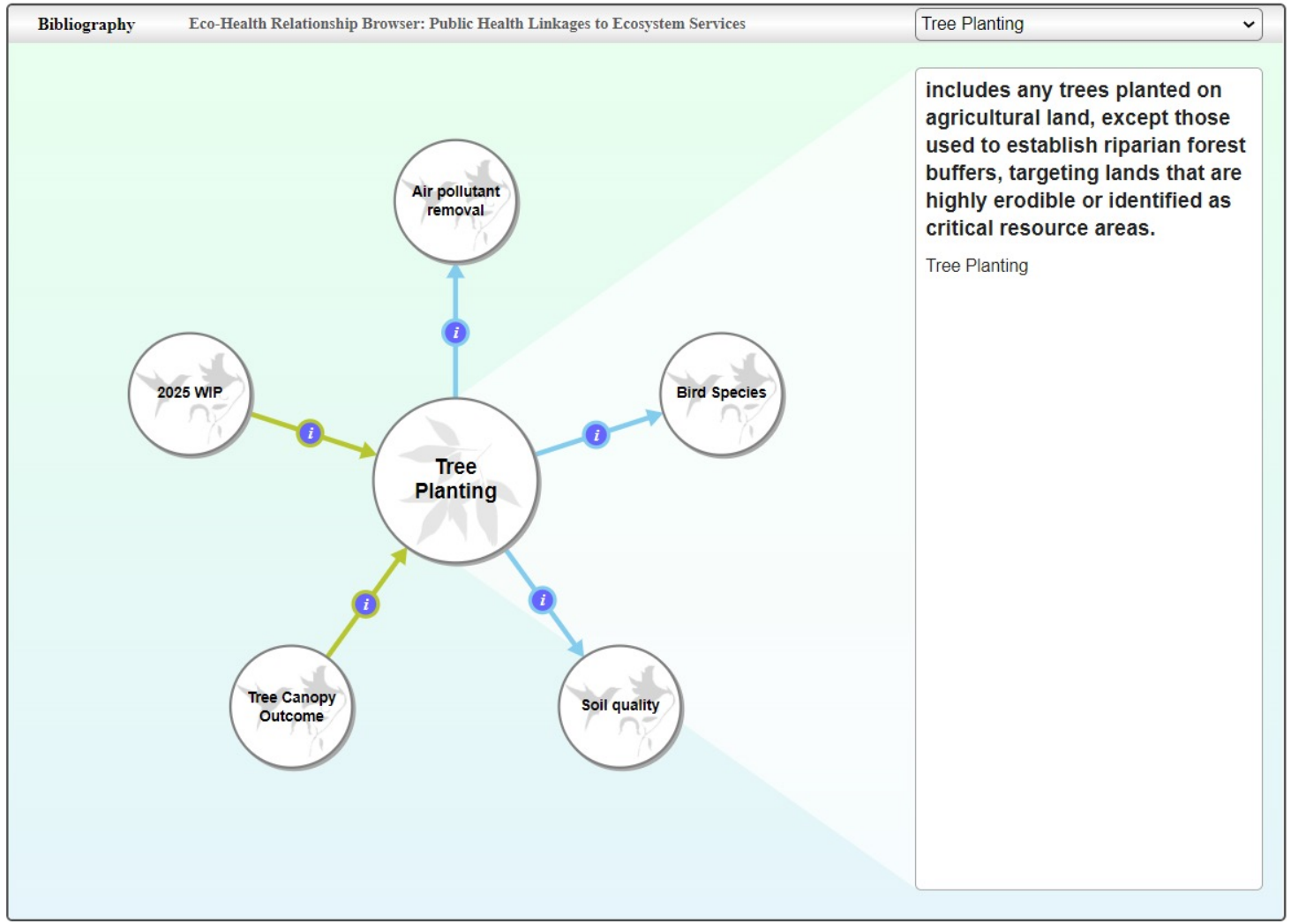
USGS Gap: https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap

CAST examples:

Example ES report for 20 acres of Wetland Creation BMP:

ES	Supply of ES	Units
C sequestered	30244	Lb yr-1
Bird species richness	92	richness
Pathogen reduction	3.04 x 10^{-4}	% FIB removal

Example of visual tool to view connections:



Other tools:

Ecosystem Services Mapper:
https://chesbay.maps.arcgis.com/apps/webappviewer/index.html?id=581fd6e79bae4b2fbcf988a664b6ead6

Maps would be linked with:
Geographic Targeting Portal (under *Increased Benefits to People* tab) - https://gis.chesapeakebay.net/targeting/

Watershed Data Dashboard (under *Prioritizing Other Benefits* tab) - https://gis.chesapeakebay.net/wip/dashboard/

Chesapeake Bay Environmental Justice and Equity Dashboard (under *Socioeconomic* tab) - https://gis.chesapeakebay.net/diversity/dashboard/

Limitations:

- Most of these estimates rely on remotely sensed land use land cover data and will need to be updated as new LULC datasets become available (e.g., pending 2017/18 1m dataset)

- Because estimates are based on LULC data, these estimates are only as good as the LULC data.

- These estimates of ES per BMP acre assume that the BMP is functioning at full capacity as a wetland.

- We are also limited by the BMP data– in this analysis, we have no idea where in the county these BMPs are implemented

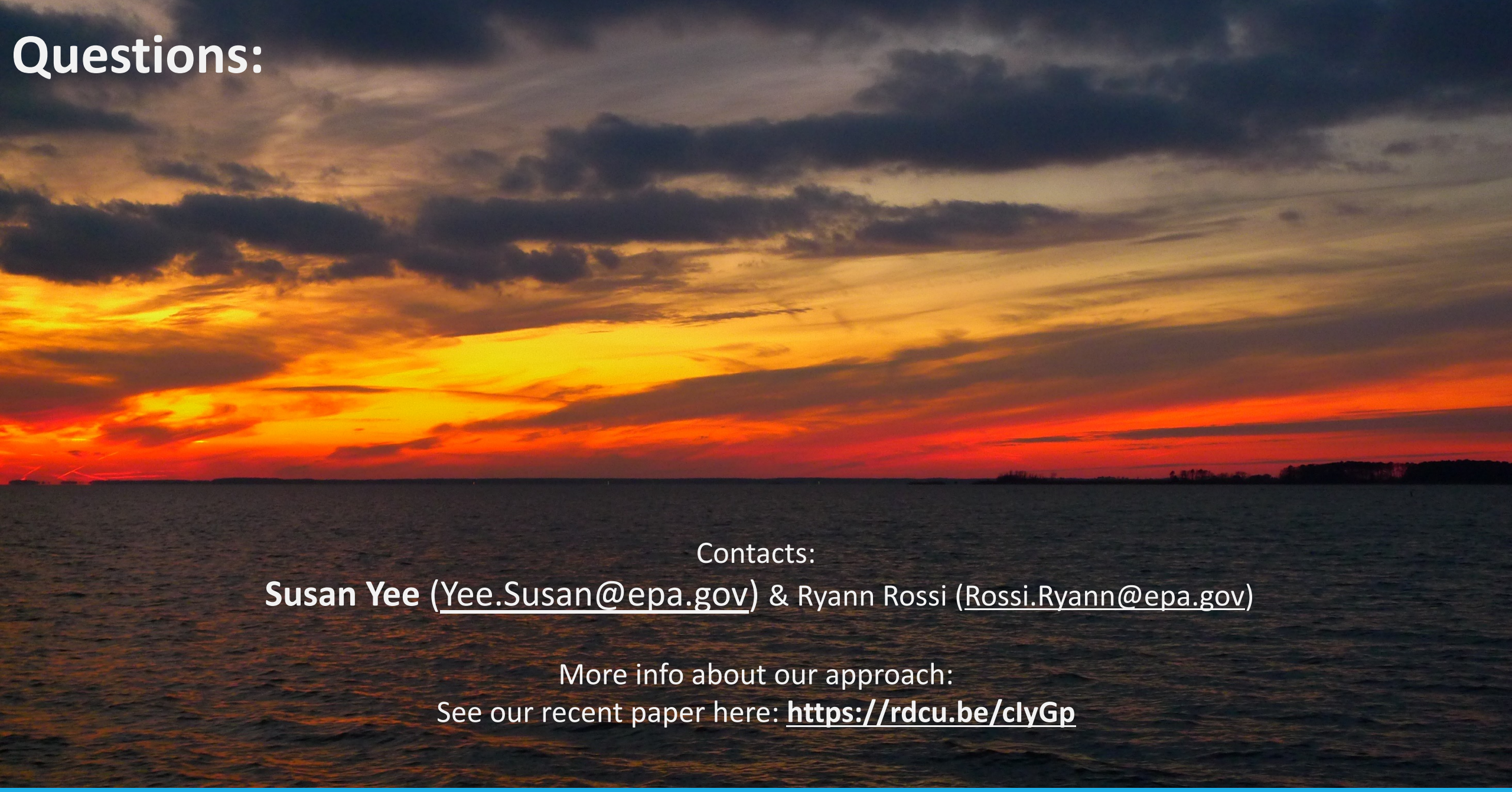
Future Directions:

- If we want to use remotely sensed data to estimate ES, then we need some better wetland data.

- We need more data (*or maybe that data exists, and we need help accessing it*) that tracks the metrics associated with ES over time.
  - How do we ensure data sharing to improve ES estimates? We've seen some great case studies that would be so useful!

- Are there other metrics that are better than using those that require lulc data?

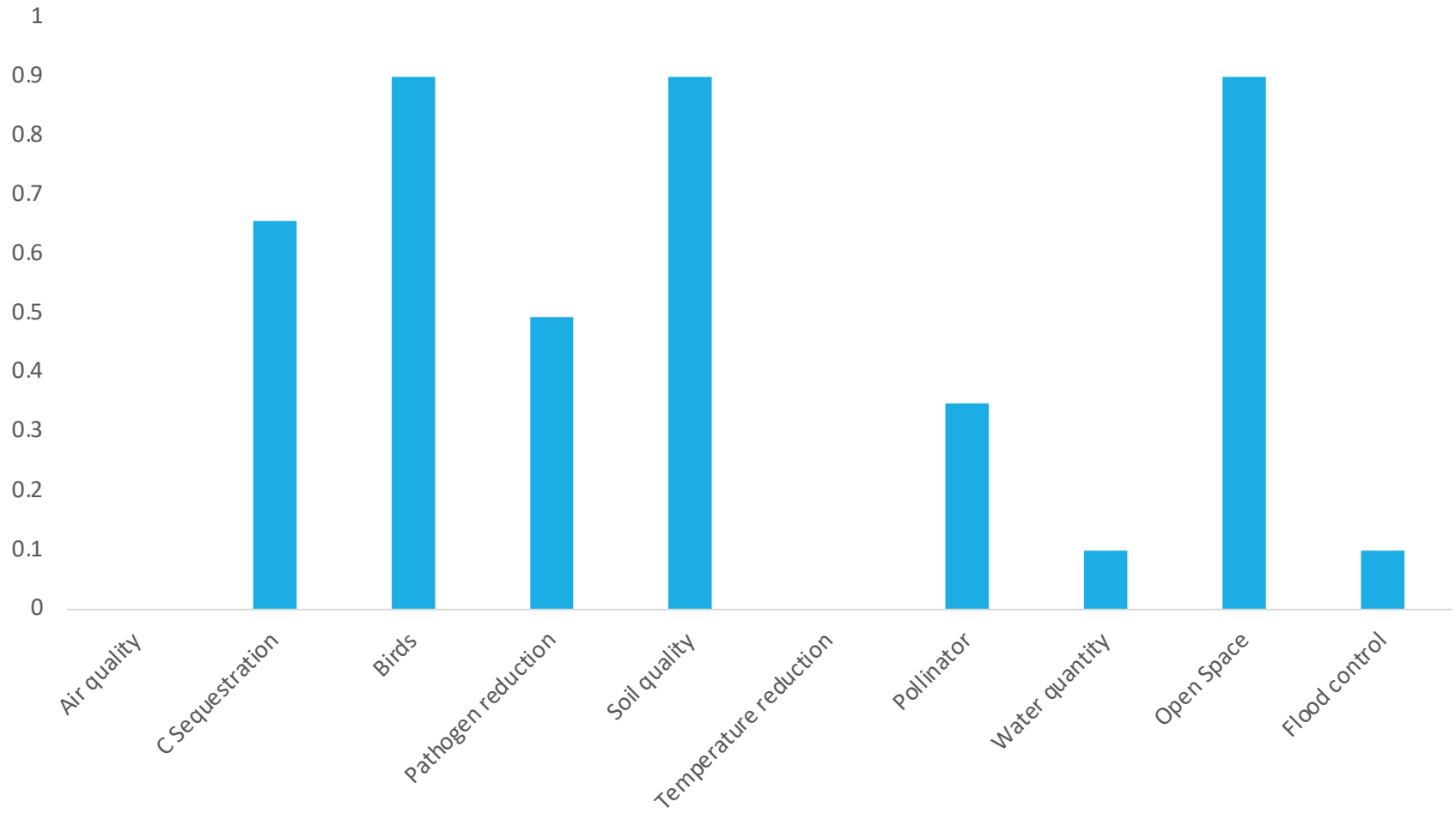
Questions:



Contacts:
Susan Yee (Yee.Susan@epa.gov) & Ryann Rossi (Rossi.Ryann@epa.gov)

More info about our approach:
See our recent paper here: **https://rdcu.be/cIyGp**

ES Quantification results: Comparing relative supply of ES



Quantify Ecosystem Services & Compare Between BMPs