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Hematodinium: A Blue Crab Parasite

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HEMATODINIUM: A BLUE CRAB PARASITE

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Virginia Institute of Marine Science

Grade Level
High School

Subject Area
Biology

VA SEA is a collaborative project between the Chesapeake Bay National Estuarine Research Reserve, the Virginia Institute of Marine Science's Marine Advisory Program, and Virginia Sea Grant. The VA SEA project is made possible through funding from the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center.

Title *Hematodinium*: A Blue Crab Parasite

Focus Use monthly survey data to measure percentage of infection, or "prevalence" of *Hematodinium* in adult and juvenile blue crabs and determine how prevalence changes through seasons.

Grade Level High School Biology

VA Science Standards

BIO.7 The student will investigate and understand that populations change through time.
b) environmental pressures affect the survival of populations.

BIO.8 The student will investigate and understand that there are dynamic equilibria within populations, communities, and ecosystems.
a) interactions within and among populations include carrying capacities, limiting factors, and growth curves; and
d) natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.

Learning Objectives

- ✓ Students will define parasitism
- ✓ Students will calculate prevalence and graph it on a temporal scale
- ✓ Students will compare prevalence at different times of the year in adult and juvenile crabs
- ✓ Students will interpret how prevalence changes with temperature based on the pattern in the data

Total length of time required for the lesson

30 minutes for preparation, 60 minutes for lesson.

Key words, vocabulary

Symbiosis – Meaning "living together" in Greek. Any close interactions between two different living organisms.

Parasitism – A type of symbiotic relationship between two organisms. The parasite lives on or in the host and benefits by causing harm to the host.

Infection – Invasion of a host by a parasite/pathogen.

Disease – A condition in an organism with impaired performance of a vital function.

Prevalence – The proportion of individuals infected with the parasite in a particular population.

Transmission – An infectious agent is passed from an infected host individual to another individual.

Juvenile crab – Blue crabs < 30 mm carapace width.

Background information

More than 50% of lives on Earth are parasites and almost every living organism has a parasite. Except for those found in humans, many parasites are overlooked because they don't impact humans, or they are difficult to study. However, some marine parasites have received attention because they can have a significant impact on commercially important seafood species like blue crabs.

In Chesapeake Bay, blue crabs are the largest commercial fishery and harvest of blue crabs average at 61 million pounds per year. In 2022, the blue crab population dropped to the lowest level in 33 years. Although blue crab population fluctuates naturally because of environmental factors, continuous declines suggest juvenile crabs need to be protected for them to grow and reproduce.

One of the biological factors that could affect blue crab population is disease. *Hematodinium* is a parasite that lives in the blood of crustaceans. (Hema- means "blood" in Greek). *Hematodinium* infects more than 40 species of crustaceans around the world. The infection causes a bitter taste in cold water crabs (i.e., snow crabs, tanner crabs) and thus is called bitter crab disease. Infected crabs do not look different and the easiest way to tell if a crab is infected is to look at a blood sample under a microscope. In blue crabs, *Hematodinium* infection is often fatal and high percentage of infection, or "prevalence", may contribute to the decline in the blue crab population. Therefore, it is important to measure percentage of infection in both adult and juvenile blue crab populations to understand its impact.

In this activity, students will measure percentage of infection ("prevalence") of *Hematodinium* in adult and juvenile blue crabs with mock monthly samples. Students will then graph the data and look for patterns over time.

Materials & Supplies

- Worksheet (Appendix I)

- 12 bags/trays of blue crab samples. Each bag/trays represent one month of the year and instructor label each bag/tray with the month. As for the blue crab samples, instructor has flexibility to choose any supplies readily available. The only requirement for such supply is that students should not be able to distinguish uninfected/infected by look, so students need to examine the samples to find out which crab is infected by the parasite. Some recommended supplies for the crab samples are:
  - Option A: Play-Doh and beads
    - Adult: *blue Play-Doh ball
    - Juvenile: *yellow Play-Doh ball
    - Uninfected: Play-Doh ball without bead inside
    - Infect: Play-Doh ball with bead inside
  - Option B: Beads
    - Adult: large bead
    - Juvenile: small bead
    - Uninfected: normal bead
    - Infect: *glow-in-the-dark bead
  - Option C (Halloween): M&M's
    - Adult: *blue colored M&M's
    - Juvenile: *yellow colored M&M's
    - Uninfected: *chocolate flavored M&M's

- Infect: *mint flavored M&M's

*Colors, flavors, types may be changed depending on supply availability

- Calculators

Teacher Preparation

Students can be divided into 12 groups or less based on class size. Each student should receive a worksheet (Appendix I). If divided in 12 groups, each group will be provided a bag of mock samples. If divided in fewer groups, each group will be provided multiple bags, preferably based on season (Spring: Mar-May, Summer: June-August, Fall: September-November, Winter: December-February). Below is the representative data for prevalence from the literature (in References). The instructor can decide the number of infected and uninfected crabs to put in each sample bag as long as prevalence levels and trends stay similar. For a sample set up, the instructor can refer to the table below, which has a total of 40 crabs (20 adult and 20 juvenile) in each month.

Month	Adult crab			Prevalence (%)	Juvenile crab			Prevalence (%)
	Infected	Uninfected	Total		Infected	Uninfected	Total	
January	9	11	20	45.0	13	7	20	65.0
February	3	17	20	15.0	11	9	20	55.0
March	2	18	20	10.0	11	9	20	55.0
April	3	17	20	15.0	12	8	20	60.0
May	3	17	20	15.0	12	8	20	60.0
June	4	16	20	20.0	18	2	20	90.0
July	6	14	20	30.0	16	4	20	80.0
August	5	15	20	25.0	13	7	20	65.0
September	7	13	20	35.0	13	7	20	65.0
October	10	10	20	50.0	20	0	20	100.0
November	16	4	20	80.0	19	1	20	95.0
December	15	5	20	75.0	18	2	20	90.0

Procedure

I. Introduction

The instructor will provide background information on symbiosis and parasitism. Examples of parasites from different phyla will be provided in the PowerPoint. Students will be introduced to the blue crab, the biology of *Hematodinium*, and how two organisms interact in terms of infection, disease, and transmission.

II. Activity

Depending on the class size, each group will be provided with one or multiple bags of blue crab samples that represent one or multiple monthly samples. Students will conduct a "dissection" by ripping the Play-Doh, turning the light off, or eating the M&M to find out which crab is infected. Student will then count the number of infected and uninfected adult and juvenile crabs and record on the datasheet. Students will calculate prevalence based on the equation. Student will share their results in the table to the whole class and discuss the first set of questions in the worksheet.

Student will plot the prevalence of *Hematodinium* in adult and juvenile crabs in each month on a line graph. This step can also be done on a board by the instructor. Instructor will lead the discussion for the second set of questions either at the end of the session or the beginning of next session.

Assessment

Students can be given some time to think about the questions on the worksheet and the instructor may lead discussions on the questions as a class or within groups. Students should be encouraged to come up with different answers to open-ended questions.

References

Blue Crabs. Chesapeake Bay Foundation. (n.d.). Retrieved December 1, 2022, from https://www.cbf.org/about-the-bay/more-than-just-the-bay/chesapeake-wildlife/blue-crabs/index.html

Messick, G. A. (1994). *Hematodinium perezi* infections in adult and juvenile blue crabs *Callinectes sapidus* from coastal bays of Maryland and Virginia, USA. *Diseases of Aquatic Organisms*, *19*, 77–82. https://doi.org/10.3354/dao019077

Messick, G. A., & Shields, J. D. (2000). Epizootiology of the parasitic dinoflagellate *Hematodinium* sp. in the American blue crab *Callinectes sapidus*. *Diseases of Aquatic Organisms*, *43*, 139–152. https://doi.org/10.3354/dao043139

Small, H. J., Huchin-Mian, J. P., Reece, K. S., Pagenkopp Lohan, K. M., Butler, M. J., & Shields, J. D. (2019). Parasitic dinoflagellate *Hematodinium perezi* prevalence in larval and juvenile blue crabs *Callinectes sapidus* from coastal bays of Virginia. *Diseases of Aquatic Organisms*, *134*(3), 215–222. https://doi.org/10.3354/dao03371

Wachapreague Water Quality Data. Virginia Institute of Marine Science. (n.d.). Retrieved November 17, 2022, from https://www.vims.edu/esl/research/water_quality/wachapreague.php

2022 Blue Crab Winter Dredge Survey. Maryland Department of Natural Resources. (n.d.). Retrieved December 1, 2022, from https://dnr.maryland.gov/fisheries/pages/blue-crab/dredge.aspx

Appendix I

Worksheet

Name_____

Introduction: The blue crab population in Chesapeake Bay is decreasing and you are wondering why. Scientists recently reported finding a parasite called *Hematodinium* in blue crabs and you decide to look more closely at its impact. You go out each month and collect adult and juvenile blue crabs from an area known to have *Hematodinium*. After dissection, you record the number of crabs with infection.

PART 1

Instructions:

Step 1: Note the month of your sample.

Step 2: Count the number of adult and juvenile, infected and uninfected crabs in each monthly sample. Your instructor will provide you with a key.

Step 3: Complete "Total" column.

Step 4: Calculate and complete "Prevalence (%)" column using the following equation:

Prevalence (%) = # of infected crabs/ total # of crabs x 100%

Month	Adult crab			Prevalence (%)	Juvenile crab			Prevalence (%)
	Infected	Uninfected	Total		Infected	Uninfected	Total	
January								
February								
March								
April								
May								
June								
July								
August								
September								
October								
November								
December								

Step 5: Share your “Prevalence (%)” data with other groups.

Questions:

1. What’s the range of prevalence in adult crabs? In juvenile crabs?

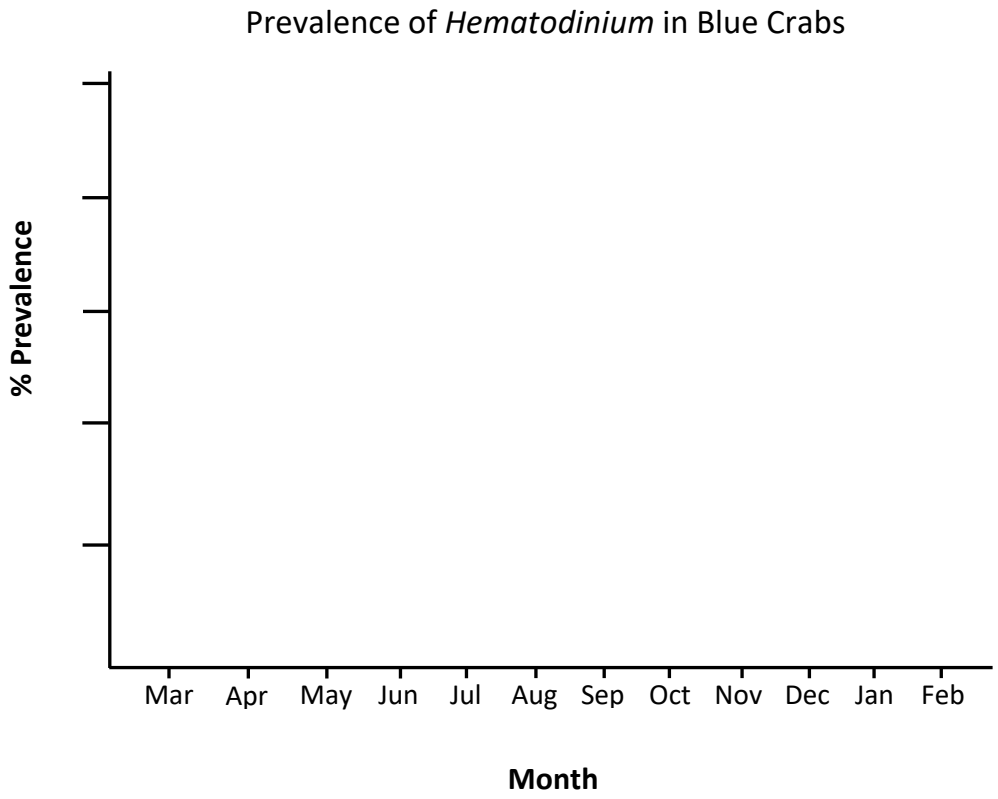
2. Prevalence is highest in which month in adult crabs? In juvenile crabs?

PART 2

Step 6: Label the ticks on y axes.

Step 7: Using two different colors, then create a line graph for each set of points by connecting them with the appropriate color.

Step 8: Label the legend for each line.



Questions:

1. Do you see a pattern in the prevalence over time? Based on the temperature and salinity data from the site where you collected crabs (Appendix IV), which environmental factor do you think contribute to the pattern?

2. Compare the prevalence trends in adult and juvenile crabs, what do you notice? Can you come up with an explanation for this difference?

Open-ended Questions:

1. After the assessment, you know that prevalence of *Hematodinium* in juvenile crabs can reach up to 100% in the fall! Given that most infection is fatal, what are some potential management strategies that could be implemented to help protect the blue crab population from the impact of disease like *Hematodinium*?

2. Based on what you learned about the pattern in prevalence, what effect may global warming have on the crab and the parasite?

Appendix I

Worksheet KEY

Name_____

Introduction: Blue crab population in Chesapeake Bay is decreasing and you are wondering why. Scientists recently reported finding a parasite called *Hematodinium* in blue crabs and you decide to look more closely at its impact. You go out each month and collect adult and juvenile blue crabs. After dissection, you record the number of crabs with infection.

PART 1

Instructions:

Step 1: Note the month of your sample.

Step 2: Count the number of adult and juvenile, infected and uninfected crabs in each monthly sample. Your instructor will provide you with a key.

Step 3: Complete "Total" column.

Step 4: Calculate and complete "Prevalence (%)" column using the following equation:

Prevalence (%) = # of infected crabs/ total # of crabs x 100%

Month	Adult crab			Prevalence (%)	Juvenile crab			Prevalence (%)
	Infected	Uninfected	Total		Infected	Uninfected	Total	
January	9	11	20	45.0	13	7	20	65.0
February	3	17	20	15.0	11	9	20	55.0
March	2	18	20	10.0	11	9	20	55.0
April	3	17	20	15.0	12	8	20	60.0
May	3	17	20	15.0	12	8	20	60.0
June	4	16	20	20.0	18	2	20	90.0
July	6	14	20	30.0	16	4	20	80.0
August	5	15	20	25.0	13	7	20	65.0
September	7	13	20	35.0	13	7	20	65.0
October	10	10	20	50.0	20	0	20	100.0
November	16	4	20	80.0	19	1	20	95.0
December	15	5	20	75.0	18	2	20	90.0

Step 5: Share your “Prevalence (%)” data with other groups.

Questions:

1. What’s the range of prevalence in adult crabs? In juvenile crabs?

Prevalence ranges from 10 to 80% in adult crabs and from 55 to 100% in juvenile crabs.

2. Prevalence is highest in which month in adult crabs? In juvenile crabs?

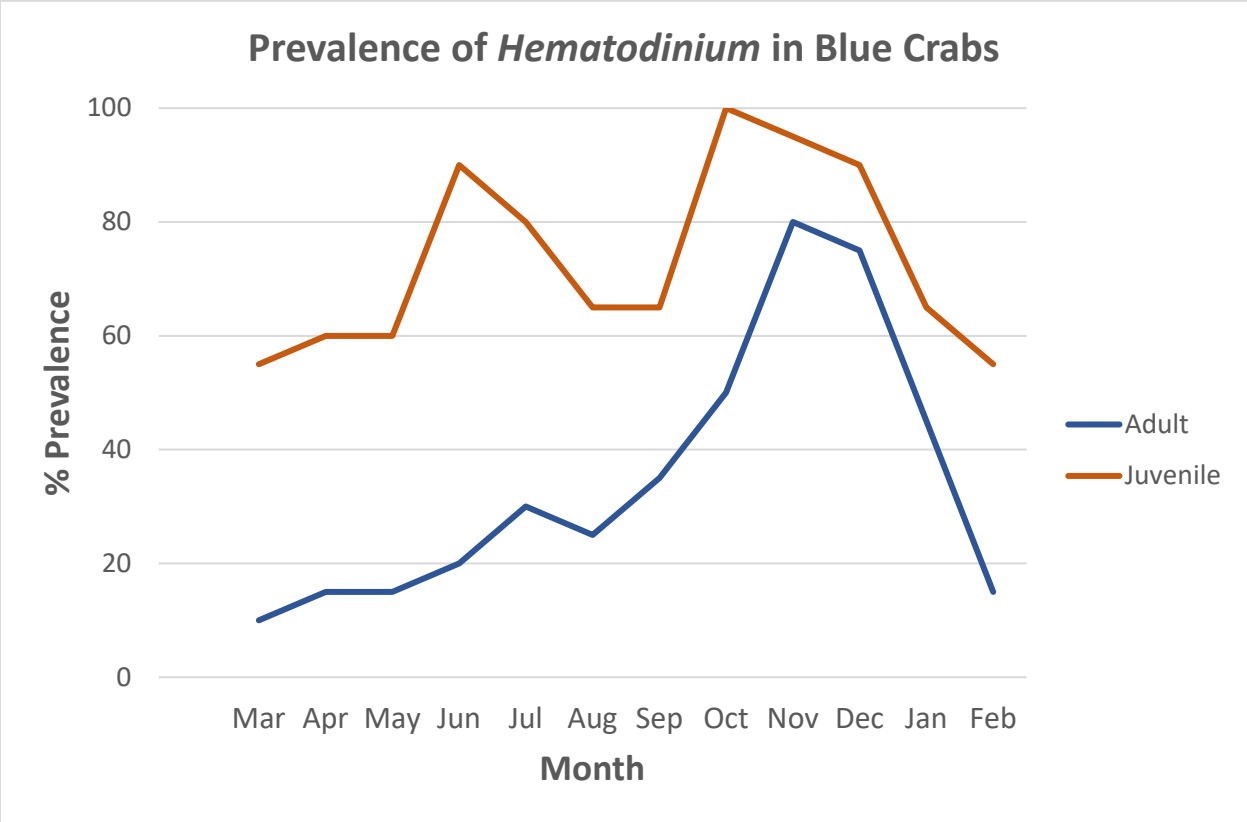
Prevalence is highest in November in adult crabs and in October in juvenile crabs.

PART 2

Step 6: Label the ticks on y axes.

Step 7: Using two different colors, then create a line graph for each set of points by connecting them with the appropriate color.

Step 8: Label the legend for each line.



Questions:

1. Do you see a pattern in the prevalence over time? Based on the temperature and salinity data from the site where you collected crabs (Appendix IV), which environmental factor do you think contribute to the pattern?

Prevalence rises in summer and peaks in fall, with highest prevalence in October through December. It then drops drastically during winter and stays low through spring.

Because the pattern is strongly seasonal, temperature is the most important driving factor. Salinity stays constantly high at this site so does not contribute to the pattern. Based on the information from the PowerPoint, student should know that transmission of *Hematodinium* is through a spore stage released from the crab into the water (called "sporulation"). As temperature rises, the parasite develops faster in the crab and sporulation is more likely to happen, thus more crabs infected. Lower prevalence in winter can be explained by either no sporulation, hence no transmission happening at lower temperature, or most crabs with infections died in the fall and only uninfected ones survived to the winter.

So why is the highest prevalence not in summer? One explanation is there's a lag in the development in the parasite. Especially in adults, parasites need more time to take over the host and lead to sporulation.

Students may also notice that there's a dip in prevalence in juveniles in the summer. The PowerPoint gives a figure on the optimal temperature for the blue crab and the parasite. At temperatures > 25°C, the performance of blue crab starts to drop while the performance of parasite stays high. In the summer, some crabs may be stressed out and die early without sporulation. In another words, the parasite fails to come out and infect new hosts. There are other explanations such as settlement time of juvenile crabs but those do not need to be discussed.

2. Compare the prevalence trends in adult and juvenile crabs, what do you notice? Can you come up with an explanation for this difference?

Although trends are similar over time, prevalence in adult crabs are constantly lower than in juveniles. Scientists do not have an answer for why juveniles have more infections than adults. Some explanations could be 1) juvenile crabs are more exposed because they come into areas in the Bay with a lot of parasites (high salinity) every year while after secondary migration, some adult crabs stay in areas with less parasites (low salinity). 2) adult crabs are constantly being removed by fishery so infected ones may be taken away from the population. 3) adult crabs are pre-selected because they are either resistant to infection or survived from infection (unlikely) while being a juvenile.

Open-ended Questions:

1. After the assessment, you know that prevalence of *Hematodinium* in juvenile crabs can reach up to 100% in the fall! Given that most infection is fatal, what are some potential management strategies that could be implemented to help protect the blue crab population from the impact of disease like *Hematodinium*?

Monitoring prevalence: Conduct regular surveys to monitor the prevalence of Hematodinium in adult and juvenile blue crab populations can help identify areas that need intervention.

Protecting juveniles: Because they are particularly vulnerable to the disease, protecting nursery habitats such as seagrass beds and limiting fishing during peak reproductive seasons could help with recruitment.

Research and development: Scientists could incorporate *Hematodinium* into population models as a mortality source and improve data-based management strategies.

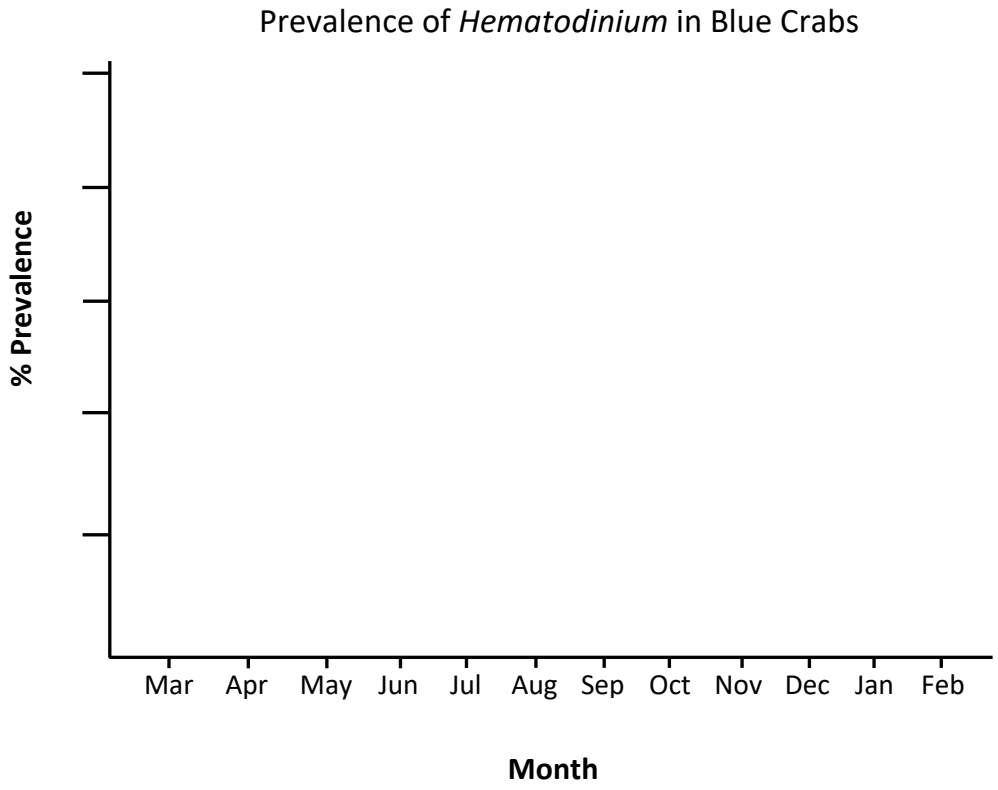
2. Based on what you learned about the pattern in prevalence, what effect may global warming have on the crab and the parasite?

Global warming is caused by burning of fossil fuels, with greenhouse gas trapping heat and leading to higher temperature. In short terms, it may increase infection prevalence in both adult and juvenile crabs because the parasite develops faster and has an increased window for sporulation. Consequently, more mortality occurs, and crab population would decline. In long terms, if extreme temperature appears frequently, more infected crabs may die before sporulation and the parasite could become extinct because of lack of transmission. However, this depends on whether the parasite can survive in other hosts, which could serve as a reservoir. Also, host and parasite are always evolving together over time, so it's possible that one or both become adapted to higher temperatures.

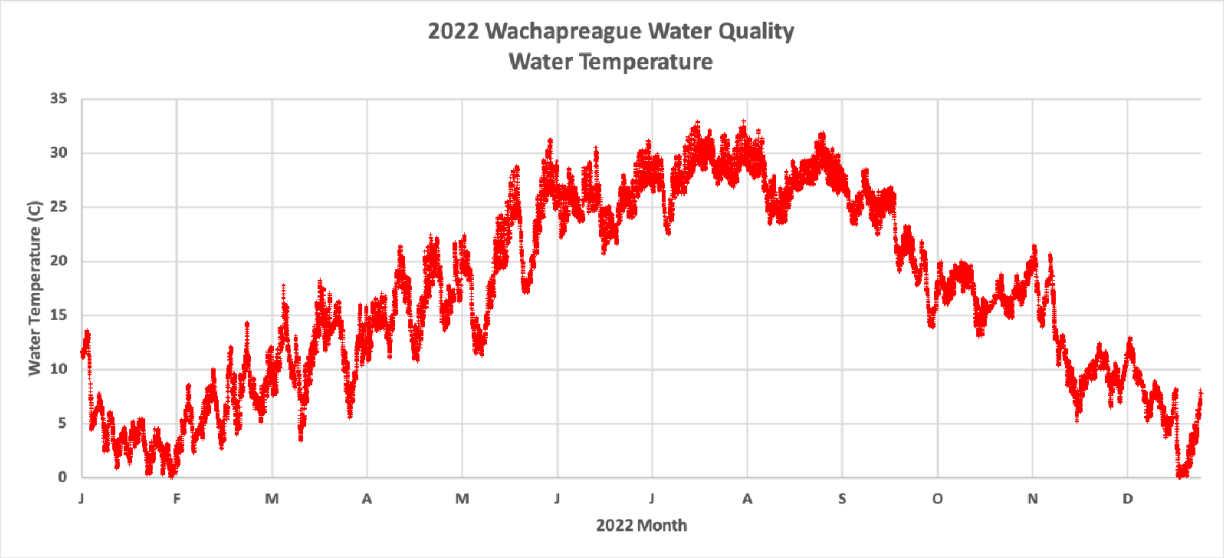
Appendix II

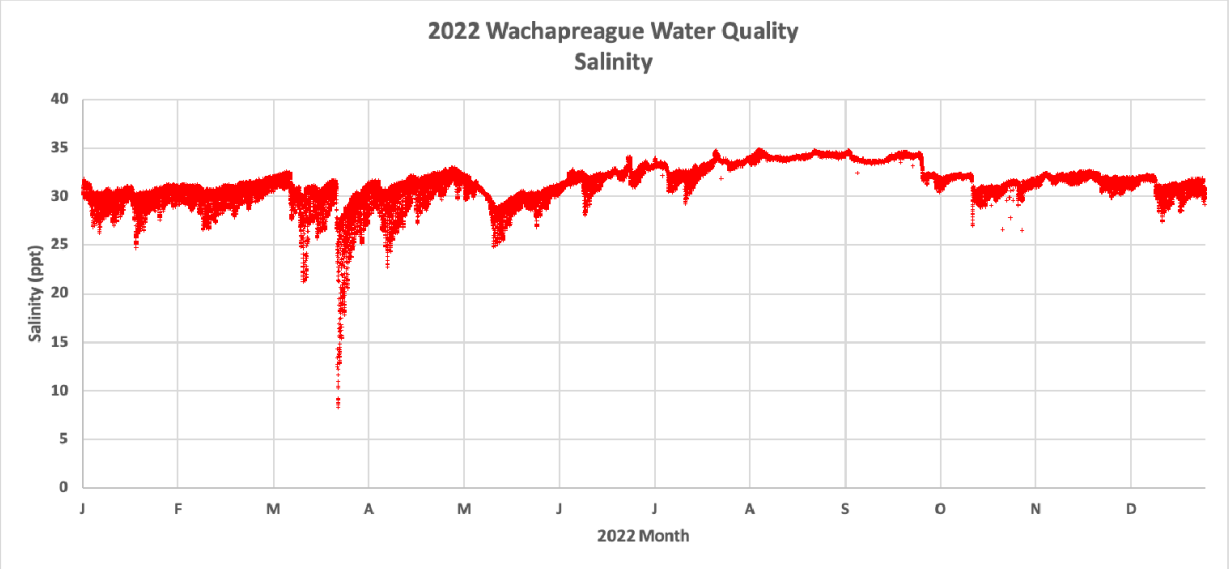
Month	Adult crab			Prevalence (%)	Juvenile crab			Prevalence (%)
	Infected	Uninfected	Total		Infected	Uninfected	Total	
January								
February								
March								
April								
May								
June								
July								
August								
September								
October								
November								
December								

Appendix III



Appendix IV


2022 Wachapreague Water Quality
Water Temperature
Water Temperature (C)
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
2022 Month


2022 Wachapreague Water Quality
Salinity
Salinity (ppt)
40
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
2022 Month