



# WAVE FEVER

## THE CLIMATE INDUCED RANGE EXPANSION OF THE ATLANTIC MARSH FIDDLER CRAB

**Kayla Martinez-Soto**  
Virginia Institute of Marine Science

**Grade Level**  
High School

**Subject Area**  
Environmental Science

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**Activity Title:** Wave Fever: The Climate Induced Range Expansion of the Atlantic Marsh Fiddler Crab

**Focus:** Global Climate Change; Range Expanding Species

**Grade Levels/Subject:** High School Environmental Science

**VA Science Standard(s) addressed:** Environmental Science Content Guidelines

**I. Scientific Skills and Processes:**

Students will identify and investigate problems scientifically and will communicate information clearly in writing, discussions, and debates.

- a. data tables, frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted;
- b. conclusions are formed based on quantitative and qualitative data;

**V. Human impact, global climate change, and civic responsibility:**

The student will investigate and understand global climate change.

- a. the use of scientific evidence in reporting changes in average global temperature, greenhouse gases, quantities of arctic and land ice, ocean temperature, ocean acidification, and sea level rise;
- b. the relationship of global climate change on the frequency or magnitude of extreme weather events; and
- c. actual and potential effects of habitat destruction, erosion, and depletion of soil fertility associated with human activities.

**Learning objectives/outcomes**

- a) Students will extrapolate data from a federal agency database to graph ocean warming in the Gulf of Maine.
- b) Students will collect data from mock field quadrats.
- c) Students will calculate and graph fiddler crab burrow densities.
- d) Students will compare fiddler crab burrow densities and Gulf of Maine water temperatures to graph a relationship.

**Total length of time required for the lesson:** 1 hour and 10 minutes

**Key words, vocabulary:**

- a) Global Climate Change - A long-term change in the average weather patterns that have come to define Earth's local, regional and global climates that have been influenced by anthropogenic activities.
- b) Range expanding species - Species that expand their historical ranges into formerly unsuitable habitat through changes in climate.
- c) Ocean Warming – When average temperatures of the oceans rise due to anthropogenic activities.
- d) Detritivore – An organism that feeds on dead organic matter

## Background information

The world is currently undergoing the largest climate-driven redistribution of species since the end of the last ice age or 21,500 years ago. On average, marine species move poleward 45 mi (72 km) per decade as a consequence of climate change. As global climate change persists, range expanding species may have negative impacts on the new habitats they move into. Despite documenting 1000s of climate-driven range expansions, we know little about how these range-expanding species affect the new habitats they enter.

The historic range of the Atlantic marsh fiddler crab (*Minuca pugnax*, Smith 1870) was between Cape Cod, Massachusetts and Daytona Beach, Florida. In 2014, Johnson (2014) found that the Atlantic marsh fiddler crab had extended its northern limit to New Hampshire (~90 mi), which is in the Gulf of Maine. The Gulf of Maine is one of the fastest warming water bodies on the globe and the Atlantic marsh fiddler crab may have recruited to its new northern limits during an 'ocean heat wave' of 2012 when temperatures were higher than average (Johnson 2014).

Range expanding species can alter salt marsh biodiversity and food webs. Salt marshes are nurseries for many marine species, habitat for wetland birds, and a buffer between land and coastline that provides storm protection. Range-expanding species may affect their health simply by their presence.

## Student handouts and other materials needed

Included in the appendices you find the following handouts:  
Temperature & Burrow Worksheets divided by group number  
Discussion Worksheet  
Completed data tables (if using pre-downloaded data)  
Pictures of quadrats (15 total)

The following is a link to a video introducing fiddler crabs:

<https://www.youtube.com/watch?v=rSDXJr-WXFI>

## Materials & Supplies, A/V/Tech Support

Computers  
Internet access  
iPad (optional)

## Classroom/Lab/Field Study Setup

Computers and internet access should be set up during this time. If possible, each student should have their own computer. If not, one computer per group will suffice. Students should be divided into 5 groups. Worksheets and pictures will be passed out to each corresponding group number.

**Procedure:**

Lab Set-up – 15 minutes

Introduction – 10 minutes

Activity – 45 minutes Discussion – 15 minutes

Breakdown and Clean-up – 10 minutes

**Engagement**

Introduce students to the lab by discussing the differences between global climate change and global warming. After some discussion, show the attached Power Point presentation. Ask students to brainstorm the implications of range expanding species in new habitats. Some acceptable answers are competition for resources, economic consequences, and reduced biodiversity. Afterward, ask how ocean warming may be facilitating the range expansion of fiddler crabs. An acceptable answer is that the warmer waters allow them to survive. This lab activity will determine the relationship between the warming of the Gulf of Maine and the densities of fiddler crabs in northern Massachusetts.

**Exploration (Part 1)**

This activity can be done using either the pre-downloaded data found in the Temperature Tables in the Appendix or by having the students download the data themselves using the instructions below.

Split students into 5 groups. Each student should have a temperature graphing worksheet and a burrow graphing worksheet for their group, as well as a short answer assessment worksheet. Each group should have three quadrat pictures corresponding to their group number.

To download the data from the internet, have at least one computer per group and have the students navigate to their internet browser and follow the procedure below.

Go to [http://www.neracoos.org/datatools/historical/graphing\\_download](http://www.neracoos.org/datatools/historical/graphing_download)

Click on “Click here to begin”

Select “Monthly Average Water Temperatures (Deg F) as your data type

Each group will be assigned **one** of the following time periods:

From 2012-01-01 0:00 to 2013-01-01 0:00 (Group 1)

From 2013-01-01 0:00 to 2014-01-01 0:00 (Group 2)

From 2014-01-01 0:00 to 2015-01-01 0:00 (Group 3)

From 2016-01-01 0:00 to 2017-01-01 0:00 (Group 4)

From 2017-01-01 0:00 to 2018-01-01 0:00 (Group 5)

Select “UNH Coastal Marine Lab Field Station (CML)” as your data location

Select “Text File - CSV (suitable for import into MS Excel)” as data format

Click on “View report now”

File usually can be found in “downloads” folder

Save file as: Sea.temp.data.“year” (e.g. Sea.temp.data.2017)

File should be saved as an excel workbook

Open the data and label headers as there are found on the attached data table.

Each group should then graph their data in excel using a scatterplot. Make sure to label axis.

Afterward, have each group calculate their average temperature for the year.

For students using the pre-downloaded Temperature Tables, have them graph the monthly temperatures for their year and calculate the average annual temperature.

Once all the groups have graphed the temperatures for their year and calculated their average annual temperature, have one student from each group share their corresponding year and average. As a class, the students should graph the average temperature per year.

### **Explanation**

Discuss with each group if they see a pattern in the data. There are seasonal patterns within the data but, this is not the focus of the activity. The average annual temperature should pulse in the years 2012 and 2016 as the Gulf of Maine warms up. It may be a slight change, but discuss with students how much energy (i.e. heat) is needed to warm water and change its temperature on the scale of an ocean.

### **Elaboration**

Once students finish discussing ocean warming, discuss the picture of the quadrat with fiddler crab burrows. Discuss how a fiddler crab is considered a detritivore and if they would have any impact on the plants. The answer is that they would not have direct interactions with the plants but with the algae or detritus on the sediment surface. Make sure to show the slides of the range expansion of the Atlantic marsh fiddler crab in the background. Included, there is an example on how to count fiddler crab burrows.

### **Exploration (Part 2)**

Once the discussion ends, have students analyze the pictures of the quadrats. The quadrat represents  $1/25^{\text{th}}$  of a meter<sup>2</sup>. Have the students count the number of fiddler crab burrows within the quadrat. Record the number on the worksheet. The students should graph the number of fiddler crabs per year on the provided worksheet.

### **Elaboration**

Redistribute the students into 5 new groups where there is at least one student (or expert) per year (jigsaw group learning). Have each group discuss their findings from their previous groups and if they saw a pattern in the data. The number of fiddler crabs should be rising as the years progress. Compare both the average water temperatures and fiddler crab graphs divided by year. Discuss with students if they observe a relationship between the two graphs. The relationship between the ocean temperatures of the Gulf of Maine and the number of fiddler crabs in the novel habitat is that both are rising. In practice, scientists would run a linear regression to statistically test the significance of this relationship. Please note, the ocean heat waves of 2012 and 2016. These heat waves are what allowed the fiddler crabs to settle in the new habitat.

### **Evaluation**

To evaluate the students understanding of the relationship between ocean warming and range expanding species, have the students move back into their initial groups of 5 and discuss further the trends they saw during other years using the guided discussion worksheet.

### **Assessment**

On the guided discussion worksheets, there will be follow up questions to disseminate patterns found on the graphs. This is to make students understand how ocean heat waves can allow for new species to move into a vulnerable habitat.

### **Extension**

Included in the references is an article on the range expansion of Blue Crabs into the Gulf of Maine. Students could discuss the paper and construct an infographic or poster on an 8 by 11 piece of paper. It can be drawn, printed, painted, etc. The main objective of the activity is to inform local Virginia fisherman about ocean warming and range expanding species and how Blue Crabs may enter new areas where they can be harvested.

### **References**

Bertness, M. D. 1985. Fiddler Crab Regulation of *Spartina alterniflora* Production on a New England Salt Marsh. *Ecology* 66:1042–1055.

Gittman, R. K., and D. A. Keller. 2013. Fiddler crabs facilitate *Spartina alterniflora* growth ,mitigating periwinkle overgrazing of marsh habitat. *Ecology* 94:2709–2718.

Grimes, B., M. Huish, and H. Kerby. 1989. Atlantic fiddler crab species profile.

Holdredge, C., M. D. Bertness, N. C. Herrmann, and K. B. Gedan. 2010. Fiddler crab control of cordgrass primary production in sandy sediments. *Marine Ecology Progress Series* 399:253–259.

Johnson, D. S. 2014. Fiddler on the roof: a northern range extension for the marsh fiddler crab *Uca pugnax*. *Journal of Crustacean Biology* 34:671–673.

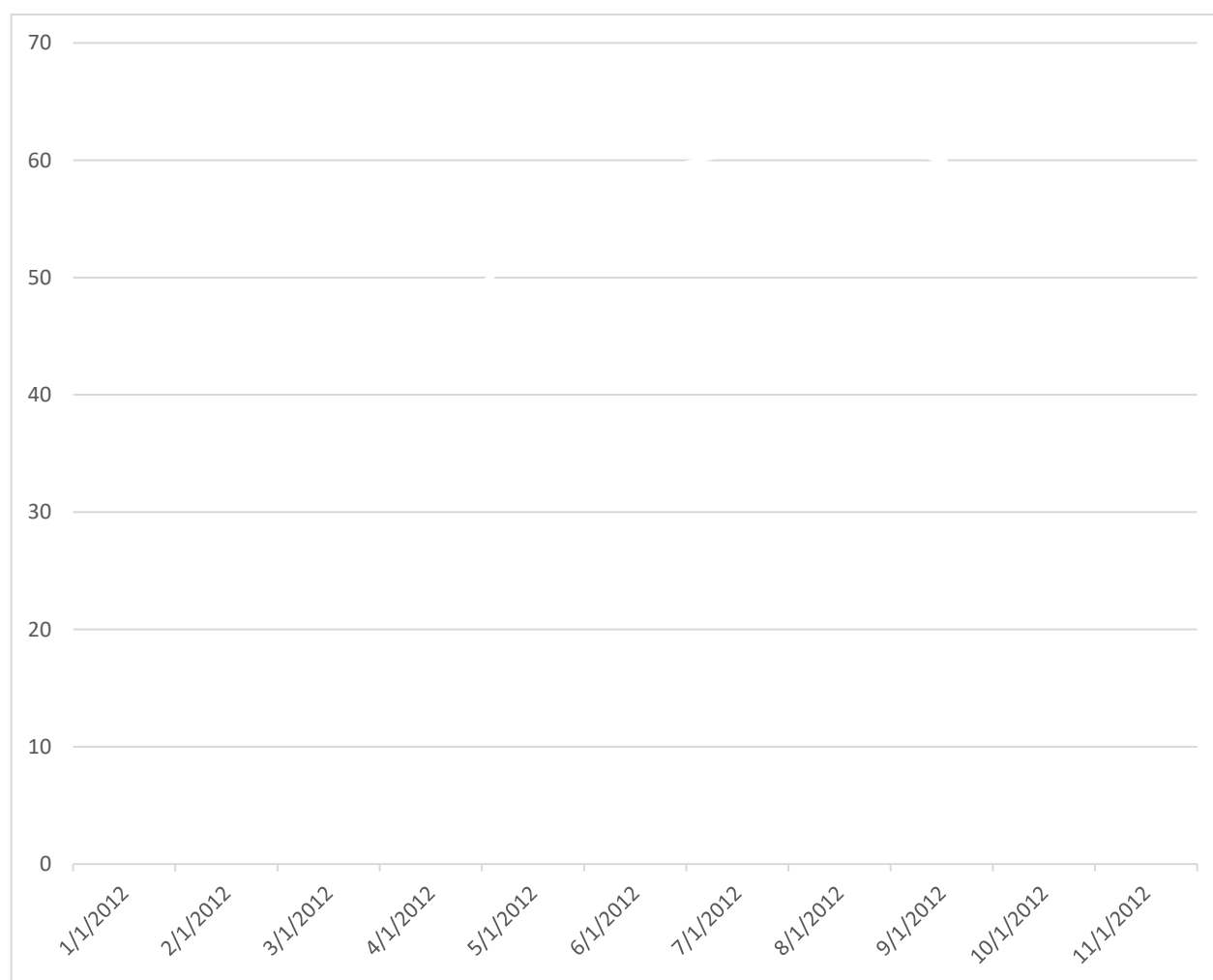
Johnson, D. S. 2015. The savory swimmer swims north: a northern range extension of the blue crab *Callinectes sapidus*? *Journal of Crustacean Biology* 35:105–110.

Appendix: Worksheets

## Group 1: Year 2012 - Temperature

Group Members: \_\_\_\_\_

**Directions:** Once you have extracted your data from NOAA's Buoy Depository, graph the temperatures to your corresponding year below. Make sure to label your axes!



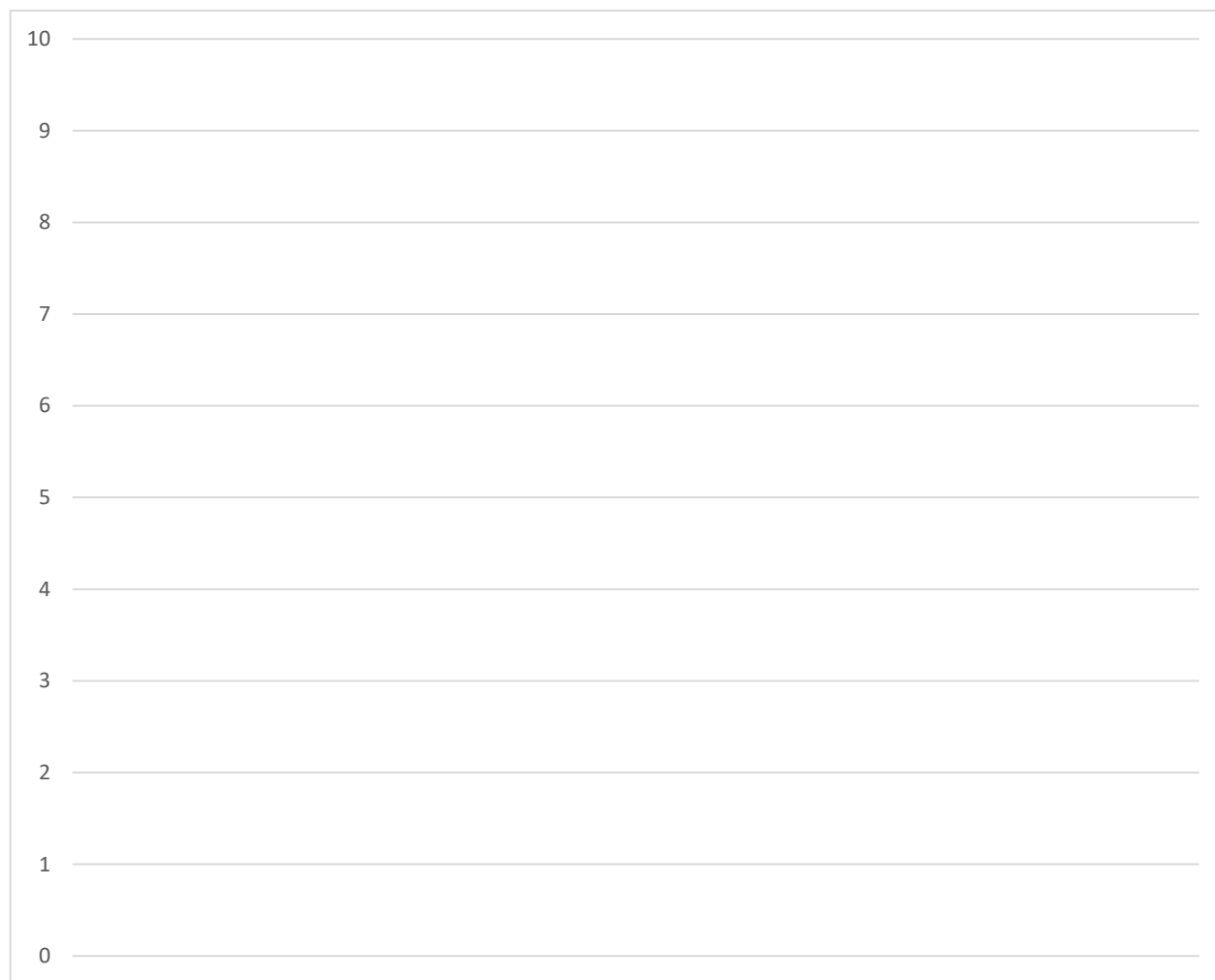
Average Annual Temperature: \_\_\_\_\_



# Group 1: Year 2012 - Burrows

Group Members: \_\_\_\_\_

**Directions:** Review the three pictures of quadrats in the field. Look for quarter size and oblong fiddler burrows. Count the burrows for each quadrat and graph them below. Make sure to label your axes!



Quadrat 1

Quadrat 2

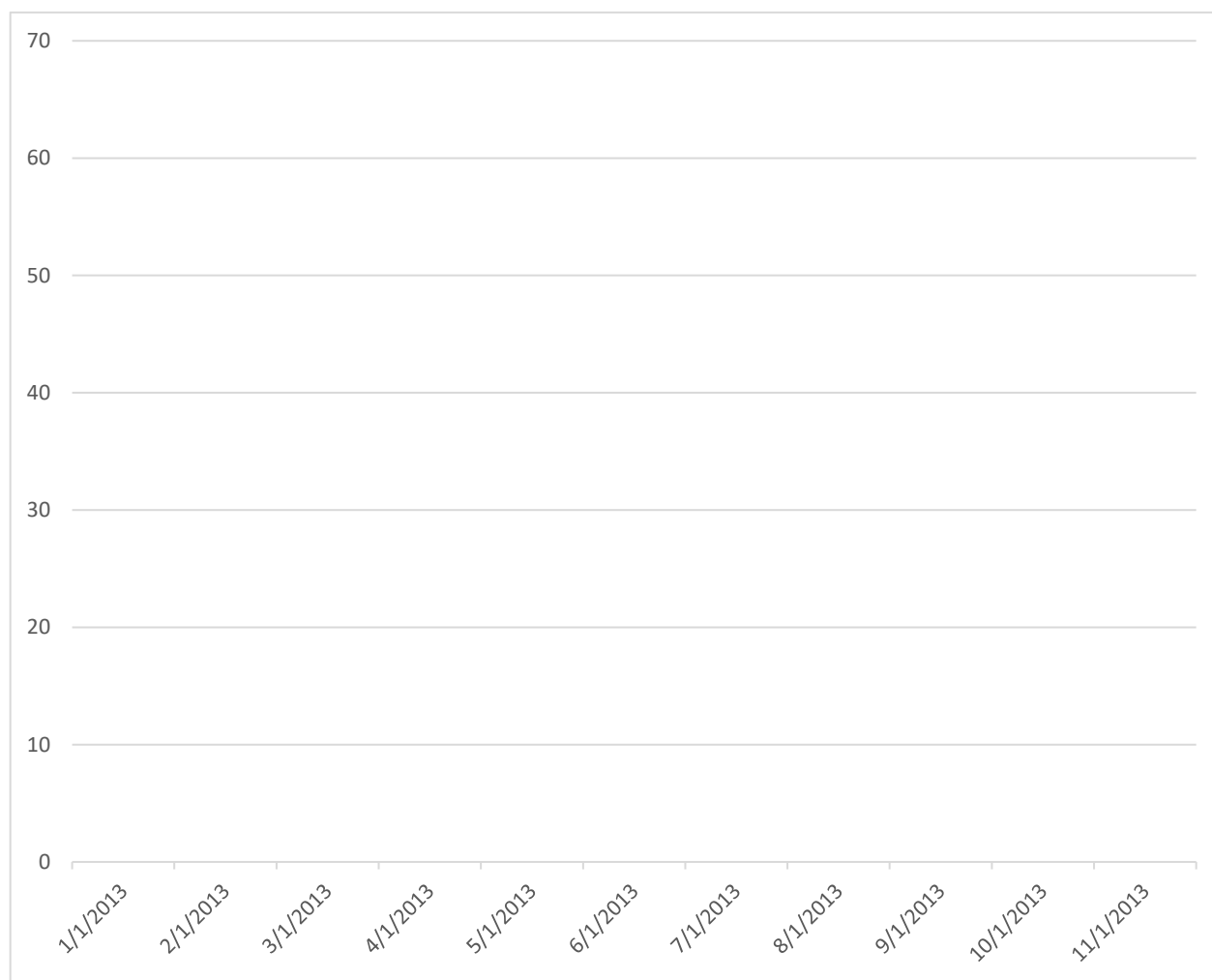
Quadrat 3

Average Annual Burrow Count: \_\_\_\_\_

## Group 2: Year 2013 - Temperature

Group Members: \_\_\_\_\_

**Directions:** Once you have extracted your data from NOAA's Buoy Depository, graph the temperatures to your corresponding year below. Make sure to label your axes!



Average Annual Temperature: \_\_\_\_\_

## Group 2: Year 2013 - Burrows

Group Members: \_\_\_\_\_

**Directions:** Review the three pictures of quadrats in the field. Look for quarter size and oblong fiddler burrows. Count the burrows for each quadrat and graph them below. Make sure to label your axes!



Quadrat 1

Quadrat 2

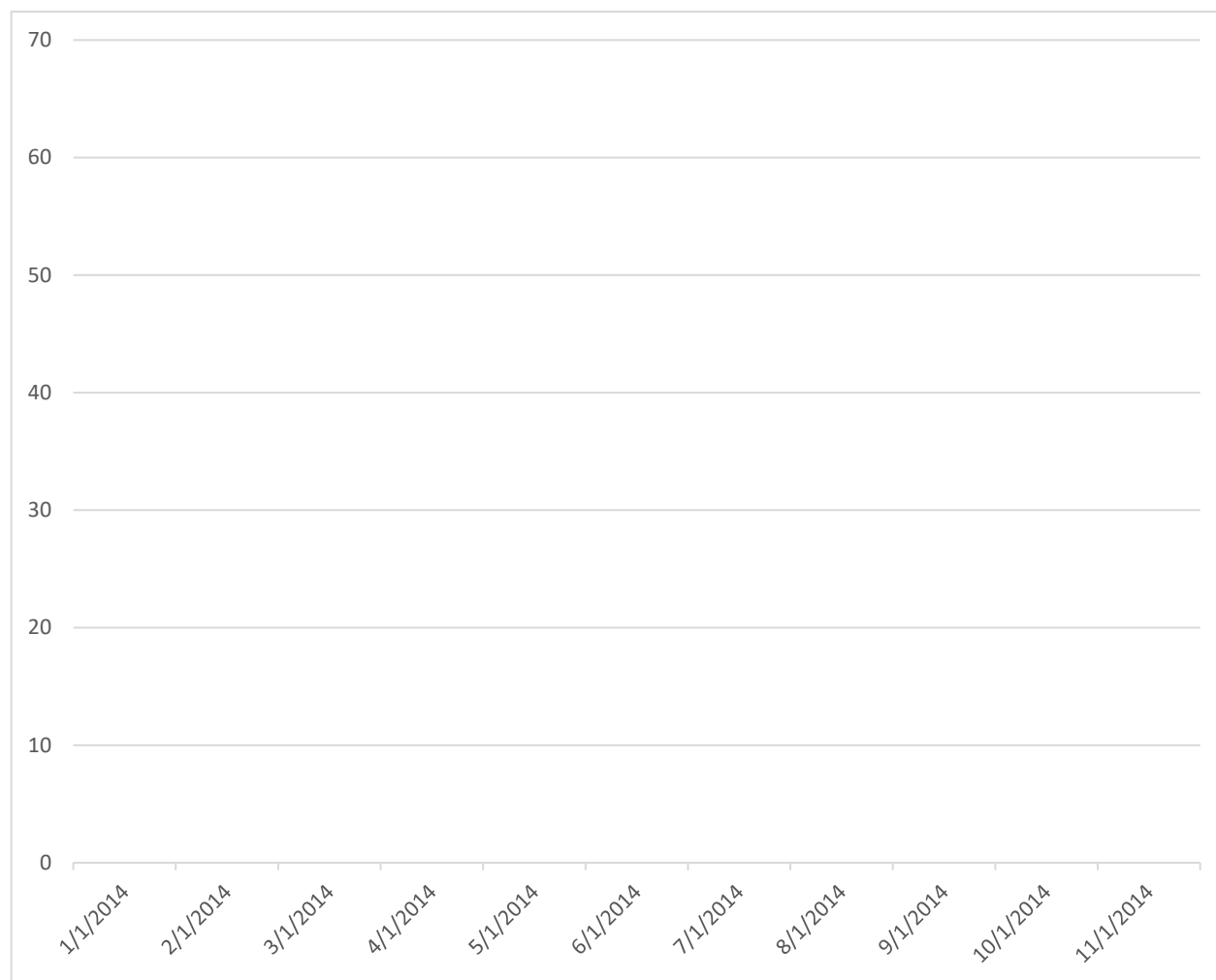
Quadrat 3

Average Annual Burrow Count: \_\_\_\_\_

## Group 3: Year 2014 - Temperature

Group Members: \_\_\_\_\_

**Directions:** Once you have extracted your data from NOAA's Buoy Depository, graph the temperatures to your corresponding year below. Make sure to label your axes!



Average Annual Temperature: \_\_\_\_\_

## Group 3: Year 2014 - Burrows

Group Members: \_\_\_\_\_

**Directions:** Review the three pictures of quadrats in the field. Look for quarter size and oblong fiddler burrows. Count the burrows for each quadrat and graph them below. Make sure to label your axes!



Quadrat 1

Quadrat 2

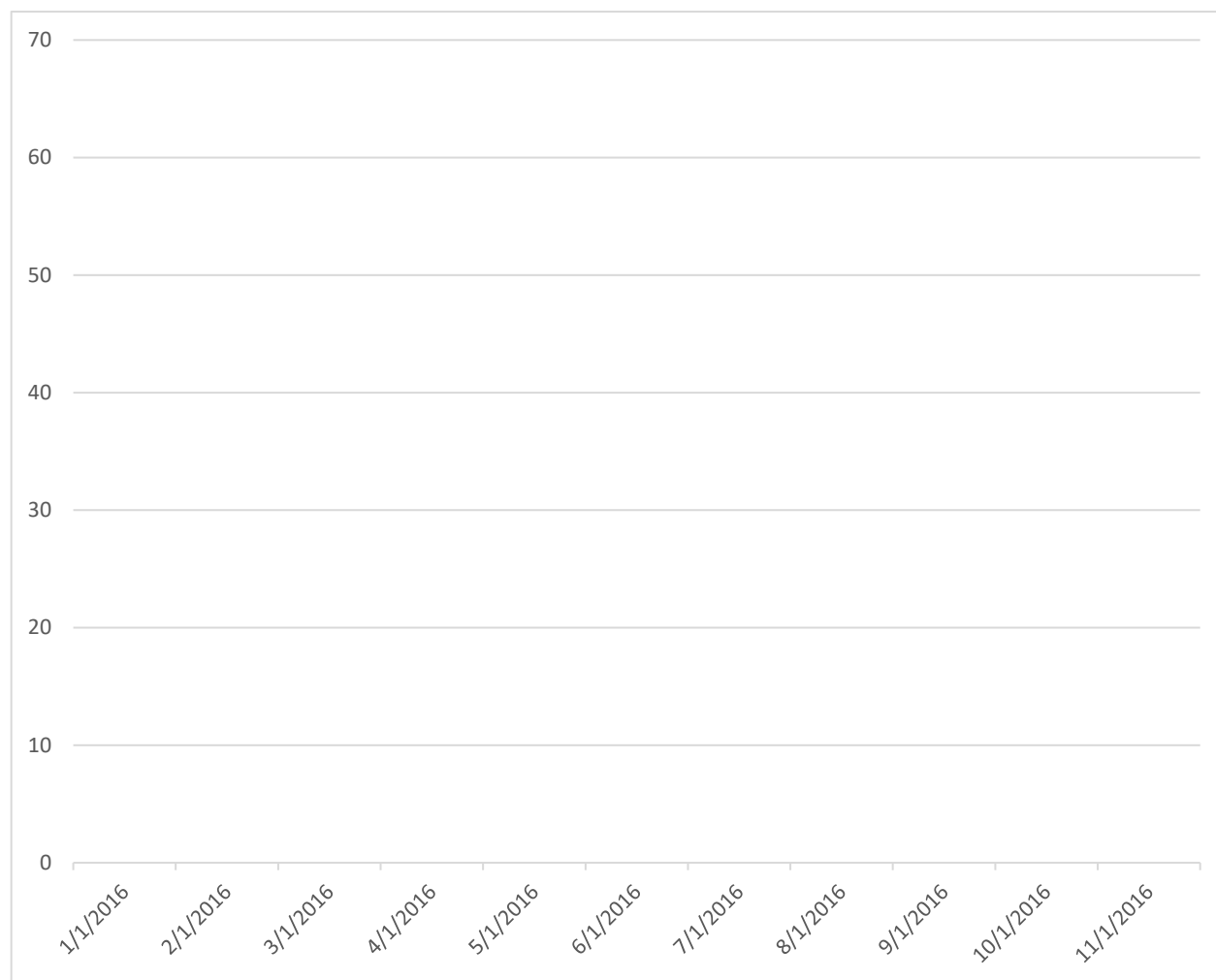
Quadrat 3

Average Annual Burrow Count: \_\_\_\_\_

## Group 4: Year 2016 - Temperature

Group Members: \_\_\_\_\_

**Directions:** Once you have extracted your data from NOAA's Buoy Depository, graph the temperatures to your corresponding year below. Make sure to label your axes!



Average Annual Temperature: \_\_\_\_\_

## Group 4: Year 2016 - Burrows

Group Members: \_\_\_\_\_

**Directions:** Review the three pictures of quadrats in the field. Look for quarter size and oblong fiddler burrows. Count the burrows for each quadrat and graph them below. Make sure to label your axes!



Quadrat 1

Quadrat 2

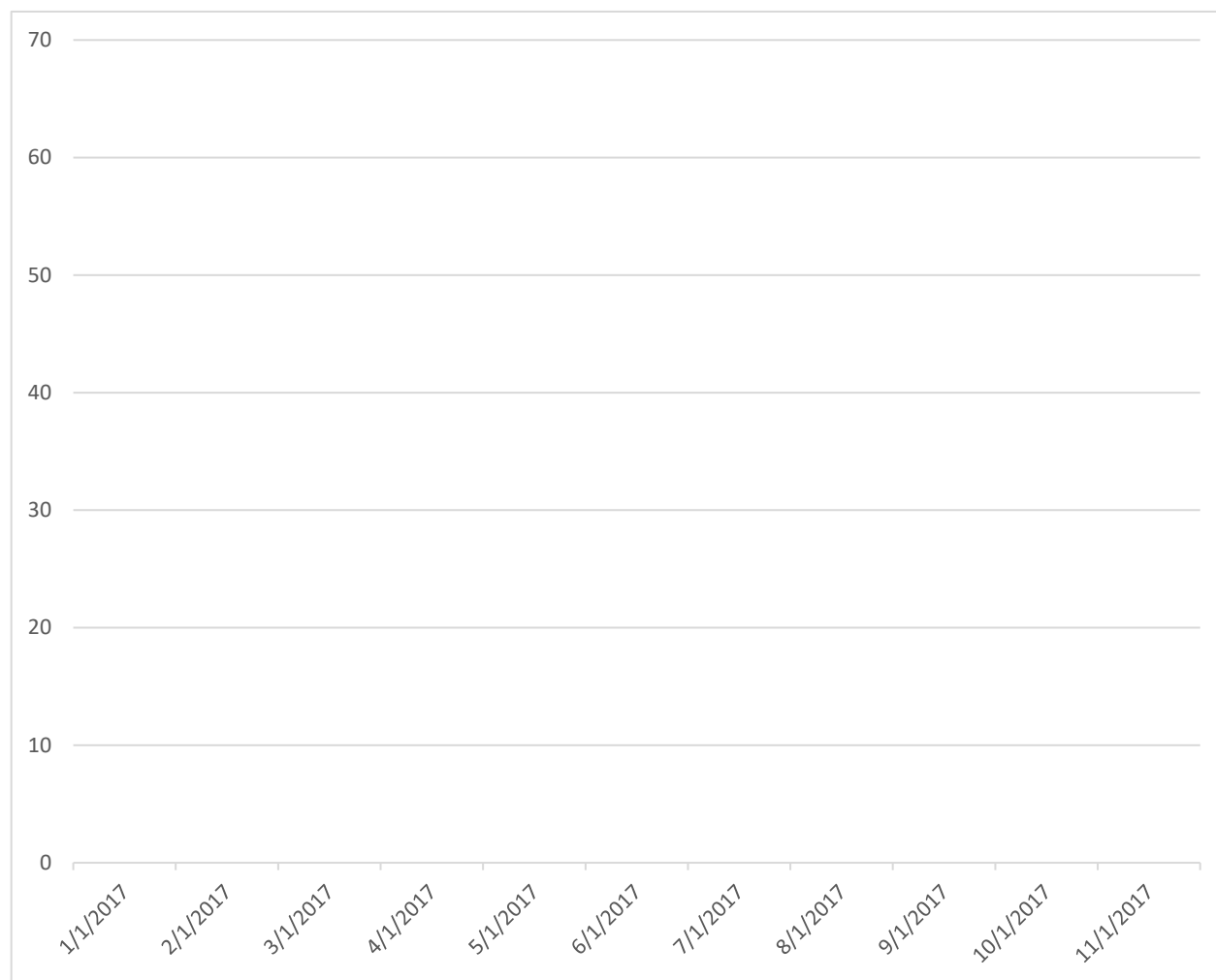
Quadrat 3

Average Annual Burrow Count: \_\_\_\_\_

## Group 5: Year 2017 - Temperature

Group Members: \_\_\_\_\_

**Directions:** Once you have extracted your data from NOAA's Buoy Depository, graph the temperatures to your corresponding year below. Make sure to label your axes!



Average Annual Temperature: \_\_\_\_\_



## Group 5: Year 2017 - Burrows

Group Members: \_\_\_\_\_

**Directions:** Review the three pictures of quadrats in the field. Look for quarter size and oblong fiddler burrows. Count the burrows for each quadrat and graph them below. Make sure to label your axes!



Quadrat 1

Quadrat 2

Quadrat 3

Average Annual Burrow Count: \_\_\_\_\_

# Guided Discussion

**Group Members:** \_\_\_\_\_

**Directions:** Read each question below and discussion potential answer with your group members. Make sure to write down short answer responses.

1. Compare and contrast global climate change and global warming.
2. What are some services that fiddler crabs provide to salt marshes?
3. What was the general trend observed with annual average temperatures?
4. What was the general trend observed with annual average fiddler burrow counts?
5. What are the x and y variables?

Appendix: Monthly Average Temperature Tables

**2012:** Average Temp = 51.84

Months	Monthly Average Water Temperatures (Deg F)
1/1/2012	42.6
2/1/2012	41.7
3/1/2012	43.1
4/1/2012	46
5/1/2012	52.9
6/1/2012	58.5
7/1/2012	60.9
8/1/2012	63.8
9/1/2012	59.8
10/1/2012	54.3
11/1/2012	51.6
12/1/2012	46.9

**2013:** Average Temp = 49.82

Months	Monthly Average Water Temperatures (Deg F)
1/1/2013	40.6
2/1/2013	37.6
3/1/2013	39.1
4/1/2013	44.2
5/1/2013	51.3
6/1/2013	56.8
7/1/2013	63
8/1/2013	59.9
9/1/2013	59.1
10/1/2013	56.6
11/1/2013	47.5
12/1/2013	42.1

**2014:** Average Temp = 49.17

Months	Monthly Average Water Temperatures (Deg F)
1/1/2014	39
2/1/2014	36.1
3/1/2014	37.1
4/1/2014	41.1
5/1/2014	49.8
6/1/2014	57.2
7/1/2014	56.8
8/1/2014	62.1
9/1/2014	61.3
10/1/2014	54.7
11/1/2014	50.7
12/1/2014	44.1

**2016:** Average Temp = 51.73

Months	Monthly Average Water Temperatures (Deg F)
1/1/2016	42.7
2/1/2016	40.4
3/1/2016	42.2
4/1/2016	45.8
5/1/2016	50.7
6/1/2016	56.8
7/1/2016	61.2
8/1/2016	63.3
9/1/2016	61.9
10/1/2016	58.1
11/1/2016	52
12/1/2016	45.6

**2017:** Average Temp = 49.62

<b>Months</b>	<b>Monthly Average Water Temperatures (Deg F)</b>
1/1/2017	42
2/1/2017	39.2
3/1/2017	38.3
4/1/2017	43.3
5/1/2017	49.5
6/1/2017	52.9
7/1/2017	59.2
8/1/2017	60.9
9/1/2017	59.9
10/1/2017	56.5
11/1/2017	48.9
12/1/2017	44.8

## Appendix: Answer Keys

### Fiddler Crab Burrow Counts

#### **Group 1**

Picture #1 – 2 burrows

Picture #2 – 1 burrow

Picture #3 – 2 burrows

Average – 1.67

#### **Group 2**

Picture #1 – 2 burrows

Picture #2 – 3 burrows

Picture #3 – 2 burrows

Average – 2.33

#### **Group 3**

Picture #1 – 3 burrows

Picture #2 – 4 burrows

Picture #3 – 1 burrow

Average – 2.67

#### **Group 4**

Picture #1 – 4 burrows

Picture #2 – 5 burrows

Picture #3 – 5 burrows

Average – 4.67

#### **Group 5**

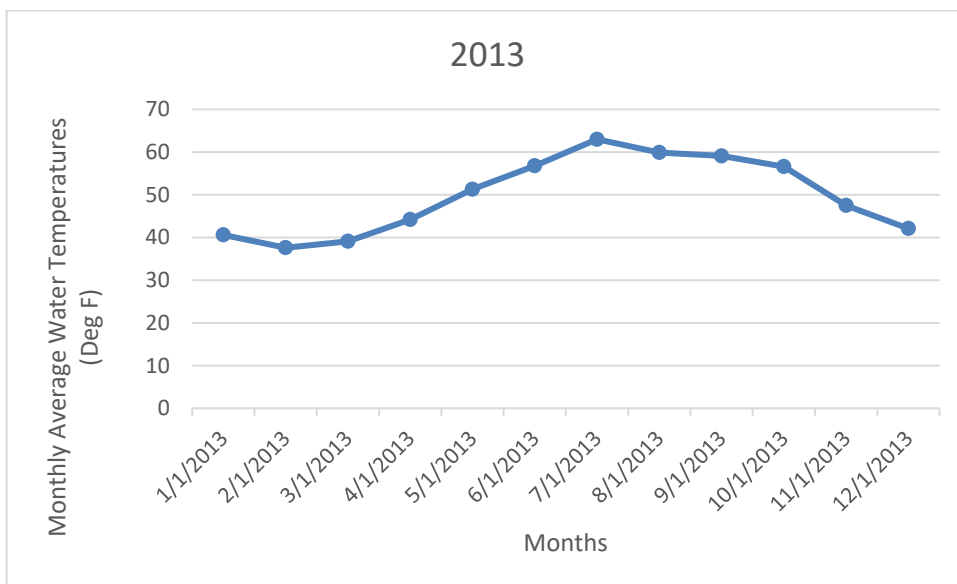
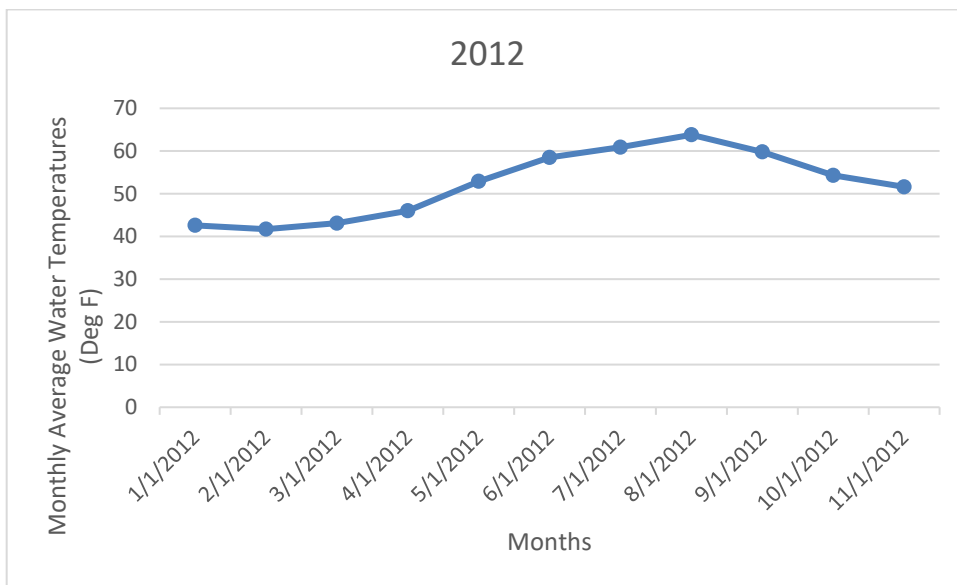
Picture #1 – 4 burrows

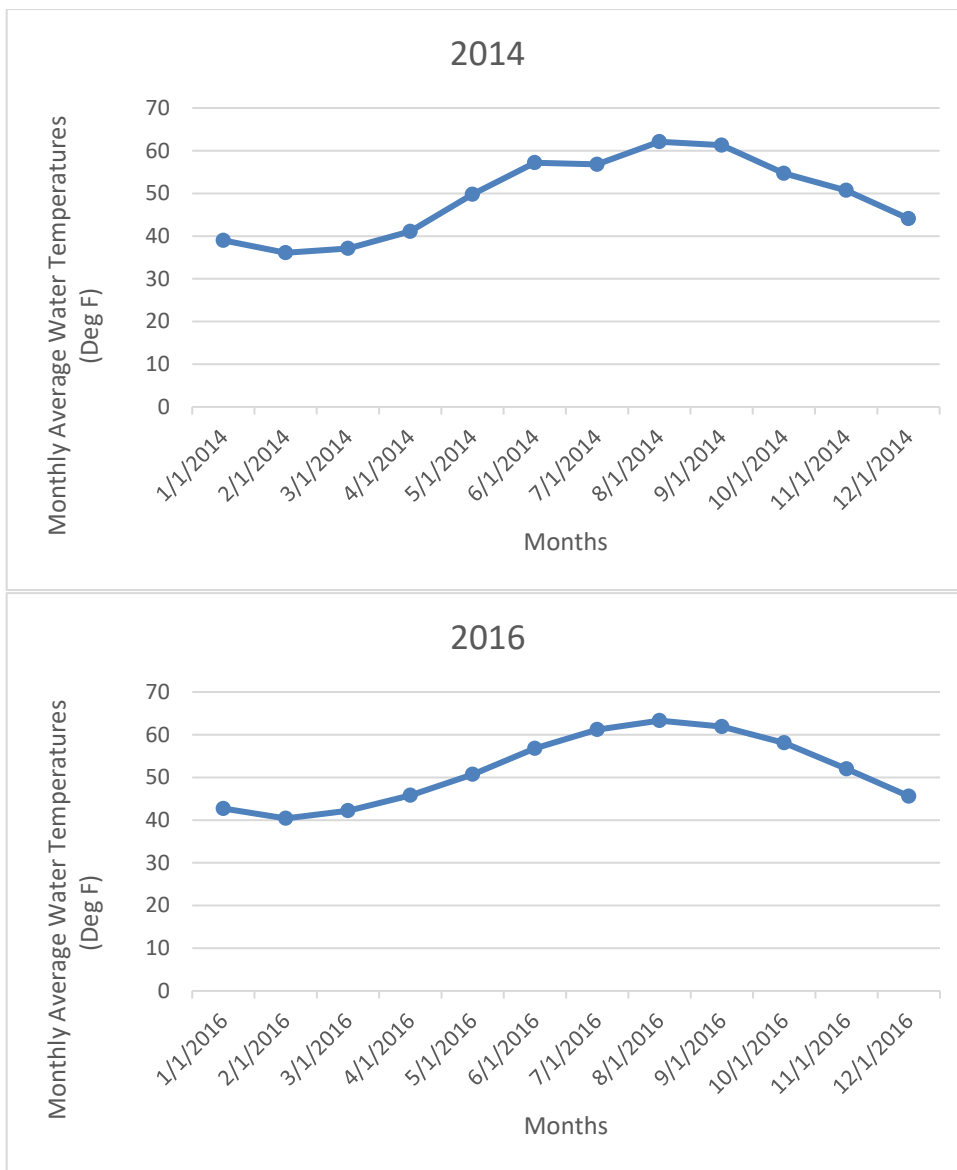
Picture #2 – 7 burrows

Picture #3 – 5 burrows

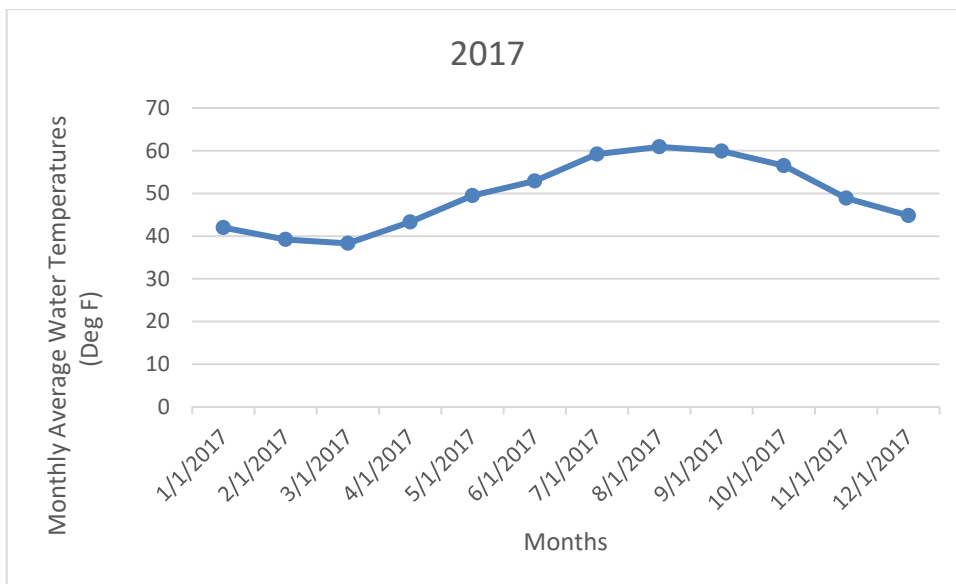
Average – 5.33

### Temperature Graphs with Annual Averages









## Guided Discussion

**Group Members:** \_\_\_\_\_

**Directions:** Read each question below and discussion potential answer with your group members. Make sure to write down short answer responses.

1. Compare and contrast global climate change and global warming.

*Global climate change is a measurable change in climate during different times in the Earth's geologic history. Global warming is the warming of the Earth's atmosphere exclusively due to anthropogenic activities. Both include some impact from humans.*

2. What are some services that fiddler crabs provide to salt marshes?

*Fiddler crabs are detritivores, so they consume dead organic matter in salt marshes. They oxygenate the soils and allow nutrients to easily reach plant roots. They do this by digging into the sediments and acting as bioengineers.*

3. What was the general trend observed with annual average temperatures?

*Annual average temperatures peaked in 2012 and 2016.*

4. What was the general trend observed with annual average fiddler burrow counts?

*Annual average fiddler burrow counts are increasing every passing year.*

5. What are the x and y variables?

*X - variable = Temperature*

*Y - variable = Fiddler burrow counts*