North Carolina's Underwater Grasses:

A Lesson Plan on Ecosystem Monitoring and Assessment

Lesson plan developed by:

Albemarle - Pamlico National Estuary Partnership

Objective

North Carolina's underwater grasses are used as a case study to demonstrate how environmental monitoring and assessment can help evaluate an ecosystem's condition. Monitoring ecosystem health is analogous to monitoring human health. The people who make environmental management decisions are the doctors, the Albemarle-Pamlico Estuary is the patient and the monitoring of submerged aquatic vegetation is one way to check the vital signs. The monitoring results can be used to do an assessment of the ecosystem's condition.

After an introduction to the estuarine system and reading an excerpt from the 2012 Albemarle-Pamlico Ecosystem Assessment, students must demonstrate an understanding of how natural resources are managed through a role play activity and group discussions. Students also must compare human impacts on the density of SAV and assess different ways to prevent its decline. Through this exercise they should be able to recognize the challenges of monitoring ecologically important species and develop environmental management recommendations.

Materials

- Indicator report - 5 page report on the extent of submerged aquatic vegetation from APNEP's 2012 Ecosystem Assessment.
- Student worksheets

Duration

- One class period

Grade Levels

- High School

Procedures:

1. If unfamiliar, read the background information on the estuarine system, monitoring and assessment, and submerged aquatic vegetation.

2. Lead the pre-lesson discussion with students to introduce conservation management, ecosystem indicators, and SAV.

3. Have students read the indicator report.

4. Have students get in groups and complete the worksheet. Each group should attempt all questions, but assign groups one question to present to the rest of the class.

North Carolina Standards

- Bio.2.1.1, Bio.2.1.2, Bio.2.1.3, Bio.2.2.1, Bio.2.2.2, EEn.2.7.1, EEn.2.7.2, EEn.2.7.3

Next Generation Science Standards

- HS-LS2-2, HS-LS2-3, HS-LS2-6, HS-LS2-7, HS-ESS3-3

Virginia Standards

- BIO.7.b, BIO.8.b, BIO.8.d

N.C. Essential Standards:

- Bio.2.1: Analyze the interdependence of living organisms within their environments.
  - Bio.2.1.1: Compare the flow of energy and cycling of matter (water, carbon, nitrogen and oxygen) through ecosystems relating the significance of each to maintaining the health and sustainability of an ecosystem.
  - Bio.2.1.2: Analyze the survival and reproductive success of organisms in terms of behavioral, structural, and reproductive adaptations.
  - Bio.2.1.3: Explain various ways organisms interact with each other (including predation, competition, parasitism, mutualism) and with their environments resulting in stability within ecosystems.
  - Bio.2.1.4: Explain why ecosystems can be relatively stable over hundreds or thousands of years, even though populations may fluctuate (emphasizing availability of food, availability of shelter, number of predators and disease)
- Bio 2.2: Understand the impact of human activities on the environment
  - Bio 2.2.1: Infer how human activities (including population growth, pollution, global warming, burning of fossil fuels, habitat destruction and introduction of nonnative species) may impact the environment.
  - Bio 2.2.2: Explain how the use, protection and conservation of natural resources by humans impact the environment from one generation to the next.
- EEn.2.7.1: Explain how abiotic and biotic factors interact to create the various biomes in North Carolina
- EEn.2.7.2: Explain why biodiversity is important to the biosphere.
- EEn.2.7.3: Explain how human activities impact the biosphere

Next Generation Science Standards:

- HS-LS2-2- Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales
- HS-LS2-3-Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-6- Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7- Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-ESS3-3- Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Virginia Standards of Learning

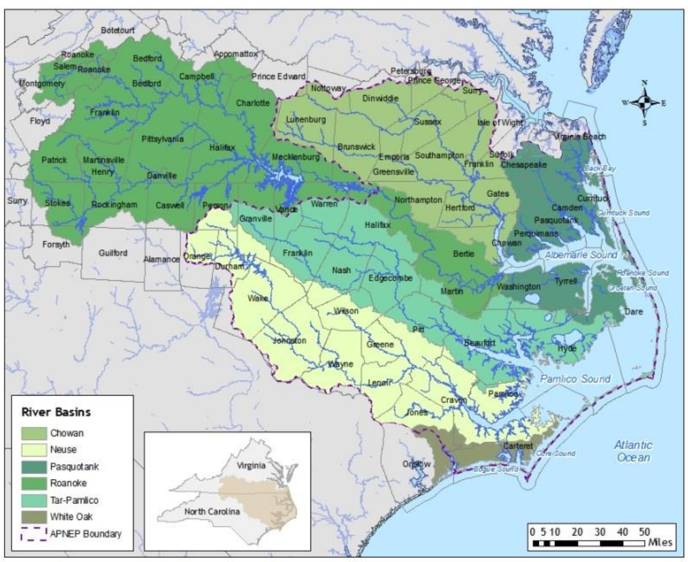
- BIO.7 The student will investigate and understand how populations change through time. Key concepts include

    a) evidence found in fossil records;
    b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations;
    c) how natural selection leads to adaptations;
    d) emergence of new species; and
    e) scientific evidence and explanations for biological evolution.

- BIO.8: The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include
    a) interactions within and among populations including carrying capacities, limiting factors, and growth curves;
    b) nutrient cycling with energy flow through ecosystems;
    c) succession patterns in ecosystems;
    d) the effects of natural events and human activities on ecosystems; and
    e) analysis of the flora, fauna, and microorganisms of Virginia ecosystems.

What is the Albemarle-Pamlico Estuarine System?

The Albemarle-Pamlico Estuarine System is comprised of an extensive complex of creeks, rivers, swamps, marshes, and open water sounds dominating northeastern North Carolina. This system is one of the largest and most important in the United States. Covering approximately 7,530 square kilometers (2,900 square miles), the waters of the system comprise the second largest estuarine system on the East Coast of the United States, exceeded in area by only the Chesapeake Bay. With a **watershed** exceeding 30,000 miles and encompassing cities like Raleigh, NC and Greenville, NC, there is a large human influence on the estuarine system. Albemarle Sound is not directly connected to the Atlantic Ocean and Pamlico Sound has very few inlets; both lay behind an extensive chain of barrier islands referred to as the “Outer Banks”. Located at the convergence of the warmer Gulf Stream and the cooler Labrador Current, the Albemarle-Pamlico Sounds are critical to fisheries in North Carolina and all along the east coast.



Map: Major river basins and sounds of the Albemarle- Pamlico Estuarine System

Ecosystem-based management (EBM) is a comprehensive approach to conserve and protect entire broad **ecosystems** instead of looking at single issues. The Albemarle-Pamlico National Estuary Partnership uses this strategy to pursue its mission of identifying, restoring, and protecting the significant resources of the Albemarle-Pamlico estuarine system.

Why Monitor and Assess?

A major challenge of ecosystem based management is assessing the current state of the ecosystem. The successful management of our natural environment is predicated on our ability to define and measure the things that make it healthy. **Monitoring** and **assessment** serve a number of purposes. Analogous to a routine doctor's visit, taking measures of ecosystem health provides objective information about the status of the environment for managers and policymakers to consider. It helps prevent a shifting baseline by providing quantifiable information about the way things were in the past. Assessments tell us whether efforts to protect the environment are working and are absolutely essential to ensure accountability for natural resource management agencies.

Monitoring and assessment help answer the questions:

1. What is the status of the Albemarle-Pamlico Estuarine System?
2. What are the greatest challenges facing the Albemarle-Pamlico Estuarine System?

More specifically, information from these assessments allow scientists and managers to addresses the condition of the sounds, diagnoses issues and forecasts trends for various elements or components of the ecosystem:

- Magnitude: what is the condition of the ecosystem component?
- Extent: over what geographic area does the component extend?
- Trend: how has condition and range of the component changed over time?
- Cause: what **stressors** are believed to be responsible for changing trends?
- Source: what agents are responsible for stressor intensity?
- Vulnerability: what is the likelihood of stressors causing a loss in human well-being or ecological integrity over the coming decade and beyond?
- Solutions: what combination of approaches and tools are the most effective and efficient to reduce impacts from stressors?

What is Submerged Aquatic Vegetation?

Underwater grasses or submerged aquatic vegetation (SAV) are plants that grow underwater. They are similar to sea grass but grow in the shallow, brackish waters of the sounds and its tributaries. They provide many **ecosystem services** to the sound's habitats:

- Habitat, food, and shelter for aquatic life
- Absorb and recycle nutrients like nitrogen and phosphorus
- Absorb CO_2
- Stabilize the shoreline by absorbing wave energy
- Add oxygen to the water
- Filter sediment
- Act as a gauge of water quality

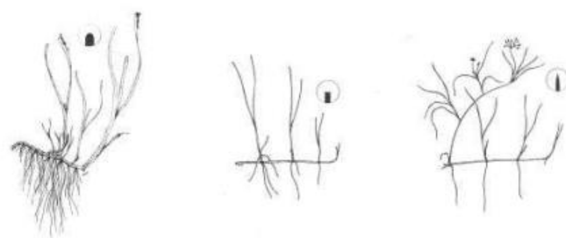


Image: Three common SAV species in NC.

SAV is an extremely important habitat for fish and waterfowl, and by extension it's important the hunters and fishermen that reside in and flock to eastern North Carolina. SAV has great ecological and economic value, and North Carolina's SAV resources are more abundant than most. The larger Chesapeake Bay is estimated to have only approximately half of North Carolina's 138,000 acres.[1]

On top of being a high value resource, SAV is valuable to scientists for its role as a sensitive bioindicator. Like a canary in a coal mine, the decline of these species can be a sign that the water quality is too low for the plants to survive. It is possible that the species is declining in NC. Rough estimates in the 1980s suggested that up to 200,000 acres of SAV existed in North Carolina's sounds, and the first effort to comprehensively survey SAV from the air accounted for 138,000 visible acres in 2011. A sustained monitoring effort is a critical to protecting and maintaining SAV in the Albemarle-Pamlico Sounds.

[1] http://www.chesapeakebay.net/indicators/indicator/bay_grass_abundance_baywide

Pre-lesson discussion questions to introduce topic

1. **What is ecosystem health?**

    a. Scientists study the Albemarle-Pamlico's health by monitoring important habitats, species, and water quality measures. Just like we have to visit the doctor to get our temperature checked and blood tested, there are ways to measure ecosystem health with indicators that help identify the stressors to the system. Some examples of indicators used to measure ecosystem health include:

        i. Human population- Humans consume natural resources and produce waste therefore impacting the surrounding environment and potentially stressing the natural resources of the Albemarle-Pamlico region.

        ii. Shellfish closures- Humans consume oysters, clams, and mussels from the sounds. These shellfish are filter feeders but they can also consume and concentrate pathogens like bacteria and viruses. High levels of certain bacteria can indicate contamination by human or animal waste, which is an ecological and human health concern. For this reason, shellfish beds must be monitored and they are closed when bacterial levels increase.

        iii. Suspended sediment- Eroded soil and particulate organic matter that was moved from the land to the water is called suspended sediment. Streams that drain agricultural and urban watersheds have increased suspended sediment loads. These streams can significantly affect biota by decreasing biodiversity and primary productivity. High concentrations of suspended sediment decrease water clarity and when deposited on the stream bed, the sediments can smother organisms on the bottom.

        iv. Nutrients (Nitrogen and Phosphorus)- Nutrients are essential for plant life but in excess they lead to excess plant and algae growth in a condition called eutrophication. Nutrient loads have increased over time and are a major factor in declining water quality.

        v. Chlorophyll a concentrations – Chl a is used to provide an index of phytoplankton biomass. Phytoplankton growth is determined by the amount of nutrients available so this measurement is also a proxy for nutrient concentrations. Excess nutrients can lead to overgrowth of phytoplankton which is called a bloom. These blooms can block sunlight from reaching SAV and can consume all oxygen from the water column causing fish kills. Some blooms even produce toxins which can be harmful to human health. In NC, chl a concentrations > 40 ug/L are in violation of the state water quality standards.

vi. Dissolved oxygen concentrations- DO concentrations are the amount of tiny oxygen bubbles in the water column. Very low oxygen levels can stress fish and shellfish.

2. What is the difference between monitoring and assessment?

a. Monitoring is the process of collecting data about certain indicators like those described in question one. There are many important considerations when developing a monitoring program. The length of time, frequency, and technique vary depending on the system being monitored. Monitoring is typically conducted to answer specific questions about the environment. For example, monitoring can be done to ensure compliance with pollution permits, assess environmental conditions or protect human health.

b. Assessment is the process that happens once monitoring data is collected. Monitoring data is analyzed to assess how the ecosystem is doing (status), whether it's improving (trends), and whether restoration projects and policy decisions are having their desired effect on the environment. Environmental managers use the results of an assessment to adapt their approach to environmental protection, improving what works while discontinuing efforts that are less successful.

3. Do you think sea grass abundance can be used as indicator of water quality?

a. Sea grasses are very sensitive to environmental degradation like pollution and therefore serve as a "canary in a coal mine" for poor water quality. Healthy sea grass beds can absorb some of the nutrient and sediment pollution, but when there is too much, sunlight becomes blocked stressing the sea grass populations by preventing or slowing photosynthesis.

We will be focusing on sea grass as a way to learn about the process of using environmental indicators to study the health of the Albemarle-Pamlico Estuarine System. You will be reading a short report on the ecological indicator: Submerged aquatic vegetation and then discussing how it is managed in NC.

Student Worksheet

1. Why is SAV important?
2. Why does SAV have higher light requirements than other plants?
3. What is the maximum depth these plants can grow in order to get enough sunlight?
4. Name a common brackish water SAV species.
5. What is the size range of sea grass beds in NC?
6. What are the major threats to SAV? What are some changing conditions that could make SAV populations more unstable?
7. How can humans minimize their impact on SAV?
8. Why do we need regular monitoring of the species?
9. What is the mean number of acres per reporting region?
10. How is SAV monitored?
11. What are some of the obstacles of monitoring?
12. Why can the 2006-2008 data not be compared to the 1985-1990 data?
13. If you could compare these numbers, what would be the percent decrease?

*Bonus. Where is the most SAV found in the sounds? Why do you think these areas are good?

Role-play activity: SAV management in NC

In North Carolina, stakeholders concerned with SAV include commercial and recreational fishermen, boaters, tourists, water utilities, coastal developers and homeowners, state and local governments, and factories with water needs. Questions that environmental managers have to consider include: How can we sustain the ecological benefits of our natural resources and while maximizing economic benefits as well? Should humans try and fix natural cycles when they are disturbed by human influences?

As a group, you are in charge making decisions related to SAV in North Carolina over the next ten years. Answer these questions as a group making sure to justify your answer.

1. Fishermen have offered to help your agency monitor SAV abundance because they know how important it is for fish populations. You have to decide which areas and how often to monitor. Due to limited funds you can only monitor 4 of the 9 regions from Table 1. Which ones do you choose and why? Out of these 4 regions, you can choose to do extensive monitoring of all beds once every 5 years or you can monitor only the dense beds once a year, which approach do you choose and why?

2. You have been asked to create a sign that will be posted at boat ramps across North Carolina informing citizens about the importance of SAV and how to protect the species. What are the key points you should convey? Sketch a draft design.

3. A coastal developer wants to build a neighborhood along the waterfront, which includes 20 large homes and the creation (through dredging) of a marina. The neighborhood has SAV along the waterfront. It's up to you whether or not to allow them to proceed. Should you allow the homes to be built? The marina? If so, what conditions (if any) do you think are appropriate? Now consider the issue from the perspective of the developer and a commercial fisherman. How might your decision affect their livelihoods?

4. Your agency has $200,000 for restoration projects for an area with SAV beds that have shown signs of eutrophication (algae densely growing on the plants). Based on your answers to question 7 (the ways humans can help save SAV), how would you spend this money?

Extension:
Coastal development can have a large impact on SAV abundance. More runoff leads to more sediment entering the waterways and this can block sunlight needed for SAV to survive. Research one low impact development technique that could lower the amount of sediment that runs off into the sounds during storms.

Teacher Answers to Worksheet

1. Why is SAV important?

    SAV provide habitat, food and shelter for aquatic life. For example, juvenile fish and crabs hide in the grasses to protect themselves from predators. They also absorb nutrients and sediment pollution, and can act as a gauge of water quality. Changes in this species are likely to affect other aquatic species.

2. Why does SAV have the highest light requirements of all other plants?

    The sediments where SAV grow are waterlogged and therefore anaerobic meaning they have no oxygen. SAV need to produce a lot of oxygen in order to aerate their roots. In the same way terrestrial plants release oxygen during photosynthesis, underwater SAV also release oxygen during photosynthesis. To a certain extent, the more available sunlight, the more oxygen the plant can produce. Also, there are other aquatic animals that need the oxygen added to the water column by SAV photosynthesis.

3. What is the maximum depth these plants can grow in order to get enough sunlight?

    Most SAV beds are found in waters less than 2m deep in order to get the sunlight they need to photosynthesize.

4. Name a common brackish water SAV species.

    Widgeongrass, Wild Celery

5. What is the size range of sea grass beds in NC?

    Small patches less than a meter to beds of many acres

6. What are the major threats to SAV? What are some changing conditions that could make SAV populations more unstable?

    Physical harm (dredging), water quality decline, storms with heavy rains that increase sediment runoff, and increased water temperatures

7. How can humans minimize their impact on SAV? (critical thinking- answer not in indicator report)

    Be aware of fishing gear and propellers in shallow areas where SAV is found
    Keep dredge and fill activities to a minimum
    Reduce fertilizers to prevent excess nutrients from making the water less clear
    Reduce runoff by reducing amount of impervious service to decrease sediment and nutrient load into rivers containing SAV

Create natural buffers to reduce the amount of nutrient and sediment runoff
Keep docks to a reasonable size and build around SAV beds to prevent shading the species from sunlight
Reduce fossil fuel consumption because rising water temperatures can affect SAV extent

8. Why do we need regular monitoring of the species?

   SAV distribution varies seasonally in response to many of the stressors discussed in pre-lesson discussion question 1 and its high value makes it essential that declines and positive responses can be detected in order to inform protection and restoration activities.

9. What is the mean number of acres per reporting region?

   Mean # of acres: total/9 regions= 137,951/9= 15,328 acres

10. How is SAV monitored?

    a. Aerial surveys of SAV in the Albemarle-Pamlico region using sophisticated plane-mounted cameras. Analysis of the flight imagery produces SAV maps.
    b. Boat-based sonar surveys: survey the sounds' shorelines using sonar. Because turbidity is higher on the western side of the sounds, boat-based sonar can detect SAV in areas where it is difficult to detect by air.

11. What are some of the obstacles of monitoring?

    White caps, turbidity, no species specific information

12. Why can the 2006-2008 data not be compared to the 1985-1990 data?

    Different monitoring techniques were used to collect the data.

13. If you could compare these numbers, what would be the percent decrease?

    31% Decrease: (200,000-138,000/200,000)= 0.31

*Bonus. Where is the most SAV found in the sounds? Why do you think these areas are good?

Along the eastern coast of the sounds (western coast of the Outer Banks). Some potential answers include they are far from fast moving rivers so there may be less suspended sediment, the barrier islands block wave energy, the water is shallow.

<u>Role-play activity: SAV management in NC</u>

In North Carolina, stakeholders concerned with SAV include commercial and recreational fishermen, boaters, tourists, water utilities, coastal developers and homeowners, state and local governments, and factories with water needs. Questions that environmental managers have to consider include: How can we sustain the ecological benefits of our natural resources and while maximizing economic benefits as well? Should humans try and fix natural cycles when they are disturbed by human influences?

As a group, you are in charge making decisions related to SAV in North Carolina over the next ten years. Answer these questions as a group making sure to justify your answer.

1. Fishermen have offered to help your agency monitor SAV abundance because they know how important it is for fish populations. You have to decide which areas and how often to monitor. Due to limited funds you can only monitor 4 of the 9 regions from Table 1. Which ones do you choose and why? Out of these 4 regions, you can choose to do extensive monitoring of all beds once every 5 years or you can monitor only the dense beds once a year, which approach do you choose and why?

Answer: Generally, the regions with the most SAV would be monitored. Regarding experimental design, answers can vary. Monitoring every five years would give a full census of SAV and long term trends could eventually be detected. Small sites visited yearly (sentinel sites) for SAV monitoring allow detection of short-term trends in SAV coverage, which can help determine whether management approaches are working. Help students hone in on the questions they want to answer with SAV monitoring. Scientists and managers create a hypothesis related to their end goals, determine which method to use, collect the data on SAV, analyze the data, and create a conclusion.

2. You have been asked to create a sign that will be posted at boat ramps across North Carolina informing citizens about the importance of SAV and how to protect the species. What are the key points you should convey? Sketch a draft design.

Answer example: http://www.apnep.org/web/apnep/responsibleboating

3. A coastal developer wants to build a neighborhood along the waterfront, which includes 20 large homes and the creation (through dredging) of a marina. The neighborhood has SAV along the waterfront. It's up to you whether or not to allow them to proceed. Should you allow the homes to be built? The marina? If so, what conditions (if any) do you think are appropriate? Now consider the issue from the perspective of the developer and a commercial fisherman. How might your decision affect their livelihoods?

Answer: Answers will vary. At this level, students should weigh the values of environmental protection and economic development, recognizing that what's good for some isn't necessarily good for others. Commercial fishermen and developers both have an economic interest in the *decision. Runoff from home construction, hard surfaces, and lawn fertilizer could cause some SAV degradation. Dredging of a marina would cause direct impacts to SAV beds and also cause indirect effects by stirring up sediment in the water column. Boat traffic would also impact SAV. Conditions could vary and students should be creative. Silt fencing, low impact development, SAV restoration projects, protection of a buffer area near the shoreline, or assessment of mitigation costs might be some examples.*

4. Your agency has $200,000 for restoration projects for an area with SAV beds that have shown signs of eutrophication (algae densely growing on the plants). Based on question 7 (the ways humans can help save SAV), how would you spend this money?

Answer: Potential examples include testing the water quality for high nutrients, creating buffers to prevent the nutrients from entering the water, planting new SAV species, and educating people in the area about how to protect SAV

<u>Extension:</u>
Coastal development can have a large impact on SAV abundance. More runoff leads to more sediment entering the waterways and this can block sunlight needed for SAV to survive. Research one low impact development technique that could lower the amount of sediment that runs off into the sounds during storms.

For more information on SAV:

http://portal.ncdenr.org/c/document_library/get_file?uuid=ade99b7e-8380-46dc-b72a-54038b8bad9a&groupId=61563

References

Albemarle-Pamlico National Estuary Partnership 2012 Albemarle-Pamlico Ecosystem Assessment:
http://www.apnep.org/c/document_library/get_file?uuid=1c126d0c-2589-40c7-ac41-125f99ad0c70&groupId=61563

http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_stressor_response.aspx

http://www.chesapeakebay.net/indicators/indicator/bay_grass_abundance_baywide

EXTENT OF SUBMERGED AQUATIC VEGETATION

Dean Carpenter[24], **Jud Kenworthy**[25], **Don Field**[26]

Why Is the Extent of Submerged Aquatic Vegetation Important?

Underwater vascular plants are key components of aquatic ecosystems that play multiple roles in keeping Albemarle-Pamlico Estuarine System (APES) waters healthy by providing habitat, food, and shelter for aquatic life, absorbing and recycling nutrients and filtering sediment, and acting as a barometer of water quality (Thayer et al., 1984). More commonly called "submerged aquatic vegetation" (SAV) these plants enrich shallow aquatic environments around the world, providing sanctuaries for crabs and finfish, and sustenance for waterfowl (Bergstrom et al., 2006:2). SAV includes marine, estuarine, and riverine vascular plants that are rooted in sediment (Deaton et al., 2010:223) and is one of five types of aquatic plants in APES waters, the others being floating aquatic vegetation, emergent aquatic vegetation, micro- and macroalgae, and blue-greens (cyanobacteria) (Bergstrom et al., 2006:2). Because SAV are rooted in anaerobic sediments, they need to produce a large amount of oxygen to aerate the roots, and therefore have the highest light requirements of all aquatic plants (Deaton et al., 2010:223). SAV can become stressed by eutrophication and other environmental conditions which impair water transparency and/or diminish the oxygen content of water and sediments. The plant's response to these factors enables them to be sensitive bio-indicators of environmental health (Biber et al., 2004).

While more than 500 species of SAV inhabit the world's rivers, lakes, estuaries, and oceans (Bergstrom et al., 2006:2), APES and its tidal tributaries are home to about 14 common species (Deaton et al., 2010:222). High salinity (18-30 ppt) species in APES include the temperate species, eelgrass (*Zostera marina*) and tropical species, shoal grass (*Halodule wrightii*). Brackish (5-18 ppt) species include widgeongrass (*Ruppia maritima*) and the co-occurrence of these three species is unique to North Carolina (Deaton et al., 2010:223). Low salinity (0-5 ppt) species are diverse and include wild celery (*Vallisneria americana*), Eurasian milfoil (*Myriophyllum spicatum*), busy pondweed (*Najas guadalupensis*), redhead grass (*Potamogeton perfoliatus*), and sago pondweed (*Potamogeton pectinatus*) (Deaton et al., 2010:223, 227-228). Beds of SAV occur here in subtidal water generally < 2m deep, and occasionally intertidal areas of sheltered estuarine and riverine waters where there is unconsolidated substrate (loose sediment), adequate light reaching the bottom, and moderate to negligible current velocities or wave turbulence (Thayer et al., 1984; Ferguson and Wood, 1994 in Deaton et al., 2010:224). SAV coverage ranges from small isolated patches less than a meter in diameter to continuous meadows covering many acres.

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Because SAV distribution, abundance, and density varies seasonally and annually in response to climatic variability coupled with its sensitivity to other stressors, large-scale SAV changes may occur. The major threats to SAV habitat include channel dredging and water quality degradation from excessive nutrient and sediment loading, plus the emerging threat of accelerated sea level rise, barrier island stability, and increasing water temperatures (Deaton et al., 2010:270). The high value of this resource through its multiple ecosystem services makes it essential that we have the ability to detect any onset of dramatic declines or of positive responses from APNEP protection and restoration activities via regular monitoring of this indicator.

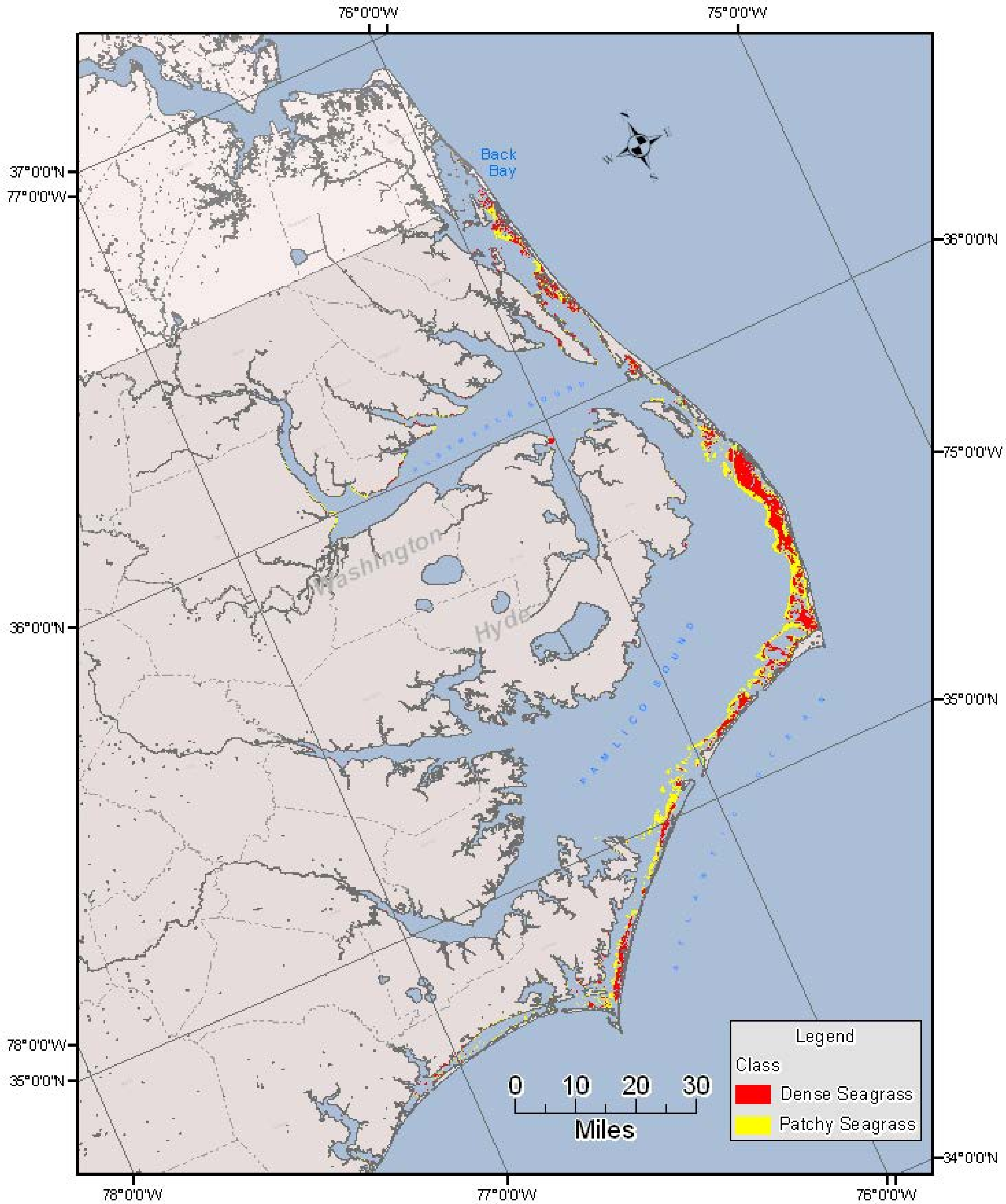

Figure 1. SAV location by density class in the APES, 2006-2008.

What Does This Indicator Report?

This indicator provides the extent and location of SAV by density class (dense, patchy, sparse to none) during the years 2006-2008.

What Do the Data Show?

The extent of visible SAV in the APES for the 2006-2008 sample period, excluding impounded beds, was 137,951 acres, or 99.6% of the total acreage visible SAV delineated from the APES coasts south to the South Carolina border (see Figure 1). The extent values by APES sub-region and density class is furnished in Table 1.

Table 1. Extent of visible SAV during 2006-2008 within APES reporting regions (acres).

	Chowan	Lower Neuse	Pamlico	White Oak	East Albemarle, Croatan Sound	Lower Roanoke	Pamlico Sound	South Coastal	West Albemarle	**TOTAL**
Dense	82	1,046	165	8,786	14,701	4	44,695	7	1,075	70,561
Patchy	598	1,909	52	10,572	9,789	92	42,511	53	1,814	67,390
TOTAL	680	2,955	217	19,358	24,490	97	87,206	60	2,890	137,951

Why Can't This Entire Indicator Be Reported at This Time?

Although aerial imagery enabled near-complete spatial coverage of the APES estuaries and lower tributaries within a relatively narrow time window (2006-2008), a substantial portion of SAV beds will remain invisible from remote sensing due to environmental factors above (e.g., haze), on (e.g., white-caps) and below (e.g., turbidity) the water's surface. The imagery also does not permit the discrimination of individual species coverage. To derive an extent estimate for this "invisible" portion, as well as species-specific information, will require monitoring from surface vessels using specialized equipment (e.g., underwater cameras, acoustics) or in situ with snorkel or SCUBA diving.

Understanding the Data

Based on interpretation and ground-truthing by NOAA of remotely-sensed imagery taken 1985-1990, the total area of visible SAV in APES was approximately 134,000 acres (Ferguson and Wood, 1994 in Street et al., 2005:259). Based on interpretation by NOAA of remotely-sensed imagery taken 1990-1992, the total area of SAV for seven of eight sub-regions in APES (all but Currituck) was approximately 115,000 acres (Ferguson and Wood, 1994:83-89). Surfaced-based mapping in western Pamlico Sound, Neuse River, and Tar/Pamlico River by North Carolina's Division of Marine Fisheries and Division of Water Quality have increased the total area of mapped SAV since to over 150,000 acres (Deaton et al., 2010:270).

It is not recommended that the data from 1985-1990 be compared directly to the 2006-2008 data in Table 1 because these two estimates were based on different technologies and protocols for data acquisition and interpretation. Furthermore there was a substantial fraction of SAV in North Carolina that was difficult to detect from aerial imagery: almost half (664 of 1,347 frames or 49.3 %) of the 2006-2008 imagery was located in the river systems on the western boundaries of the Albemarle –Pamlico systems. While some of the imagery in these areas was interpretable, some could only be partially interpreted or not interpreted at all. Data acquisition was limited by sea surface conditions and water quality. Some of the areas remotely sensed had either high surface reflectivity (poor sun angle and/or surface waves) or the water clarity was too poor for sufficient penetration to image the bottom features. These areas were located primarily along the western boundaries of Albemarle and Pamlico Sounds and in the riverine systems where it will be necessary to utilize ground based sampling to verify the presence of SAV and map their distribution. The eastern regions of Albemarle and Pamlico Sounds, Core Sound, Back Sound and Bogue Sound can all be reliably delineated and mapped using this remote sensing tool, but it will be necessary to verify species composition and deep edges of these seagrass beds with boat based survey protocols. The potential SAV habitat south of Bogue Sound has not been adequately sampled to verify the capability of the remotely sensed data to detect SAV and will require further investigation.