Understanding Changes in Seagrass Communities: Impacts from Local Environmental Factors

Grade Level: 7-12

Subject Area: Life Science, Biology, and Environmental Science

Virginia Standards of Learning: LS.1, LS.11, BIO.8

Objectives:
Students will:
- Describe basic seagrass biology, values of seagrass, and threats to seagrass
- Determine the interactions between water quality and seagrass
- Simulate an ecological research method
- Evaluate community change with actual trends in seagrass cover from the Chesapeake Bay

Summary:
Students will work in groups to determine what happened to seagrass communities during June and August in 2010 and 2011. Students will estimate percent cover visually at four locations along a mock transect and analyze trends in the data collected. Students will use water quality data to help understand the trends in seagrass cover.

Vocabulary: transect, quadrat, percent cover, rhizome, epiphytes, ecosystem services

Materials:
16 coated wire or plastic mesh squares (I used coated wire mesh with 1 inch by 1 inch squares, but this exact type of mesh is not necessary)
Green ribbon (to represent *Zostera marina*)
Green yarn (to represent *Ruppia maritima*)
Clear Tape
Masking Tape
Marker

Procedure:

Introduction

**Information to aid in the discussion points listed below is provided in the background information section. **

1) Ask students what they already know about submerged aquatic vegetation. Make a table on the board with the columns: basic information, ecosystem services, and threats to organize the information provided.

2) Provide a quick overview of seagrass biology, using the two seagrass species found in the Chesapeake Bay (*Zostera marina* and *Ruppia maritima*) as examples. Clarify the difference between seagrass and algae.

3) Discuss the value of seagrass ecosystems, the threats currently facing these ecosystems both globally and regionally, and current global trends in seagrass distribution.

4) Have students work in pairs to discuss the answer to the question: "What environmental variables control the distribution of seagrass?" Wait until after completing the exercise to discuss this question as a full group, because the answer should become clear as the lesson progresses.

5) Give a quick description of the research at CBNERR that this lesson is based on. Use maps and images to orient students to the location of the actual fixed transect that the data utilized in the mock transects comes from (See Appendix 1). Point out the differences between the actual and simplified methodology.

Set-up

1) Lay down mock seagrass patches in a grid according to the respective dates and distances from shore (Figure 1). Each table should also have a data sheet found in Appendix 2.

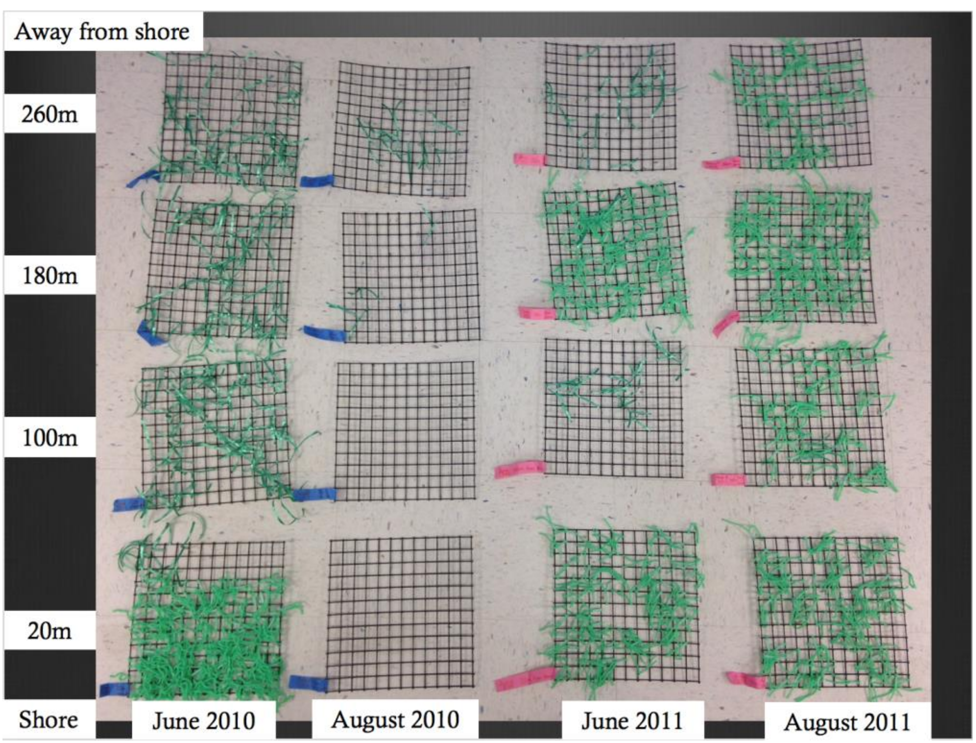

Figure 1: The mock seagrass patches laid out by location in space and time.

2) Compile the data the students collect into a comprehensive table (such as Figure 2) in a space viewable by everyone that allows for easy comparison of the percent cover of the two species at different points in time and distances from shore.

	Percent Cover at 20m from shore	Percent Cover at 100m from shore	Percent Cover at 180m from shore	Percent Cover at 260m from shore
June 2010	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:
August 2010	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:
June 2011	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:
August 2011	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:	Z: R: Overall:

Figure 2: Sample data table.

Activity

1) Divide students into four groups. Explain to the students that the four different transects are all the same fixed transect, but at four different time periods. Clarify that the distances from shore are provided since the seagrass patches cannot be laid apart as far as they would actually be due to space constraints.

2) Give students tips on how to most effectively visually estimate percent cover:

- Percent cover is usually less than you think.
- Suggest dividing the larger area into smaller areas, so that it is easier to focus (with the 1 inch by 1 inch wire mesh, look at squares that are 2 inches by 2 inches).
- Explain to students how they can count squares of dense coverage and total squares and use this fraction to help in estimation of percent cover.
- The PowerPoint designed to accompany this lesson plan has slides with grids with green and white squares designed for practicing estimation of percent cover.

3) As the students work through the steps, check-in with each group to see if the percent coverage data is roughly similar to what it was designed to be (See table in Appendix 3).

4) Have students add their group's data to the larger table on the board. Discuss the trends in the percent cover data they have just collected:

- The June 2010 data reflects a standard zonation pattern when *Z. marina* is present in high densities. *R. maritima* dominates close to shore and *Z. marina* dominates farther away from shore.
- There is a major loss of seagrass from June to August of 2010.
- *Z. marina* remains in the region in 2011, but at greatly reduced percent cover.
- In 2011, *R. maritima* colonizes the space previously occupied by *Z. marina* in June 2010 and recolonizes inshore space that it had disappeared from in August of 2011.

5) Show the students the figure from the Moore et al., 2014 paper that the mock transects they just observed were based on (Appendix 4). Do the distances from shore chosen make sense in the context of the full figure?

6) At this point, teachers with a shorter class period may want to proceed directly to discussion. In this version of the lesson plan, the teacher provides the water quality changes responsible for the major die-off as opposed to providing the students with temperature and turbidity graphs. For a shortened version, skip activity steps 7-8 and go to step 9. For the complete version, continue onto steps 7 and 8, and skip step 9.

7) Have the students split into pairs and give each pair the temperature and turbidity data (See Appendix 5). Ask the students to look for trends in the water quality data, which could explain the major loss of *Z. marina* in 2010. Explain to the students that they have been given 2009 in addition to 2010 and 2011, so that 2009 can serve as further evidence of what normal conditions might be. Remind them that finding no trend is still an important result in the scientific process.

8) Come together as a group and discuss the trends found and their potential significance for the survival of seagrass:

- There are no major trends in turbidity that should have an influence on a long enough time scale to make a difference in the big picture trends we are seeing.
    - Students may focus on short terms peaks in water clarity, but these shifts are on a different scale than our shifts in seagrass communities.
    - Elevated turbidity is found to influence seagrass communities in the Chesapeake Bay if it remains elevated for around 20 days or more (Moore et al., 1997). This did not occur in a time period that would explain the die-off.
    - Ask the students: why would an increase in turbidity affect seagrass?
        - Less light is able to reach the seagrass, which affects the plant's ability to photosynthesize.

- The primary trend students should notice in the temperature data is the hotter temperatures in June of 2010 than in June of 2009 or 2011.
    - Daily mean water temperatures increased from 25 to 30 degrees Celsius over two weeks (Moore et al., 2014).
    - Ask the students: why might temperature have an effect on seagrass?
        - Increased temperatures lead to increased respiration rates for the plant, which means an increase in the need for photosynthesis and thus a higher light requirement (Moore et al., 1997).
- In general, the influences of high temperatures and high turbidity can have a compound negative effect (Moore et al., 2012), but for the purposes of this time period temperature is the more important variable.

9) For shortened version without the water quality data: Have students get into small groups and reflect on their initial response to the question of what environmental variables influence the distribution of seagrass. Have each group determine one environmental variable that they believe is primarily responsible for the die-off of eelgrass. The variable responsible for the major die-off is temperature.

- Increased temperatures lead to increased respiration rates for the plant, which means an increase in the need for photosynthesis and thus a higher light requirement (Moore et al., 1997).

Wrap up

Possible wrap up discussion questions:

1) Why was widgeon grass able to colonize the substrate after the eelgrass had died off?
- *Widgeon grass can tolerate higher temperatures than eelgrass.*

2) In the typical zonation pattern present in the Chesapeake Bay, widgeon grass dominates the near shore waters. If widgeon grass was artificially excluded, do you think eelgrass could grow there?
- *Even though no one has attempted this experiment, because it would be practically difficult to exclude one seagrass species and not the other, we can assume that eelgrass would most likely still not be able to grow there because the shallows are warmer.*

3) Within its Chesapeake Bay range, do you think eelgrass has been disappearing equally from all regions or more in its upriver sections or more in its downriver sections?
- *The eelgrass has been disappearing more in the upper river due to decreased water clarity in upriver regions (Moore et al., 1997).*

4) Do you think, based on the physical shape of the seagrasses, that one might be more valuable as a habitat?

- *Without experimental backing, we can assume from the morphology of the two plants that eelgrass provides more shelter for animals that live in seagrass meadows than widgeon grass. Also, eelgrass blades provide more surface area for epiphytes.*

Extension:
Rising temperatures are a result of anthropogenic climate change. Since the Chesapeake Bay is currently the southernmost location of eelgrass along the East coast of the U.S, it could potentially be lost from the Bay as temperatures continue to rise. Activities dealing with global climate change and increases in ocean temperatures would be a good follow up to this activity.

<u>Background Information:</u>

Submerged aquatic vegetation (SAV) refers to angiosperm species that live underwater with a rhizome, a root-like system, buried in the sand. SAV species are often confused with algae, but algae have more primitive characteristics such as a lack of veins to carry molecules around the plant. Seagrass refers more specifically to SAV species that are found in marine or higher salinity brackish waters. Despite the word “grass” in seagrass, seagrass is more closely related to gingers and terrestrial lilies than terrestrial grasses (McKenzie and Campbell, 2002). SAV species lack the waxy cuticle that keeps land plants from drying out. SAV blades contain specialized cells that retain gases and allow the blades to float up in the water column (“Submerged Aquatic Vegetation”). SAV species can reproduce both sexually and asexually. In asexual reproduction, the rhizome spreads along under the sand and new genetically identical shoots sprout upwards. In sexual reproduction, the SAV plants produce reproductive shoots with flowers (Eriksson, 1989).

SAV is limited to water shallow enough to allow for adequate light absorption (“Submerged Aquatic Vegetation”). Epiphytes, such as algae and sponges, grow on the blades of seagrass. Algal epiphytes are normally kept in balance with the actions of grazers and predators, but in high nutrient conditions, they can seriously reduce the amount of seagrass surface area available for light absorption (Duarte et al., 2006).

Seagrass ecosystems are incredibly valuable in estuaries such as the Chesapeake Bay. Some key ecosystem services of seagrass include enhancing regional biodiversity, sequestering and exporting carbon, stabilizing sediment, mitigating the effects of eutrophication, absorbing wave energy, and serving as a nursery or food source for important fauna (Orth et al., 2006). Seagrass meadows are currently declining around the world due to both direct and indirect anthropogenic threats (Short et al., 2011). Examples of threats are high levels of nutrient and sediment run-off, elevated water temperatures, dredging and other detrimental fishing practices, and boat traffic (Orth et al., 2006). These valuable ecosystems are especially susceptible to reduced water clarity because of their high light requirements (Dennison et al., 1993). Understanding patterns of seagrass community change could help in analyzing the overall health of the saline portions of the Chesapeake Bay.

The two species of seagrass found in the brackish waters of the far downstream York River, a major tributary of the Chesapeake Bay in Virginia, are *Zostera marina* (eelgrass) and *Ruppia maritima* (widgeon grass) (Moore et al., 2014). The Chesapeake Bay is the southernmost limit of eelgrass distribution, as the species thrives in cool water and cannot survive temperatures above 25 degrees Celsius for extended periods of time ("Submerged Aquatic Vegetation").

Scientists at the Chesapeake Bay National Estuarine Research Reserve, led by Dr. Kenneth A. Moore, have been monitoring seagrass communities along fixed transects around Goodwin Island and along the shore by the Virginia Institute of Marine Science from 2004 to the present (Moore et al., 2014). The data used in the exercise is from a 700 meter fixed transect branching out from Goodwin Island. Monitoring methods include taking the water depth every 10 meters. Every 20 meters, percent cover of eelgrass and widgeon grass are estimated visually. Then, a quadrat is thrown three times randomly and with each throw, the scientists estimate percent cover of each species within the quadrat. A plastic circle is also placed around the densest patch of eelgrass and the number of shoots within the circle is counted, and this number will allow for an estimation of density. The longest eelgrass strand within the quadrat is also recorded. This methodology was simplified for this lesson plan.

References:

Dennison, William C., Robert J. Orth, Kenneth A. Moore, J. Court Stevenson, Virginia Carter, Stan Kollar, Peter W. Bergstrom, and Richard A. Batiuk. "Assessing Water Quality with Submersed Aquatic Vegetation." *BioScience* 43.2 (1993): 86-94.

Duarte, Carlos M., Anthony WD Larkum, and Robert Joseph Orth, eds. *Seagrasses: Biology, Ecology and Conservation*. Springer, 2006.

Eriksson, Ove. "Seedling Dynamics and Life Histories in Clonal Plants." *Oikos* 55.2 (1989): 231-38.

McKenzie, L.J. & Campbell, S.J. "Seagrass – Watch: Manual for Community (citizen) Monitoring of Seagrass Habitat. Western Pacific Edition" Queensland Northern Fisheries Centre, Cairns, Australia (2002): 43pp.

Moore, Kenneth A., Erin C. Shields, and David B. Parrish. "Impacts of Varying Estuarine Temperature and Light Conditions on Zostera Marina (Eelgrass) and Its Interactions With Ruppia Maritima (Widgeongrass)." *Estuaries and Coasts* 37.S1 (2013): 20-30.

Moore, Kenneth A., Erin C. Shields, David B. Parrish, and Robert J. Orth. "Eelgrass Survival in Two Contrasting Systems: Role of Turbidity and Summer Water Temperatures." *Marine Ecology Progress Series* 448 (2012): 247-58.

Moore, Kenneth A., Richard L. Wetzel, and Robert J. Orth. "Seasonal Pulses of Turbidity and Their Relations to Eelgrass (Zostera Marina L.) Survival in an Estuary." *Journal of Experimental Marine Biology and Ecology* 215.1 (1997): 115-34.

Orth, Robert J., Tim J. B. Carruthers, William C. Dennison, Carlos M. Duarte, James W. Fourqurean, Kenneth L. Heck, A. Randall Hughes, Gary A. Kendrick, W. Judson Kenworthy, Suzanne Olyarnik, Frederick T. Short, Michelle Waycott, and Susan L. Williams. "A Global Crisis for Seagrass Ecosystems." *BioScience* 56.12 (2006): 987-96.

Short, Frederick T., Beth Polidoro, Suzanne R. Livingstone, Kent E. Carpenter, Salomão Bandeira, Japar Sidik Bujang, Hilconida P. Calumpong, Tim J. B. Carruthers, Robert G. Coles, William C. Dennison, Paul L. A. Erftemeijer, Miguel D. Fortes, Aaren S. Freeman, T.g. Jagtap, Abu Hena M. Kamal, Gary A. Kendrick, W. Judson Kenworthy, Yayu A. La Nafie, Ichwan M. Nasution, Robert J. Orth, Anchana Prathep, Jonnell C. Sanciangco, Brigitta Van Tussenbroek, Sheila G. Vergara, Michelle Waycott, and Joseph C. Zieman. "Extinction Risk Assessment of the World’s Seagrass Species." Biological Conservation 144.7 (2011): 1961-971.

"Submerged Aquatic Vegetation." *Chesapeake Bay Office*. NOAA, n.d. Web. 05 July 2016.

Appendix 1: Moore et al., 2014 figures

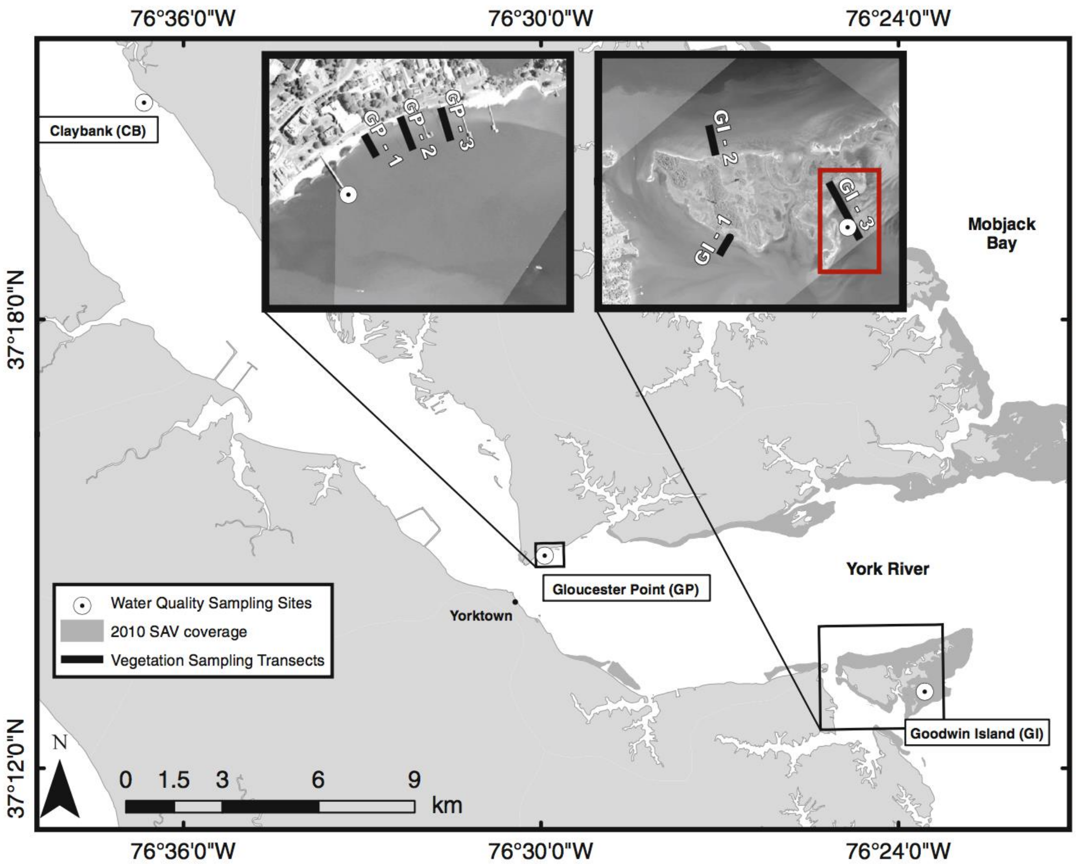

Figure 3: Map of the location of the fixed transects in the Moore et al., 2014 paper. The red box was placed around the specific transect that we are mimicking.

Appendix 2: Data Sheets

Group 1: 20 meters from shore

Group Members: ____

You are a team of marine scientists surveying seagrass along a fixed transect off of Goodwin Island in the York River, VA.

Repeat steps 1-3 at all four locations in space and time that are found in your data table below.

1) Visually estimate the percent cover of the *Zostera marina* (ribbon).

2) Visually estimate the percent cover of the *Ruppia maritima* (yarn).

3) Combine these numbers to get overall percent cover of seagrass.

4) Once you have completed steps 1-3 at all four sites, add the data you have just collected to the larger table on the board and wait for the other research groups to finish.

	Z. marina percent cover	*R. maritima* percent cover	Overall percent cover
June 2010 at 20 m from shore			
August 2010 at 20 m from shore			
June 2011 at 20 m from shore			
August 2011 at 20 m from shore			

Group 2: 100 meters from shore

Group Members: ____

You are a team of marine scientists surveying seagrass along a fixed transect off of Goodwin Island in the York River, VA.

Repeat steps 1-3 at all four locations in space and time that are found in your data table below.

1) Visually estimate the percent cover of the *Zostera marina* (ribbon).

2) Visually estimate the percent cover of the *Ruppia maritima* (yarn).

3) Combine these numbers to get overall percent cover of seagrass.

4) Once you have completed steps 1-3 at all four sites, add the data you have just collected to the larger table on the board and wait for the other research groups to finish.

	Z. marina percent cover	*R. maritima* percent cover	Overall percent cover
June 2010 at 100 m from shore			
August 2010 at 100 m from shore			
June 2011 at 100 m from shore			
August 2011 at 100 m from shore			

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Group 3: 180 meters from shore

Group Members: ____

You are a team of marine scientists surveying seagrass along a fixed transect off of Goodwin Island in the York River, VA.

Repeat steps 1-3 at all four locations in space and time that are found in your data table below.

1) Visually estimate the percent cover of the *Zostera marina* (ribbon).

2) Visually estimate the percent cover of the *Ruppia maritima* (yarn).

3) Combine these numbers to get overall percent cover of seagrass.

4) Once you have completed steps 1-3 at all four sites, add the data you have just collected to the larger table on the board and wait for the other research groups to finish.

	Z. marina percent cover	*R. maritima* percent cover	Overall percent cover
June 2010 at 180 m from shore			
August 2010 at 180 m from shore			
June 2011 at 180 m from shore			
August 2011 at 180 m from shore			

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Group 4: 260 meters from shore

Group Members: ____

You are a team of marine scientists surveying seagrass along a fixed transect off of Goodwin Island in the York River, VA.

Repeat steps 1-3 at all four locations in space and time that are found in your data table below.

1) Visually estimate the percent cover of the *Zostera marina* (ribbon).

2) Visually estimate the percent cover of the *Ruppia maritima* (yarn).

3) Combine these numbers to get overall percent cover of seagrass.

4) Once you have completed steps 1-3 at all four sites, add the data you have just collected to the larger table on the board and wait for the other research groups to finish.

	Z. marina percent cover	*R. maritima* percent cover	Overall percent cover
June 2010 at 260 m from shore			
August 2010 at 260 m from shore			
June 2011 at 260 m from shore			
August 2011 at 260 m from shore			

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Appendix 3: Seagrass Squares Set-up

The concept below can be adapted to work with seagrass data from any estuary, so it is possible to recreate this lesson with a more locally-relevant example.

1) Cut wire or plastic mesh into 16 squares of about a foot by a foot in size. Exact size is not important as long as you adjust the amount of ribbon and yarn you are using to create the correct percent covers. If using wire mesh, one may want to use rubber cement to cover up any sharp bits created in the cutting process.

2) Use the data in the table below when setting up the seagrass on the 16 mesh squares. For each month and year combination, there will be four squares representing samples taken at 4 different distances from shore.

- Use tape and a marker to create a label, which includes the month, year, and distance from shore of the seagrass patches.

- Tie ribbon (*Z. marina*) and yarn (*R. maritima*) of varying lengths to the mesh to reach the percent covers of *Z. marina* and *R. maritima* listed in the table below. I used clear tape around the bases of the tied ribbons and yarn. The knot should be placed in the middle of the ribbon or yarn so that it more accurately mimics multiple blades coming out of the same shoot. The same species should generally be found close together on the mesh as multiple shoots will branch out of the same rhizome.

Pictures of examples of finished products are shown on the following page.

	Percent Cover at 20m from shore	Percent Cover at 100m from shore	Percent Cover at 180m from shore	Percent Cover at 260m from shore
June, 2010	*Z. marina*: 5 *R. maritima*: 75	*Z. marina*: 50 *R. maritima*: 0	*Z. marina*: 50 *R. maritima*: 0	*Z. marina*: 40 *R. maritima*: 0
August, 2010	*Z. marina*: 0 *R. maritima*: 0	*Z. marina*: 0 *R. maritima*: 0	*Z. marina*: 2 *R. maritima*: 0	*Z. marina*: 5 *R. maritima*: 0
June, 2011	*Z. marina*: 0 *R. maritima*: 70	*Z. marina*: 10 *R. maritima*: 0	*Z. marina*: 2 *R. maritima*: 70	*Z. marina*: 15 *R. maritima*: 0
August, 2011	*Z. marina*: 0 *R. maritima*: 75	*Z. marina*: 2 *R. maritima*: 40	*Z. marina*: 0 *R. maritima*: 80	*Z. marina*: 2 *R. maritima*: 35

Example of August 2010 (260 meters from shore and 5% cover of eelgrass)

Example of June 2011 (180 meters from shore, 2% cover of eelgrass, and 70% cover of widgeon grass)

Appendix 4: Moore et al., 2014 Data used to create the seagrass squares

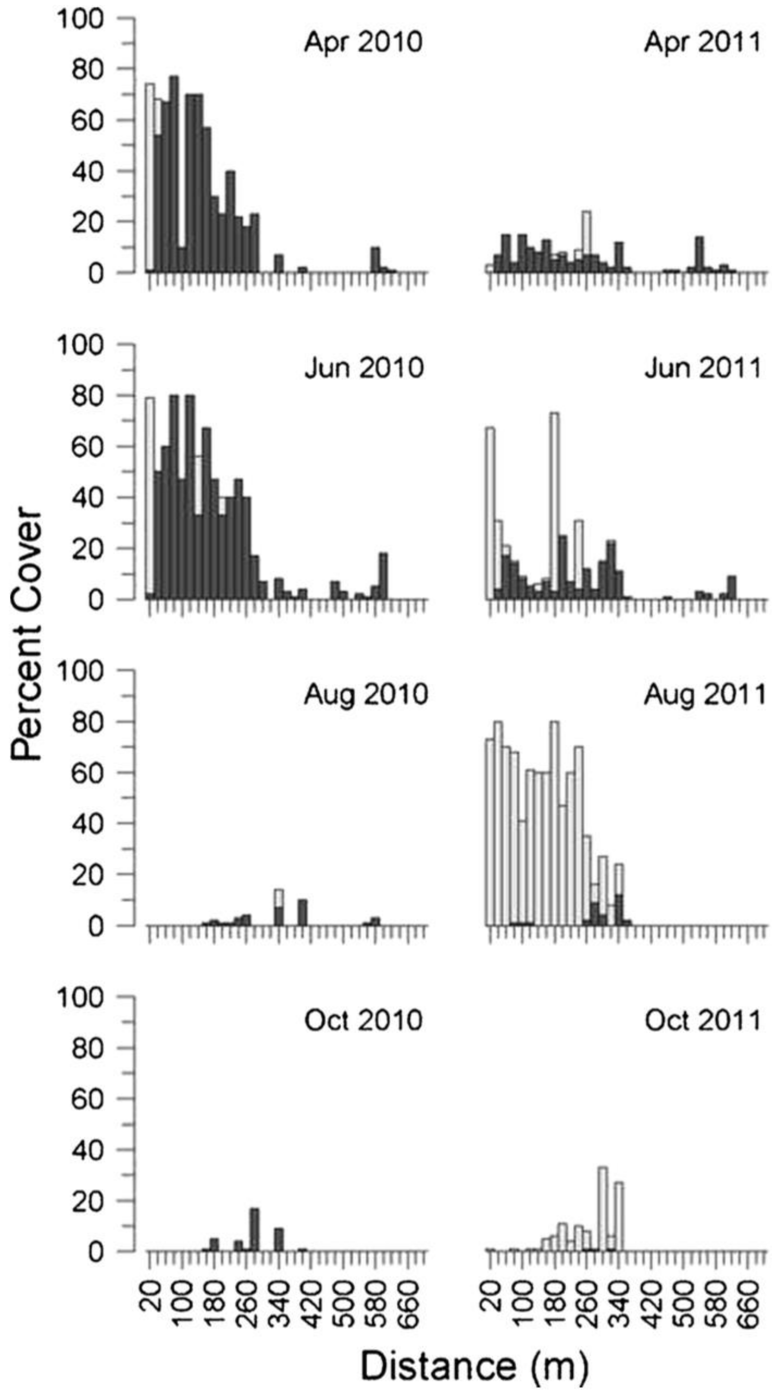
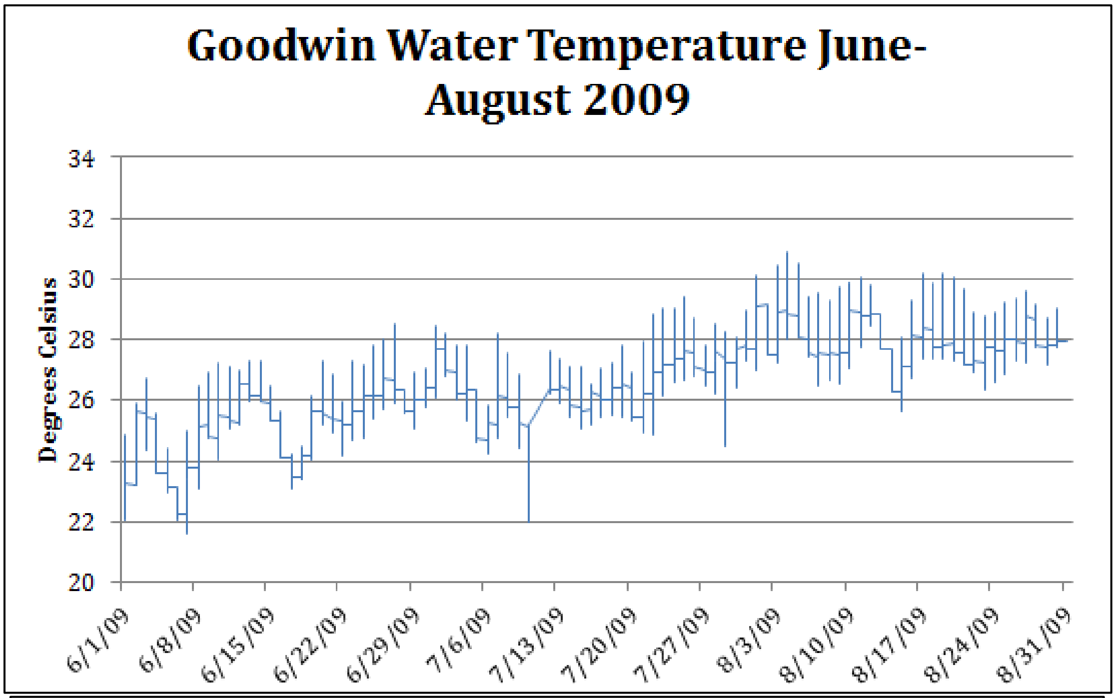
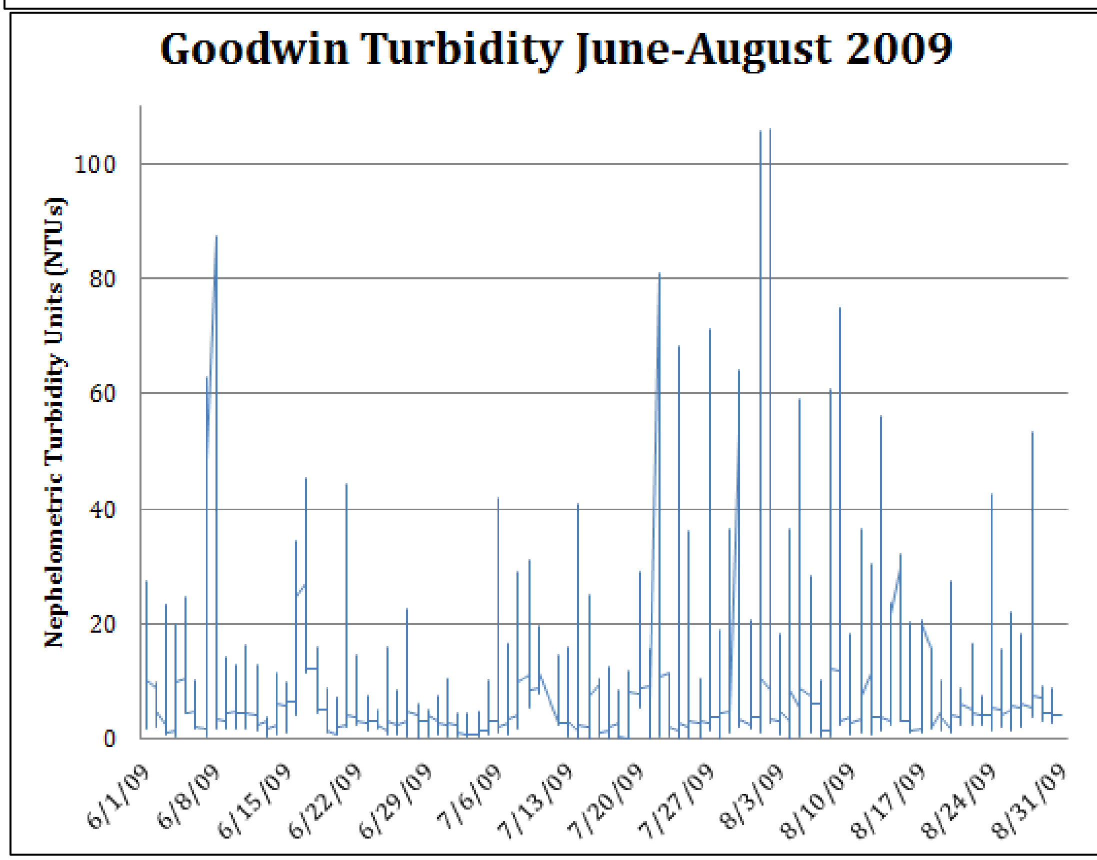


Fig. 4 Vegetative cover of *Z. marina* (*black bars*) and *R. maritima* (*gray bars*) at every distance sampled along the GI-3 transect; 2010 (*left panel*) and 2011 (*right panel*) are represented. The months included are April (**a**, **b**), June (**c**, **d**), August (**e**, **f**), and October (**g**, **h**)

Appendix 5: Water Quality Data

2009 Data





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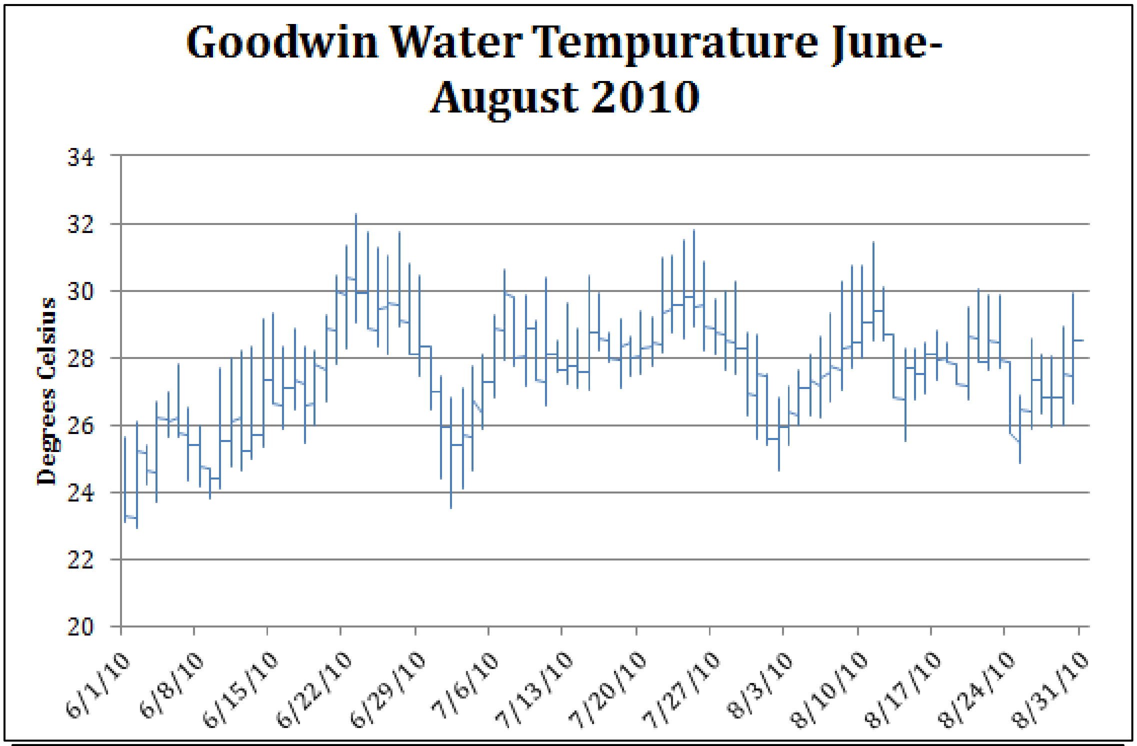
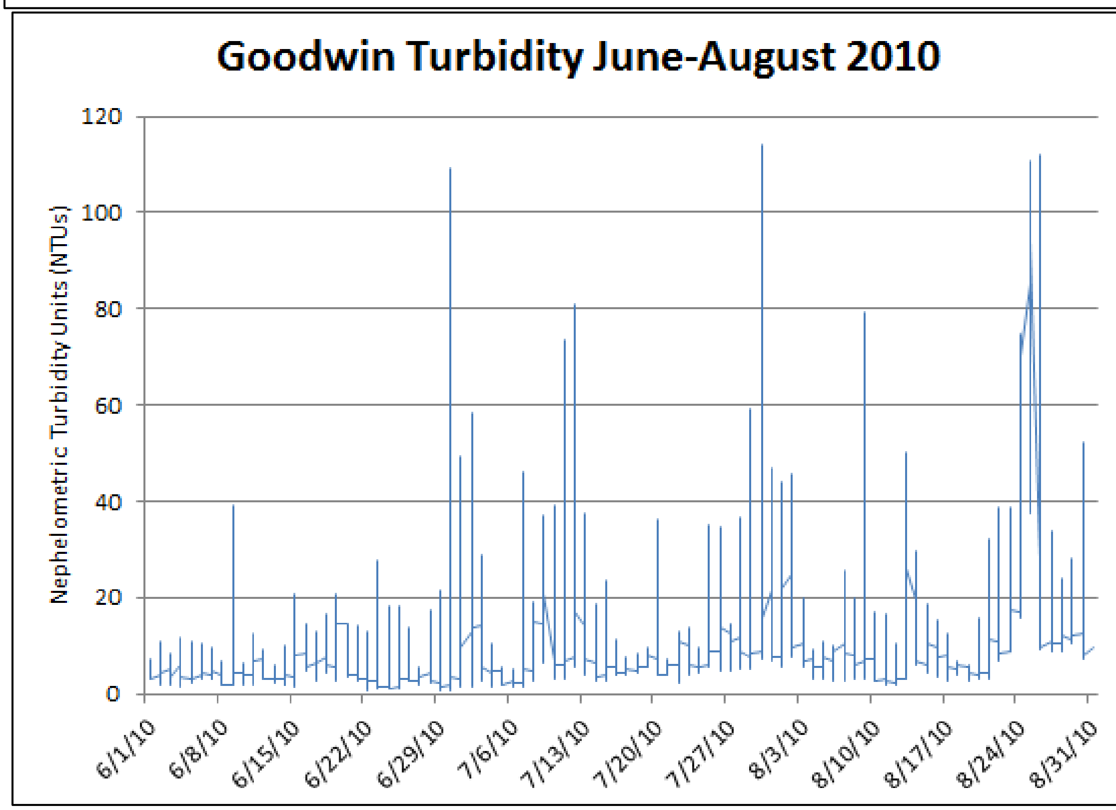
2010 Data





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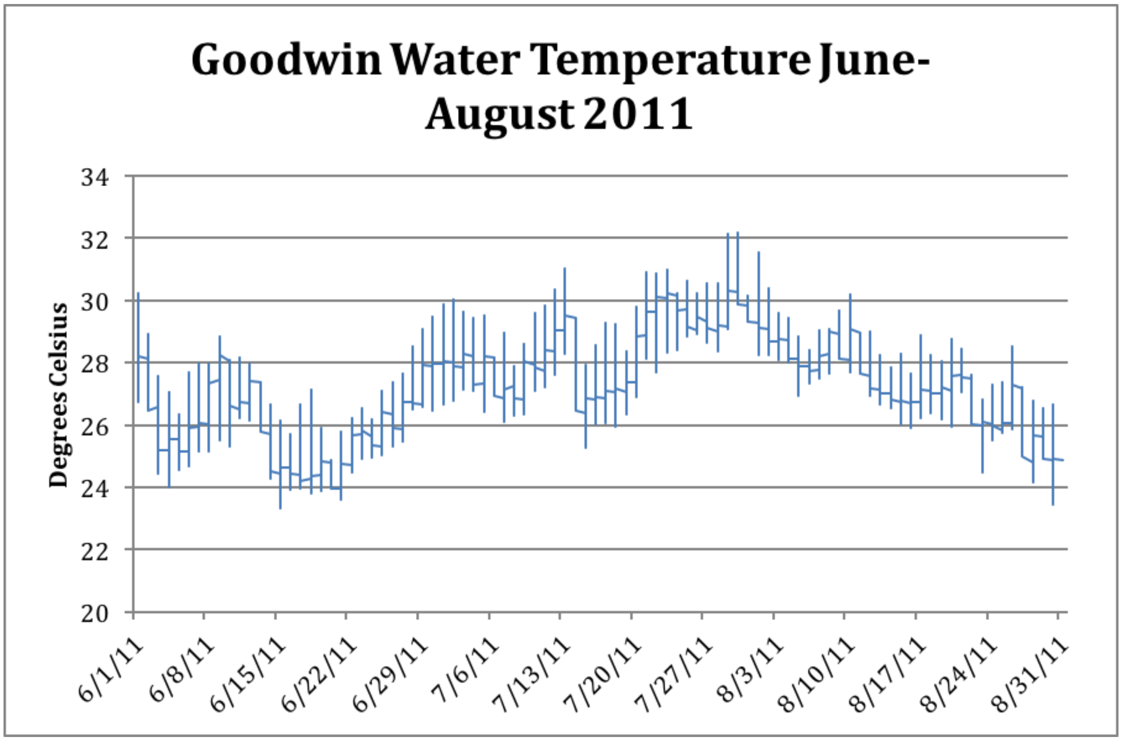
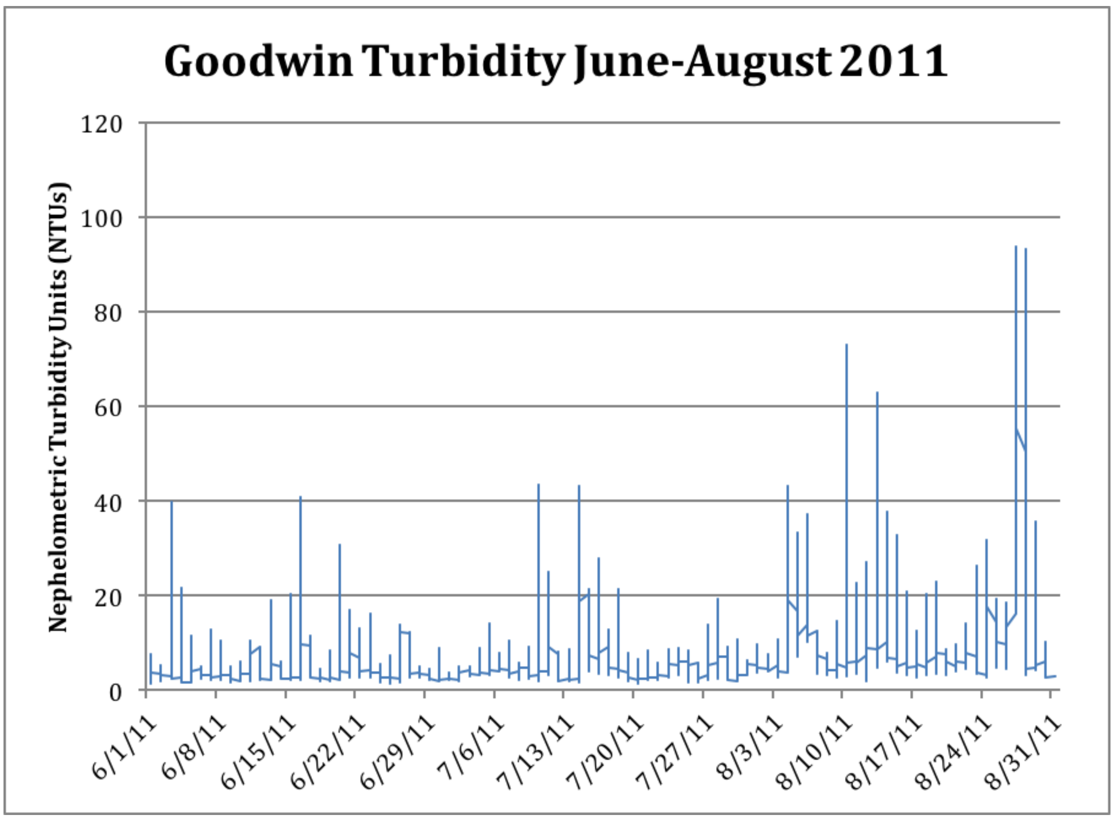
2011 Data





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