Zooplankton Migration Patterns at Scotton Landing: Behavioral Adaptations

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Summary: Zooplankton have evolved specific migration patterns that increase their chances of survival. These migrations patterns are behavioral adaptations and they are unique to each species of zooplankton in the Delaware Bay. Students will determine how zooplankton from the St. Jones River migrate and how these adaptations increase their chances of survival. Students will also explore Simpson's diversity index.

Activity Use: This activity can be used as a part of any unit on biology, evolution, adaptations, ecology, diversity, and more.

Target Grade Level: High School

Standards Addressed:
LS1.A: Structure and Function
LS1.B: Growth and Development of Organisms
LS1.C: Organization for Matter and Energy Flow in Organism
LS1.D: Information Processing
LS2.A: Interdependent Relationships in Ecosystems
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience
LS2.D: Interactions and Group Behavior

Lesson Time: Two 45 minute periods

Essential Question: How do the behavioral adaptations of zooplankton, specifically their migration patterns, increase their chances of survival?

SMART Objectives:
After completing this activity, students will be able to:

1. Name two zooplankton species in the Delaware Bay.
2. Describe two different migration patterns that zooplankton use.
3. Explain how behavioral adaptations of zooplankton increase their chances of survival.
4. Describe and interpret data from a diversity index.

Vocabulary/Key Terms: Behavioral Adaptation, Diel Vertical Migration, Tidal Migration, *Acartia tonsa*, *Rhithropanopeus harrisii*, Estuary, Holoplankton, Meroplankton, Diversity

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Introduction: Teacher Reading Material

Where is Scotton Landing?

- Scotton Landing is located along the St. Jones River near Dover, Delaware. The St. Jones River flows into the Delaware Bay. This area is an estuary. An estuary is a body of water where salt water from the ocean meets freshwater from a river. Estuaries are physically and biologically protected regions that are nursery habitats for many local species. Refer to the map provided.
  Learn more about estuaries here: http://oceanservice.noaa.gov/facts/estuary.html

- Scotton Landing experiences mixed semidiurnal tides. Tides are the daily rising and falling of the water level caused by the gravitational pull of the moon and the sun. A mixed-semidiurnal tide means that everyday there are two high tides and two low tides. However, the two high tides are different heights and the two low tides are different heights.
  Learn more about tides here:
  http://oceanservice.noaa.gov/education/tutorial_tides/tides01_intro.html
  Learn more about mixed semidiurnal tides here:
  http://oceanservice.noaa.gov/education/tutorial_tides/tides07_cycles.html

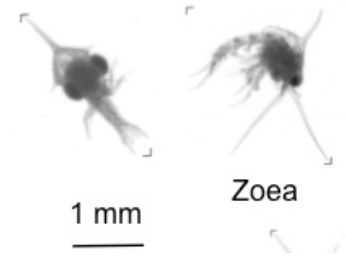
- Graphing Tidal Data: Students will be asked to graph the water level, or tides, at Scotton Landing. Water level data is determined relative to a fixed point, and values can be either positive or negative.
  Learn more about measuring water level here:
  https://tidesandcurrents.noaa.gov/datum_options.html

What are Zooplankton?

- Zooplankton are organisms that live in the water column and drift with the currents. Organisms that are zooplankton are called zooplankters. They feed on smaller phytoplankton, which photosynthesize in the surface water to create their own food. Phytoplankton must remain in the surface water where sunlight can penetrate to photosynthesize. Zooplankton migrate to the surface to feed on phytoplankton. Zooplankton are also an important food source for many local species, such as fish, that use eyes and vision to find food. Therefore, zooplankton must migrate to the surface water to feed while avoiding predation.

- Two common types of zooplankton sampled at Scotton Landing on the St. Jones River are copepods and crab larvae. Both are crustaceans. Copepods have large antennae and an exoskeleton. *Acartia tonsa* is the most abundant copepod found at Scotton Landing. Crab larvae, including white-fingered mud crab larvae (*Rhithropanopeus harrisii)*, are also common zooplankters found at Scotton Landing. *Rhithropanopeus harrisii* is a **meroplankton**: it spends only part of its life cycle as a zooplankter. *Rhithropanopeus harrisii* eggs hatch into small larvae (zoea) that live in the water column as zooplankton. The larvae will then develop into full sized mud crabs which live on the bottom of estuaries. However, the copepod *Acartia tonsa* is a **holoplankton**: it remains a zooplankter for its whole life cycle. Both *Acartia tonsa* and *Rhithropanopeus harrisii* larvae are only about the size of a grain of rice!
  Read more about crab larvae here: https://www.underthescope.udel.edu/who-am-i/large-shrimp-zooplankton
  Read more about copepods here: https://www.underthescope.udel.edu/who-am-i/small-shrimp-zooplankton

Copepod
Acartia tonsa



White-Fingered Mud Crab
Rhithropanopeus harrisii

What are Behavioral Adaptations?

- Behavioral adaptations are actions that organisms perform to increase their chances of survival. Behavioral adaptations include migration and hibernation. For example, bears hibernate in the winter to escape the cold and conserve energy when food is scarce; this behavioral adaptation increases their chances of survival. Zooplankton migrations are examples of **behavioral adaptations** that increase survival. Two types of zooplankton migrations are **diel vertical migration** and **tidal migration**.

- **Diel vertical migrators** move up and down in the water column at specific times of the day. They are deep in the water column during the day and migrate to the surface water at night. At night, vertical migrators swim to the surface of the water to feed on phytoplankton while it is dark and they cannot be seen by predators. During the daytime, the sun penetrates the water column, and prey becomes visible to predators. During the day, vertical migrators sink deeper in the water, where it is darker, so predators like fish cannot see them. Vertical migration is an example of a behavioral adaptation. By migrating and hiding from predators, diel vertical migrators have a greater chance of survival. *Acartia tonsa*, one of the most common zooplankton species at Scotton Landing, is a diel vertical migrator.

- Another behavioral adaptation is called tidal migration. **Tidal migrators** migrate to the surface water on incoming tides to maintain their position in the estuary. On incoming tides, when the water level is rising, the surface currents are being pushed upstream into the estuary. Tidal migrators drift with these currents and are pushed further into the protected estuary instead of being swept out into the ocean. This migration pattern allows zooplankton to remain protected in the estuary which increases their chances of survival. *Rhithropanopeus harrisii* is an example of a tidal migrator.

Diversity

- Diversity can describe the variation in a community and how many different species are present. Diversity is commonly measured using several diversity indices.

- **Simpson's Index (D)** is one of these indices used to describe the diversity of a community based on the number of species present and their abundance. The Simpson's Diversity Index considers:
  - The number of different species present
    - More species present indicates higher diversity.
  - The abundance of each species
    - If all species are found in relatively similar abundance, there will be higher diversity.
    - If one species dominates, and the other species have relatively low abundance, the community is less diverse.

- To make data more intuitive, Inverse Simpson's Index is used to present data. Inverse Simpson's is used in Section III of the student handout. Inverse Simpson Index is simply 1/D. Higher values indicate high diversity while lower values indicate lower diversity.

  - Inverse Simpson's Index (D_i) is calculated using the following equation:
    - p_i is the proportion of species *i*
    - *S* is the number of species

$$D_i = \frac{1}{\sum_{i=1}^{S} {p_i}^2}$$

  - Read more about Simpson's diversity index and other diversity indices here: https://docs.lib.noaa.gov/noaa_documents/time_capsules/2007/disc_1/NOAA's_200th_Celebration/Education/Celebrating%20Education%20at%20NOAA%20Formal%20Education/features/oceans_coasts/Sea_Grant/Biofilm/biofilm/diverse.htm

Learning Activity:
A student worksheet is provided with three sections (I, II, and III).
There are two versions of the student handout (A and B). Sections II and III are the same in both versions. Section I is more complex in Version A and is simplified in Version B. Students will be introduced to zooplankton and behavioral adaptations on the first page of their handout.
In research funded by the Delaware National Estuarine Research Reserve in 2016, scientists at the University of Delaware sampled water from the St. Jones River at Scotton Landing to determine the number of species and abundance of zooplankton present. In the activity, we will use water samples taken during that study.

Section I:
In Section I, students will graph zooplankton abundance data and observe zooplankton migration patterns. Water samples were taken from Scotton Landing and the number of zooplankton in each sample was determined. Data from section I was sampled at Scotton Landing between August 31st and September 1st, 2016. There are two versions (A and B) of

Section I, depending on the time available to complete the activity. Version A is more complex. Students will graph water level data and two species' abundance data on a single graph. In Version B, water level data is already graphed, zooplankton abundance values are rounded, and students will plot zooplankton abundance on two separate graphs.

Section II:

In Section II, students will be given tidal data and light data on a graph. On the graph, they will then predict zooplankton abundance based on the information provided. Data from Section II was obtained between September 7th and 8th, 2016 at Scotton Landing.

Section III

In Section III, students will learn about Simpson's diversity index. The diversity of each water sample discussed in Sections I and II was calculated using the Inverse Simpson's Index. Each water sample from Scotton Landing contained a variety of zooplankton species including *Acartia tonsa* and *Rhithropanopeus harrisii*. Based on the zooplankton species present and their abundance, the diversity of the zooplankton community was calculated. Students will analyze the graphs and respond to questions.

Solutions to Student Handouts (A and B):

Answers to Section I: Zooplankton Migration Patterns

Instructions provided for Section 1:

- In research funded by the Delaware National Estuarine Research Reserve in 2016, scientists at the University of Delaware sampled water from the St. Jones River at Scotton Landing to determine the number of species and abundance of zooplankton present. In the activity, we will use water samples taken over the course of one day during that study. Every three hours, water samples were taken from the surface of the St. Jones River at Scotton Landing. The amount of water collected in each water sample is one cubic meter: enough water to fill two large bathtubs. The total number of *Acartia tonsa* and *Rhithropanopeus harrisii* larvae in each water sample was counted. Using your knowledge of the migration patterns of *Acartia tonsa* and *Rhithropanopeus harrisii*, graph the data below to determine which zooplankton is Species 1 and which is Species 2. Plot solid circles for Species 1 and open circles for Species 2. You may connect the points of each individual species to view the overall trend. Sample Number 1 for both species has been plotted for you.

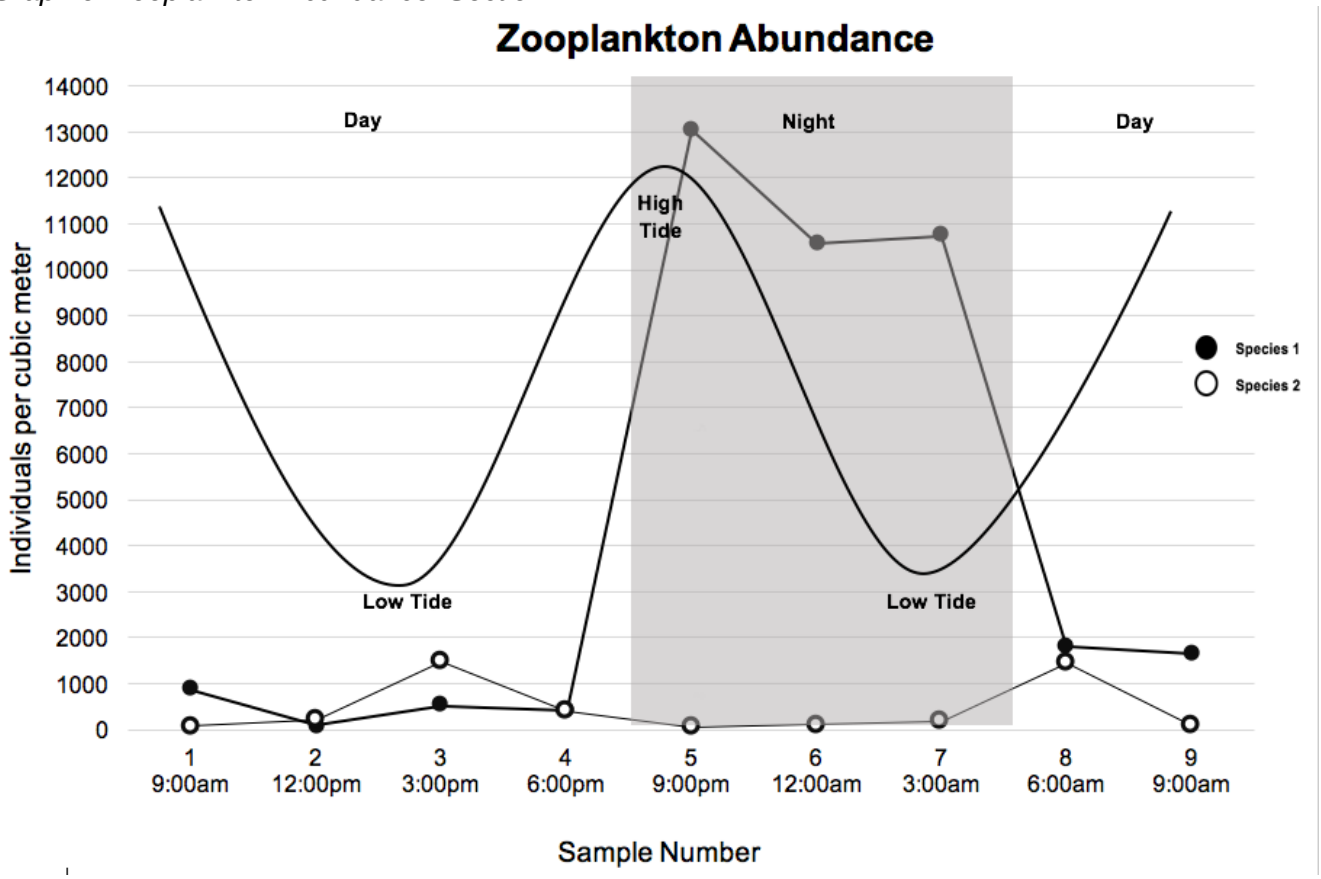
Instructions also included in Version A only:

- Begin by plotting the water level data using the y-axis on the right.
    - Water level data is determined relative to a fixed point, and values can be either positive or negative.
- Now plot the abundance of species 1 and species 2 using the y-axis on the left.
    - Plot solid circles for species 1 and open circles for species 2. You may connect the points of each individual species to view the overall trend.

Data provided for Section 1A Graph:

Sample Number	Time of Sample	Water Level (m)	Abundance of Species 1 (per cubic meter)	Abundance of Species 2 (per cubic meter)
1	9:00am	0.7 (High Tide)	872	75
2	12:00pm	0.1	92	225
3	3:00pm	-0.5 (Low Tide)	528	1,476
4	6:00pm	0.3	426	406
5	9:00pm	0.8 (High Tide)	13,043	48
6	12:00am	0.3	10,582	114
7	3:00am	-0.5 (Low Tide)	10,747	185
8	6:00am	0.1	1,806	1,442
9	9:00am	0.6 (High Tide)	1,665	98

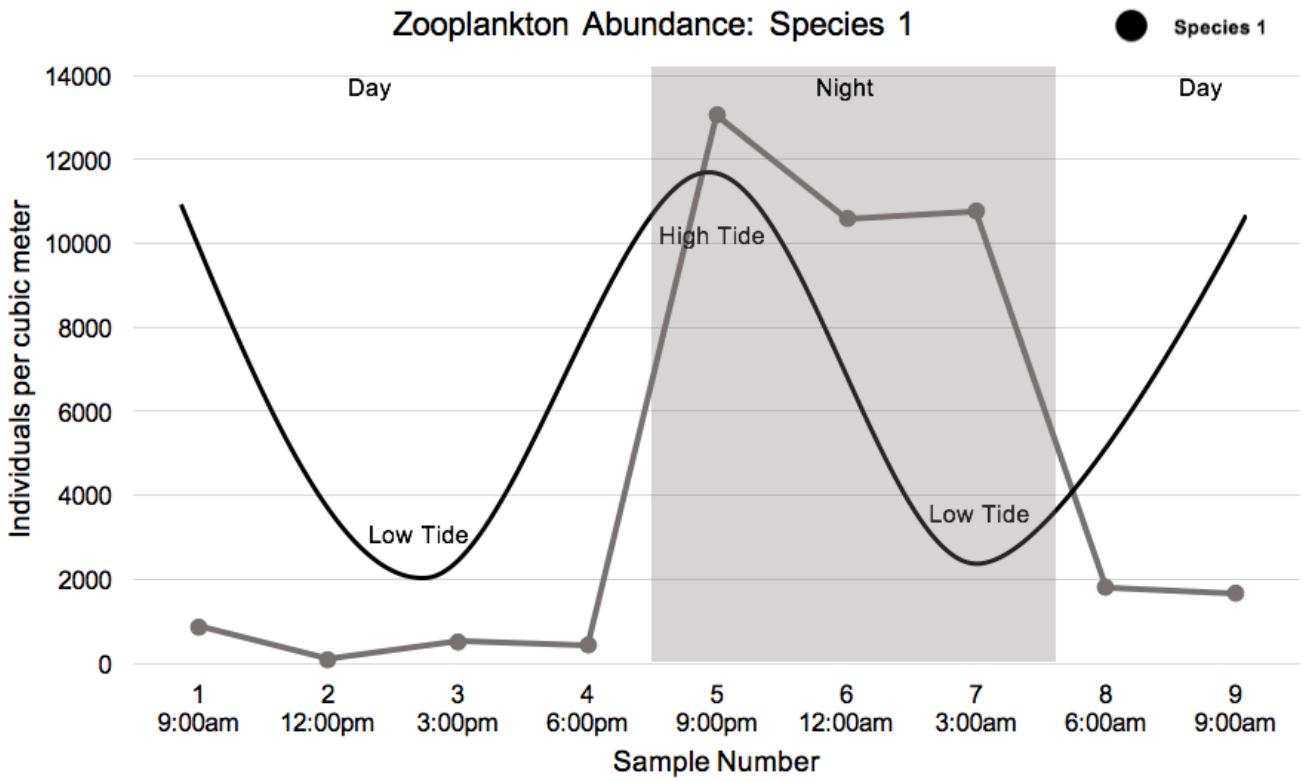
Graph of Zooplankton Abundance: Section 1A



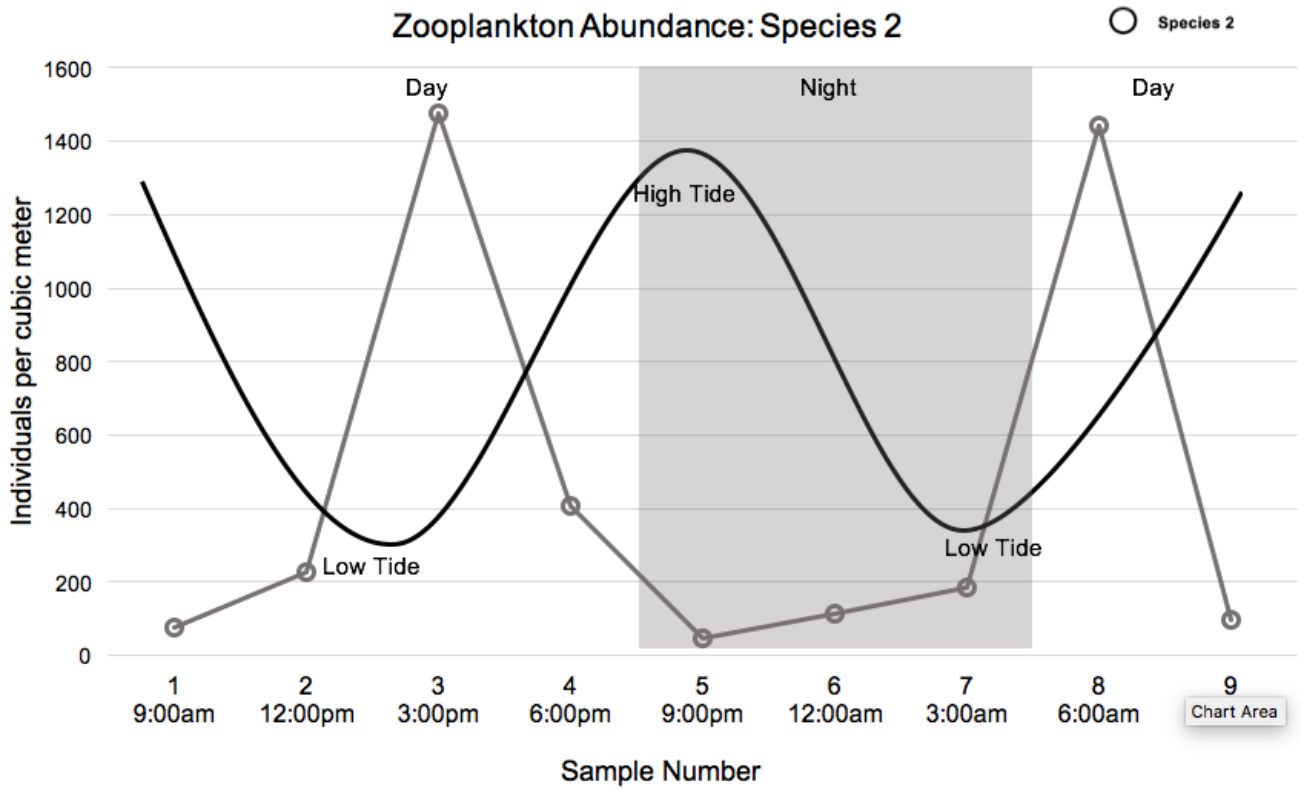
Data provided for Section 1B Graph:

Sample Number	Time of Sample	Abundance of Species 1 (per cubic meter)	Abundance of Species 2 (per cubic meter)
1	9:00am	900	100
2	12:00pm	100	200
3	3:00pm	500	1,500
4	6:00pm	400	400
5	9:00pm	13,000	100
6	12:00am	11,600	100
7	3:00am	10,700	200
8	6:00am	1,800	1,400
9	9:00am	1,700	100

Graph of Species 1 Abundance (Acartia tonsa): Section 1B



Graph of Species 2 Abundance (Rhithropanopeus harrisii): Section 1B



**Note that the y-axes of the two graphs in Version B are scaled differently for each species.*

Answers to Questions for Section 1 (Versions A and B)

1. What type of migrator is the copepod *Acartia tonsa*? Is *Acartia tonsa* species 1 or species 2?

   Acartia tonsa is a diel vertical migrator. This zooplankton migrates to the surface at night to feed on phytoplankton while it is dark and cannot be seen by predators. *Acartia tonsa* is species 1.

2. What type of migrators are white-fingered mud crab larvae? Is *Rhithropanopeus harrisii* larvae species 1 or species 2?

   White-fingered mud crab larvae are tidal migrators. They migrate to the surface on incoming tides to drift with the currents which bring them further into the protected estuary. The white-fingered mud crab is species 2.

3. Explain *Acartia tonsa*'s behavioral adaptation. How does this adaptation increase their chance of survival?

   Acartia tonsa's behavioral adaptation is its daily vertical migration. *Acartia tonsa* must feed on phytoplankton which are at the surface water. *Acartia tonsa* migrate to the surface water at night while they cannot be seen by predators. During the day as the sun penetrates the surface, *Acartia tonsa* sink deeper into the water column to escape the eyes of predators. By avoiding predators, *Acartia tonsa* increase their chance of survival.

4. Predict what would happen to the size of the *Acartia tonsa* population if they fed on phytoplankton during the day instead of at night.

   If *Acartia tonsa* fed on phytoplankton during the day, they would be visible to predators and would be preyed upon. Therefore, their chance of survival and population would decline.

5. Explain the behavioral adaptation of white-fingered mud crab larvae. How does this behavioral adaptation increase their chance of survival?

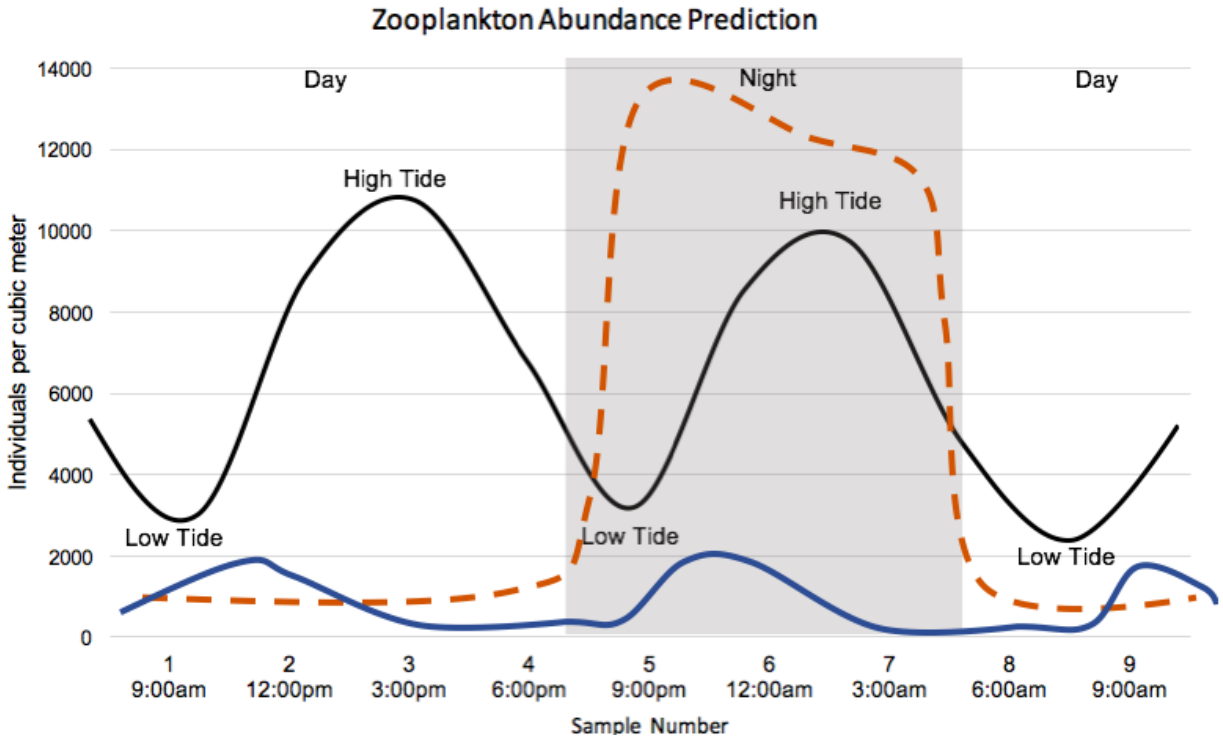
   White-fingered mud crabs are tidal migrators. They migrate to the surface water on incoming tides. When the surface water is rising, the larvae drift with the currents and are pushed into the protected estuary, instead of being swept out of the estuary. This behavioral adaptation allows white-fingered mud crab larvae to maintain their position in the protected estuary which increases their chance of survival.

6. If white-fingered mud crabs migrated to the surface on outgoing tides, when the water level is decreasing, where would they be positioned in the estuary?

   On outgoing tides, the water level is decreasing and draining from the estuaries into the ocean. Therefore, white-fingered mud crab larvae would drift out of the estuary.

Answers for Section II: Predicting Zooplankton Abundance

Students are asked to predict zooplankton abundance throughout the day. Given tidal and light data they will use their knowledge of tidal migrators and diel vertical migrators to make their predications. Zooplankton abundance predictions should resemble the graph below. The dashed line indicates *Acartia tonsa* which peaks during the night (diel vertical migrator). The solid line indicates *Rhithropanopeus harrisii* larvae that peak on incoming tides (tidal migrator).



1. When do *Acartia tonsa* peak? Why did you predict this trend?

   Acartia tonsa peak during the night time because they are diel vertical migrators. There should be an increase in abundance at night during sample numbers 4, 5 and 6. *Acartia tonsa* abundance increases at night because they migrate to the surface to feed on phytoplankton in the darkness to avoid predators. During the day, they sink into the water column when the light begins to penetrate, and they become visible to predators.

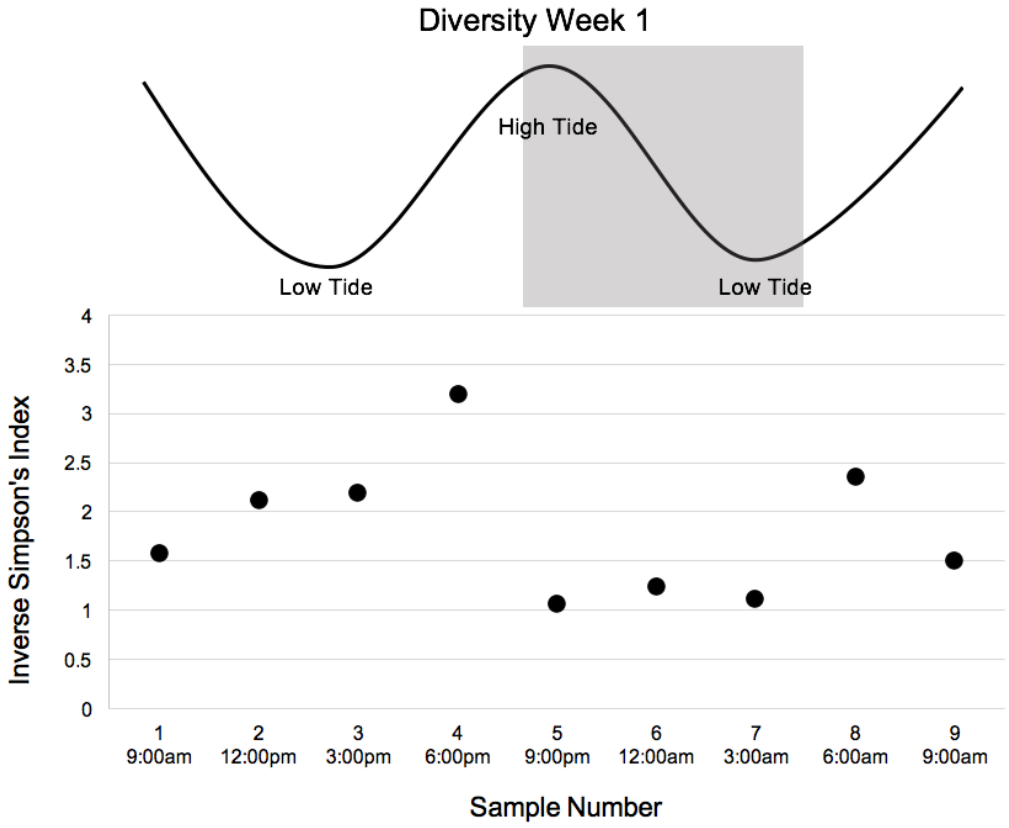
2. When do *Rhithropanopeus harrisii* larvae peak? Why did you predict this trend?

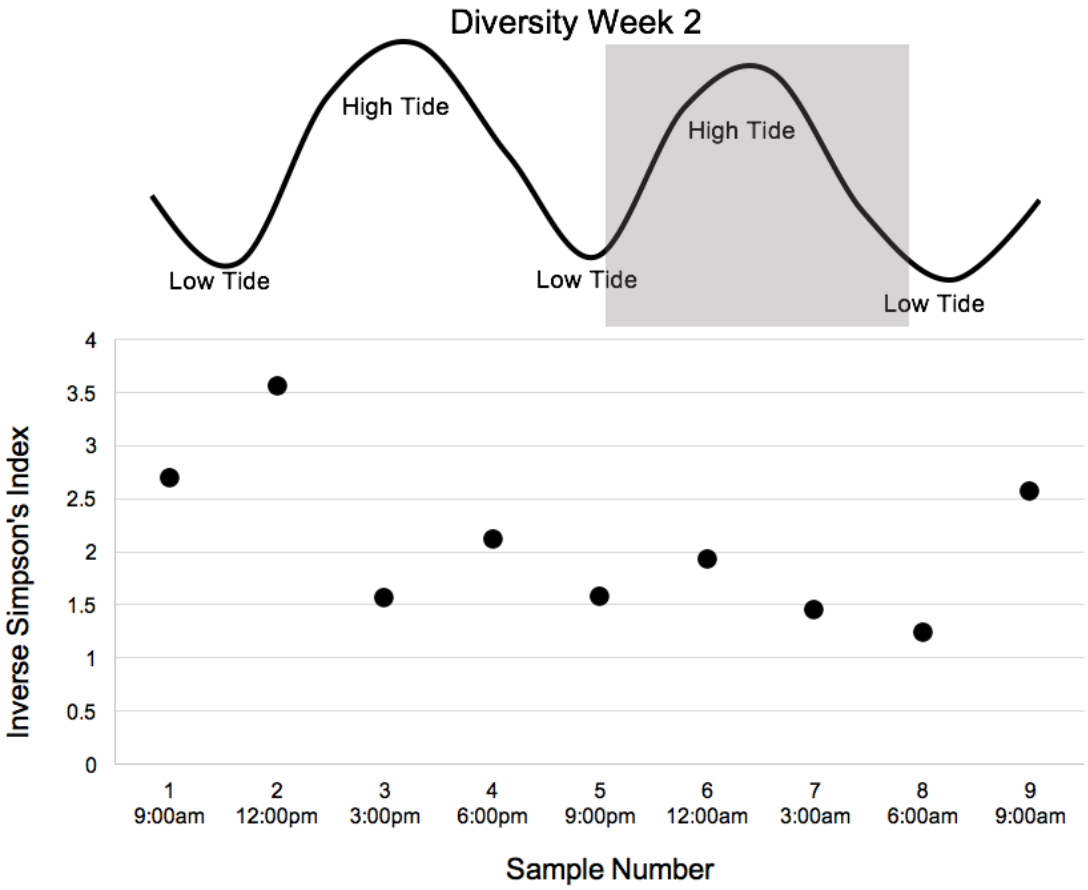
   White-fingered mud crab larvae peak on incoming tides, when the water level begins to rise. *Rhithropanopeus harrisii* larvae are tidal migrators. They are present at the surface on incoming tides to drift with the currents that get pushed further into the protected estuary instead of being swept out into the ocean.

Answers for Section III: Diversity

The diversity of each water sample discussed in Section I and Section II of the student handout was calculated using the Inverse Simpson's Index. Each water sample from Scotton Landing contained a variety of zooplankton species including *Acartia tonsa* and *Rhithropanopeus harrisii*. Based on the zooplankton species present and their relative abundance, the diversity of the zooplankton community was calculated. Higher values indicate higher diversity.

The Week 1 graph describes the diversity of the water samples used in Section I of the student handout. Week 1 water samples were taken from August 31st to September 1st, 2016. The Week 2 graph describes the diversity of the water samples from Section II. Week 2 water samples were taken from September 7th to September 8th, 2016.





1. Look at the graph for Week 1.

    a. When do we see the lowest diversity? What type of migrator is present around this time?
    The lowest diversity is during the night when diel vertical migrators, like *Acartia tonsa*, are present.

    b. When do we see the highest diversity? What type of migrator is present around this time?
    The highest diversity is observed on incoming tides when tidal migrators, like the white-fingered mud crab, are present.

    c. Is diversity increased or decreased when diel vertical migrators are present?
    Diversity is decreased when diel vertical migrators are present.

    d. Is diversity increased or decreased when tidal migrators are present?
    Diversity is increased when tidal migrators are present.

2. Look at the graph for Week 2.

    a. What is happening to the water level when we see the greatest diversity? What type of migrators are present at this tide?
    We see the greatest diversity on an incoming tide when the water level is increasing. Tidal migrators are present on incoming tides.

b. What type of migrators are present during sample 6 of week 2?

Sample 6 of week 2 occurs during the night on an incoming tide. Diel vertical migrators are present, due to the time of day. Tidal migrators are also present, due to the incoming tide.

c. A*cartia tonsa* dominates when present, due to their abundance. If diversity increases on incoming tides when tidal migrators are present, why is an increase in diversity not seen during sample 6 of week 2?

During sample 6, both tidal migrators and diel vertical migrators are present. We had previously stated that diel vertical migrators decrease diversity. *Acartia tonsa*, a diel vertical migrator, decreases diversity due to its abundance. *Acartia tonsa*'s large population dominates all other zooplankton species' abundance. Recall that Simpson's diversity considers the relative abundance of each species. If one species dominates and there are very few of the remaining species, diversity will decrease compared to a sample where all species have relatively similar abundances. Even though we expect an increase in diversity because tidal migrators are present, we do not see that increase because *Acartia tonsa*'s abundance inundates the other zooplankton species. This draws down diversity in sample 6 of week 2.

Assessment

Performance: Was the student engaged during the activity? Did the student actively participate in the lesson and discussion?

Product: Did the student complete the graphing activity? Did the student provide evidence and support for the answers to the provided questions?

Extensions:

1. Explore the website: www.underthescope.udel.edu. Click on the "Magnify it" tab and discover *Acartia tonsa* up close under the "Copepods" tab. Learn more about crab development by clicking on the "Magnify it" tab and then exploring the "From Baby Crab to Steamed Crab" tab.

SCOTTON LANDING, ST. JONES RIVER

The St. Jones River is located at the red star.

The sampling site, Scotton Landing, is located along the St. Jones River at the red arrow.