Bay Optimism:

Resilience and Restoration of Submersed Aquatic Plants in Chesapeake Bay

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Once-Threatened Trumpeter Swans Spotted on SERC Campus

by Sara Richmond

Not long ago, a trumpeter swan sighting was nearly unheard of in the Chesapeake Bay region—or many places in the United States, for that matter. After being hunted to near-extinction in the early 1900s, the birds, who can boast an 8-foot wingspan and are the largest waterfowl in the world, struggled to recover. Now the swans are starting to reappear, including two spotted recently at the Smithsonian Environmental Research Center (SERC).
Key Food for Trumpeter Swans: Sago Pondweed (*Stuckenia pectinata*)
Trumpeter swans and underwater plants inextricably connected!

Photo: National Park Service

Photo: Bert Hidding
Nursery Habitat

Sediment trapping
Nutrient absorption
Shore protection

Food for waterfowl and other animals

Dick Daniels
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Photo credit: Robert Burnett
Photo credit: Lateral Line
Photo credit: VIMS
Photo credit: Chesapeake Bay Program
Outline: The hidden life of underwater grasses

1. Quick tour of representative species
2. Trends in abundance
3. Factors in recovery
4. Restoration and resilience
Submersed aquatic macrophytes

Low salinity
- *Vallisneria americana*
- *Heteranthera dubia*
- *Elodea canadensis*
- *Callitriche* spp. (4 species)
- *Ceratophyllum demersum*
- *Zannichellia palustris*
- *Potamogeton pusillus*
- *Potamogeton crispus*
- *Stuckenia pectinata*
- *Najas* spp. (4 species)
- *Hydrilla verticillata*
- *Myriophyllum spicatum*

Medium salinity
- *Potamogeton perfoliatus*
- *Ruppia maritima*
- *Zostera marina*

High salinity
- *Zostera marina*
Submersed aquatic macrophytes

**Low salinity**
- Vallisneria americana
- Heteranthera dubia
- Elodea canadensis
- Callitriche spp.
- Ceratophyllum demersum
- Zannichellia palustris
- Potamogeton pusillus
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- Najas spp.
- Hydrilla verticillata
- Myriophyllum spicatum

**Medium salinity**
- Potamogeton perfoliatus
- Stuckenia pectinata
- Ruppia maritima
- Zannichellia palustris
- Zostera marina

**High salinity**
- Zostera marina
Wild celery (*Vallisneria americana*)

- Family Hydrocharitaceae
- Primarily freshwater species but can tolerate brackish water
- Prefers silty to sandy soil
- Tolerates low light conditions and high nutrient water
- Withstands wave action
- Valuable as waterfowl food, habitat for fish and invertebrates
Hydrilla (*Hydrilla verticillata*)

- Family Hydrocharitaceae
- Invasive, native to tropical Asia
- Freshwater
- Grows to >7m depth
- Highly polymorphic
- Reproduces asexually and sexually
- Grows rapidly under low light
- Forms thick mats
- Valuable habitat for fish
- Boom and bust plant

Photo credit: Todd Chadwell
Summer 2002 - vegetation density
Widgeongrass (Ruppia maritima)

- Family Ruppiaceae
- Boom and bust plant
- Straight, threadlike leaves
- Two forms: upright or creeping
- Freshwater to near seawater
- Grows in salt pannes
- Shallow areas
- Sandy bottom, sometimes soft mud
- High waves are damaging
- Valuable food for waterfowl

Maryland Department of Natural Resources
Eelgrass (Zostera marina)

- Family Ruppiaceae
- Boom and bust plant
- Straight, threadlike leaves
- Two forms: upright or creeping
- Freshwater to near seawater
- Grows in salt pannes
- Shallow areas
- Sandy bottom, sometimes soft mud
- High waves are damaging
- Valuable food for waterfowl
Estimated Historic Distribution of Submersed Aquatic Vegetation

Sedimentation
Eutrophication from nutrient runoff

Photo credit: All Downstream

Photo credit: W.K. Vogelbein
Stevenson et al. 1979
Hurricane Agnes Roars Up Gulf

MIAMI — Residents of a low-lying area along a strip of the Florida Panhandle were urged to evacuate Sunday as Hurricane Agnes churned toward them with winds up to 100 miles per hour and torrential rains that killed one person and injured at least 25.

At the season's first hurricane to plow north at about 12 m.p.h., from a position 250 miles south of Panama City, the National Hurricane Center in Miami recommended evacuation of the offshore islands and low-lying bays along a 10-mile strip of the Panhandle.

"EVACUATION ROADS in this area are low, and some are closed," meteorologist Joe Peltoner of the National Weather Service in Miami, said. "Vehicles may be stranded in flood waters.

The hurricane center said Agnes' coordinates at 12 midnight were latitude 26.5 north, longitude 84.7 west.

Evacuation plans are in effect in Florida's Panhandle, where Agnes was expected to cross the coast near Apalachicola late Sunday, according to the National Hurricane Center.

Agnes' coordinates at 12 midnight were latitude 26.5 north, longitude 84.7 west. Civil Defense (CDI) officials in Port St. Joe said 10 to 50 residents of low-lying sections of the town were being evacuated.

The hurricane center said Agnes was expected to cross the Panhandle coast near Apalachicola early this afternoon. If she maintained her course and speed.

The center said that even without further strengthenings, storm surges caused by Agnes could raise ocean waters above normal in coastal areas from Port St. Joe to St. Marks. Persons in coastal areas and offshore islands were warned to be alert for "nearshore flooding and dangerous waves. Evacuation may be required later in the day or early Monday."

Joe Peltoner, a hurricane forecaster with the National Hurricane Center in Miami, said the Times Sunday afternoon that he believed any additional threat to the Tampa Bay area would be relatively small, perhaps for a few hours. The eye of the hurricane, Peltoner said, would probably be about 150 miles off the Gulf Coast.

(See AGNES, PA)
Data from Virginia Institute of Marine Science

Submersed Aquatic Vegetation Cover

Total Area (ha)

Year

Susquehanna Flats
### Chesapeake Bay Health

#### Overall Bay

**Score (%) Comments**

- **Overall Bay**: 37
- **Comments**: Overall average grade for Chesapeake Bay. D+. Poor Water Quality Index due to very poor water clarity, poor chlorophyll a and good dissolved oxygen, except in the deep channel. Poor Biotic Index due to moderate benthic community and poor phytoplankton community and bay grass scores.

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#### 2006

- **Upper Western Shore**: D-
- **Upper Bay**: D-
- **Lower Western Shore (MD)**: D-
- **Potomac River**: D-
- **Rappahannock River**: D-
- **York River**: D-
- **James River**: C-
- **Elizabeth River**: C-

**Comments**:
- **Upper Western Shore**: Poor ecosystem health. There were strong improvements in total phosphorus, benthic community, and aquatic grasses. Overall, this region is showing a significantly improving trend.
- **Lower Western Shore (MD)**: Poor ecosystem health. Large improvements in chlorophyll a and benthic community and slight increases or no change in other indicators led to better scores. Over time, this region is showing a slightly improving trend.
- **Potomac River**: Moderately poor ecosystem health. This region remained steady. Some indicators improved, others declined. This region had the lowest aquatic grass score.
- **Rappahannock River**: Moderate ecosystem health. Scores improved from the previous year. There were large improvements in benthic community, total nitrogen, and chlorophyll a.

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#### 2015

- **Upper Western Shore**: C
- **Upper Bay**: C
- **Lower Western Shore (MD)**: D-
- **Potomac River**: D-
- **Rappahannock River**: C-
- **York River**: D-
- **James River**: C-
- **Elizabeth River**: D-

**Comments**:
- **Upper Western Shore**: Moderate ecosystem health. Improved the most in total nitrogen and aquatic grasses and had a perfect dissolved oxygen score. Over time, this region is showing a significantly improving trend.
- **Upper Bay**: Moderate ecosystem health. This area had improvement with gains in chlorophyll a and total nitrogen scores. Over time, this region is showing a significantly improving trend.
- **Lower Western Shore (MD)**: Poor ecosystem health. This region remained steady. Some indicators improved, others declined. Over time, this region is still very close to showing a slightly declining trend.
- **Potomac River**: Moderate ecosystem health. This region remained steady. Some indicators improved, others declined. Over time, this region is showing a significantly improving trend.
- **Rappahannock River**: Moderate ecosystem health. Scores improved from the previous year. There were large improvements in benthic community, total nitrogen, and chlorophyll a.
- **York River**: Poor ecosystem health. Declines in total phosphorus were balanced by strong increases in total nitrogen. Over time, this region is showing a slightly improving trend.
- **James River**: C-
- **Elizabeth River**: D-

**Comments**:
- **Upper Western Shore**: Moderate ecosystem health. Continued to be the highest scoring region, especially for total nitrogen and total phosphorus. Chlorophyll a and water clarity also improved from the previous year.
- **Upper Bay**: Moderately good ecosystem health. Chlorophyll a and water clarity also improved from the previous year.
- **Lower Western Shore (MD)**: Moderate ecosystem health. Chlorophyll a and water clarity also improved from the previous year.
- **Potomac River**: Moderate ecosystem health. Scores improved from the previous year. There were large improvements in benthic community, total nitrogen, and chlorophyll a.
- **Rappahannock River**: Moderate ecosystem health. Scores improved from the previous year. There were large improvements in benthic community, total nitrogen, and chlorophyll a.
- **York River**: Poor ecosystem health. Declines in total phosphorus were balanced by strong increases in total nitrogen. Over time, this region is showing a slightly improving trend.
Three indicators of Bay Health showed widespread score improvements in 2015.
Submersed Aquatic Vegetation Cover

Data from Virginia Institute of Marine Science
Factors in recovery

Sediment management

Nutrient management

Boating, fishing, and aquaculture practices

Herbicide use

Storm abatement

Genetic diversity

Photo credit: FL FWCC
What’s the Goal?

The ultimate goal of ecological restoration is reestablishing self-sustaining ecosystems that will be resilient to future perturbation without ongoing human input.

Procaccini and Piazzi 2001; Rice and Emery 2003; Ramp et al. 2006; Broadhurst et al.2008; Liu et al.2008

Photo: NOAA
The potential for resiliency

Extant populations will either

• Acclimate
  → Phenotypic plasticity

• Adapt
  → Phenotypic variation
  → Genetic variation

• Relocate
  → Natural dispersal
  → Local Restoration
  → Assisted migration

• Become Extirpated

Photo: David Ayers/USGS
Genetic Considerations for Resilience and Restoration

• Number of genotypes or alleles in populations
  – Contribute to growth and survival (Williams 2001, Hughes et al. 2009), resistance to disturbance (Hughes and Stachowiz 2004), growth and potential for reproduction (Engelhardt et al. 2014)
    • Diversity effects
    • Effects of particular individuals

• Levels of heterozygosity within individuals
  – Low heterozygosity = decreased fitness (Dudash 1990; Broadhurst et al. 2008; Frankham et al. 2011)

• Adaptation of individuals to local environments
  – Differentiation among sites
  – Homesite advantage (Montalvo and Ellstrand 2000, 2001)
  – Outbreeding depression from mixing populations (Frankham et al. 2011)
Genotype collections at 10 microsatellite loci

Collect leaf tissue and ramets from natural and restored sites

Grow collected plants

Conduct experiments on genotyped individuals to link genetic diversity with ecological traits that affect persistence
675 samples yielded 425 unique genotypes (2007-2009)

Heterozygosity significantly less than expected.
Comparison of *Vallisneria* across three rivers:

- **Kennebec River**: 2011
- **Hudson River**: 2011
- **Potomac River**: 2007-2011
How does *Vallisneria* with other SAV species from throughout the world?

From a review of 154 publications of population genetic diversity in SAV

82 publications of microsatellite diversity in 15 species
Effects of genetic diversity on individual and population performance

Engelhardt et al. 2014
Tested

- Effects of individual heterozygosity on growth and reproduction
  - 49 cloned genotypes from 14 sites
    - 20 genotypes from HWC
    - 17 genotypes from SWP
  - Effects of genotypic diversity (2, 4, or 8 genotypes)

- 516 monoculture mesocosms  120 multi-genotype mesocosms

Local adaptation based on performance in home versus foreign soil types for HWC and SWP clones

- Piscataway Park (SWP)
- Hawks Cove (HWC)
Higher heterozygosity yields larger turions

Leaf area effects vary by population

Confounded by overall higher heterozygosity in HWC

Engelhardt et al. 2014
Effects of Genotypic Diversity on Flowering

Engelhardt et al. 2014
More genotypes yield
1) Higher probability of having both males and females
2) Lower probability of non-flowering individuals

Engelhardt et al. 2014
• More genotypes = better performance
• Individual genotypes and population source affects ecological performance more than individual heterozygosity (Engelhardt et al. 2014, Marsden et al. 2013, Tumas et al. in prep)
• No strong consistent evidence of benefits of “genetic rescue”
• Some evidence for local adaptation that needs to be confirmed (Marsden et al. 2013, Engelhardt et al. 2014)
• Restoration practices that consider local adaptation of Chesapeake Bay *V. americana* populations are advised

Photo: NOAA
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Photo: NOAA