# DATA Nugget

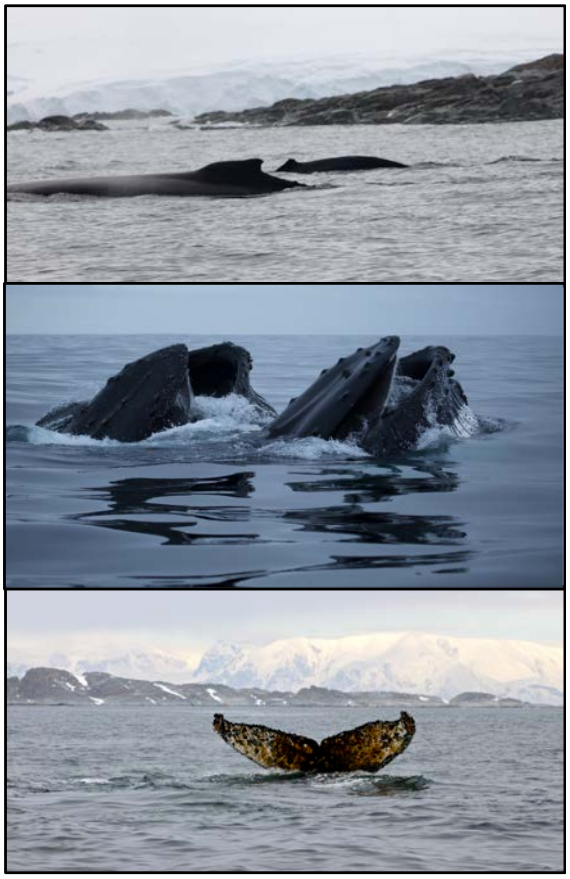
## When whale I sea you again?

Featured scientist: Logan J. Pallin from Oregon State University
Written by: Alexis Custer

*Research Background:*

People have hunted whales for over 5,000 years for their meat, oil, and blubber. In the 19th and 20th centuries, pressures on whales got even more intense as technology improved and the demand for whale products increased. This **commercial whaling** used to be very common in several countries, including the United States. Humpback whales were easy to hunt because they swim slowly, spend time in bays near the shore, and float when killed. Before commercial whaling, humpback whales were one of the most visible animals in the ocean, but by the end of the 20th century whaling had killed more than 200,000 individuals.

Today, as populations are struggling to recover from whaling, humpback whales are faced with additional challenges due to **climate change**. Their main food source is krill, which are small crustaceans that live under sea ice. As sea ice disappears, the number of krill is getting lower and lower. Humpback whale population recovery may be limited because their main food source is threatened by ongoing ocean warming.



Images of humpback whales at the Palmer Station LTER in the Western Arctic Peninsula. Photo credit: Beth Simmons.

One geographic area that was over-exploited during times of high whaling was the South Shetland Islands along the Western Antarctic Peninsula (WAP). The WAP is in the southern hemisphere in Antarctica. Humpback whales migrate every year from the equator towards the south pole. In summer they travel 25,000 km (16,000 miles) south to WAP's nutrient-rich polar waters to feed, before traveling back to the equator in the winter to breed or give birth. Today the WAP is experiencing one of the fastest rates of regional climate change with an increase in average temperatures of 6˚ C (10.8˚ F) since 1950. Loss of sea ice has been documented in recent years, along with reduced numbers of krill along the WAP.

Logan working at the Palmer Long-Term Ecological Research Field Station.

Logan is a scientist who is studying how humpback whales are recovering after commercial whaling. Logan's work helps keep track of the number of whales that visit the WAP in the summer. He also determines the **sex ratio**, or ratio of males to females, which is important for reproduction. The more females in a population compared to males, the greater the potential for having more baby whales born into the next generation. Logan predicts there may be a general trend of more females than males along the WAP as the season progresses from summer to fall. Logan thinks that female humpback whales stay longer in the WAP because they need to feed more than males in order to have extra nutrients and energy before they birth their babies later in the year. This extra energy will be needed for their milk supply to feed their babies.

Humpback whales only surface for air for a short period of time, making it difficult to determine their sex. In order to identify surfacing whales as female or male, scientists need to collect a **biopsy**, or a sample of living tissue, in order to examine the whale's DNA. Logan worked with a team of scientists at Oregon State University and Duke University to engineer a modified crossbow that could be used to collect samples. Logan uses this crossbow to collect a biopsy sample each time they spot a whale. To collect a sample, Logan aims the crossbow at the whale's back, taking care to avoid the dorsal fin, head, and fluke (tail). He mounts each arrow with a 40mm surgical stainless steel tip and a flotation device so the samples will bounce off the whale and float for collection. The samples are then frozen so they can be stored and brought back to the lab for analysis. Logan also takes pictures of each whale's fluke because each has a pattern unique to that individual, just like the human fingerprint. Additionally, at the time of biopsy, Logan records the pod size (number of whales in the area) and GPS location.

The patterns on a humpback whale's fluke are as distinct as the human fingerprint and can be used to identify individuals.

Once the samples are processed, Logan's data are added to the long-term datasets collected at the WAP. To address his question he used data from 2010-2016 along the WAP and other feeding grounds. Logan's data ranges from January to April because those are the months he is able to spend at the research station in the WAP before it gets too cold. Logan has added to the scientific knowledge we have about whales by building off of and using data collected by other scientists.

**Check for Understanding:** After reading the Research Background, students should be able to answer the following questions:

1. What is Logan curious about? What does he want to know?
   Logan is trying to determine if the number of female and male whales change throughout the season (summer to fall). He wants to understand the recovery of the species after commercial whaling and in the face of a rapidly changing environment.
2. How will Logan's data help scientists understand the recovery of humpback whales?
   Logan's research will demonstrate if female whales stay longer in the WAP than do males. This data can inform future research. For example, other scientists can determine if the females that stay longer along the WAP are pregnant, which will help them better understand the recovery of the species.
3. What data will the scientists collect?
   The scientists will collect skin and blubber samples using a modified crossbow. From these blubber samples the scientists will be able to use DNA to determine the sex of the whale. Note: the scientists first extract DNA, then amplify it using PCR and separate it using gel electrophoresis to determine the sex of each whale biopsied.

**IMPORTANT NOTE:** Remember that the WAP is located in Antarctica and is in the southern hemisphere. This means that for students living in the northern hemisphere the seasons will be reversed from what they are typically used to. Logan's data collected in January represents summer data, and as it moves through April it is getting closer to winter. This is important for student interpretation of the data. Logan predicted that he will see more female whales in the WAP as winter approaches, meaning that he expects the sex ratio and percent of males and females to shift to more female dominated as you look from January to April in the tables and on the graphs.

*Scientific Question*: In what ways does the abundance and/or sex ratio of male and female humpback whales change over the course of the year in the Western Antarctic Peninsula?

*What is the hypothesis?* Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

*Scientific Data:*

**Use the data below to answer the scientific question:**

**Teacher Note:** This activity contains many calculations, so to help students not feel overwhelmed you can use a jigsaw method by splitting students into six groups. Two groups can each analyze the same data and compare findings prior to sharing with the class. Groups 1 and 2 will complete Table 1, Groups 3 and 4 will complete Table 2, and Groups 5 and 6 will complete Table 3. After each group shares their findings, as a class complete Table 4, which averages together all 3 years of data. Individual students should each fill out Tables 1-4 with all of the calculations, and then move on to the *Interpret the Data* section.

**Teacher Note:** The scientists try to go out every day during the field season. However, sometimes bad weather or other reasons prevent them from getting on the water to collect samples. Also, just because the scientists are out on the water trying to find whales does not mean they actually collect samples that day. Therefore, the number of days the scientists collect samples is not the same each month.

It is important to note that the number of days each month that these data are from vary and that may also influence the observed differences among months (beyond actual differences in whale presence/absence). Below is a tally of the number of days they collected data each month/year, which is not necessarily how many days they went out that month/year.

| Number of Days Data are from each Month/Year | | | |
|---|---|---|---|
| | 2014 | 2015 | 2016 |
| January | 8 | 21 | 8 |
| February | 3 | 2 | 13 |
| March | 3 | 4 | 10 |
| April | n/a | n/a | 10 |

Table 1

| Number of humpback whales biopsied in **2014** | | | | |
|---|---|---|---|---|
| | January | February | March | April |
| Female | 33 | 14 | 13 | No data |
| Male | 45 | 17 | 14 | No data |
| Sex Ratio* (male:female) | 45/33 = 1.4 | 17/14 = 1.2 | 14/13 = 1.1 | No data |
| Percent Male and Female | 58% male<br>42% female | 55% male<br>45% female | 52% male<br>48% female | No data |

Table 2

| Number of humpback whales biopsied in **2015** | | | | |
|---|---|---|---|---|
| | January | February | March | April |
| Female | 50 | 3 | 18 | No data |
| Male | 45 | 1 | 11 | No data |
| Sex Ratio (male:female) | 45/50 = 0.9 | 1/3 = 0.3 | 11/18 = 0.6 | No data |
| Percent Male and Female | 47% male<br>53% female | 25% male<br>75% female | 38% male<br>62% female | No data |

Table 3

| Number of humpback whales biopsied in **2016** | | | | |
|---|---|---|---|---|
| | January | February | March | April |
| Female | 15 | 28 | 29 | 41 |
| Male | 14 | 30 | 24 | 19 |
| Sex Ratio (male:female) | 14/15=0.9 | 30/28=1.1 | 24/29=0.8 | 19/41=0.5 |
| Percent Male and Female | 48% male<br>52% female | 52% male<br>48% female | 45% male<br>55% female | 32% male<br>68% female |

Table 4

| **Average** number of humpback whales biopsied from **2014-2016** | | | | |
|---|---|---|---|---|
| | January | February | March | April |
| Average Number Females | 33 | 15 | 20 | 41 |
| Average Number Males | 35 | 16 | 16 | 19 |
| Average Sex Ratio (male:female) | 1.1 | 1.1 | 0.8 | 0.5 |
| Average Percent Male and Female | 51% male<br>49% female | 52% male<br>48% female | 44% male<br>56% female | 32% male<br>68% female |

*Sex ratio is calculated as the number of males, divided by the number of females. The greater the number above 1, the more males there are relative to females. The smaller the number below 1, the more females there are, relative to males. If the number is 1, then there are equal numbers of males and females.

What data will you graph to answer the question?

Independent variable(s): Time of year (January – April) & whale sex (male, female)

Dependent variable(s): Average sex ratio & average abundance

**Check for Understanding:** After taking some time to look at the data tables, have students discuss the question, "What type of graph should you make?" There are many different kinds of graphs, and each is appropriate for different types of data. What type of graph would be most appropriate to make with this data?

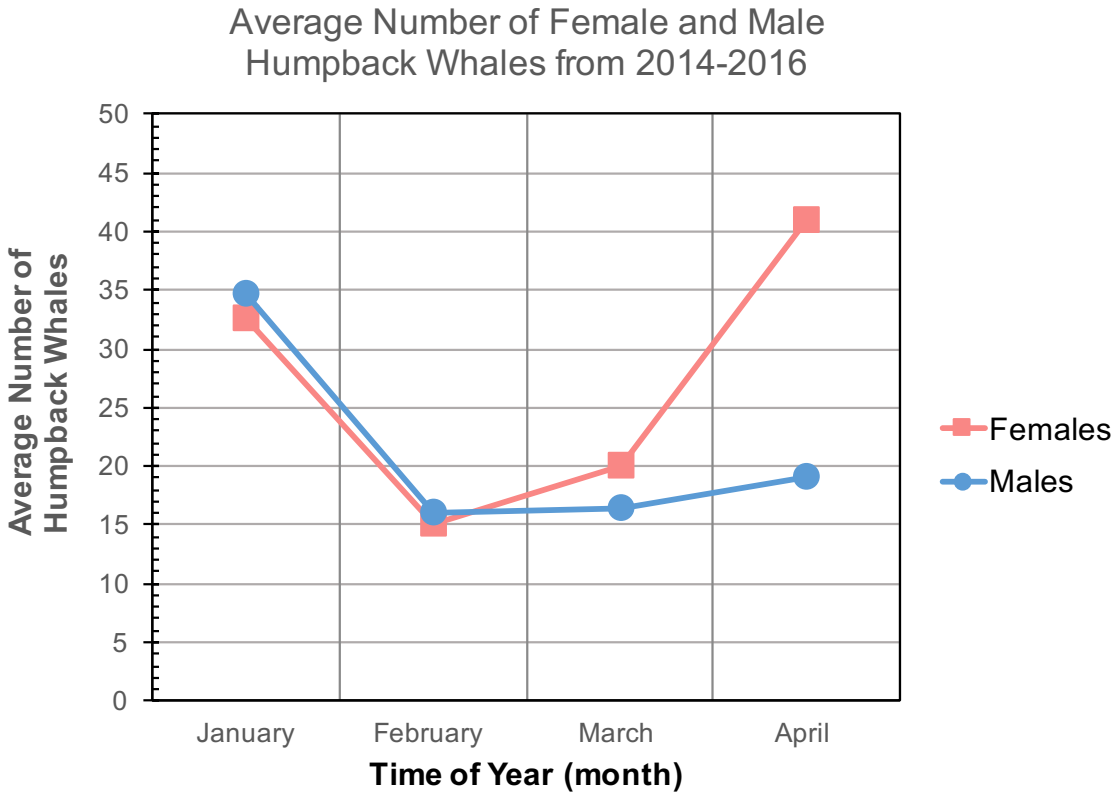
- Histograms - suitable for showing the distribution of continuous data. Breaks data into equal intervals along the x-axis, and gives the frequency of each interval on the y-axis.
- Bar graphs - suitable for when you have a categorical independent and continuous dependent variable. Used to emphasize discrete comparisons among groups. When there are multiple independent variables, make more than one bar graph. When there are multiple dependent variables, put the one you want the viewer to draw the easiest conclusion about on the x-axis, and color code the other and place it in a legend.
- Line graphs - suitable for when you have continuous independent and dependent variables, including changes over time. Used to emphasize x-y trends.
- Pie graphs - suitable for showing data that are parts of a whole (proportional data). Appropriate when comparing relative proportions.
- Divided/stacked bar graphs - suitable for showing data that are parts of a whole (proportional data). Appropriate when comparing both absolute values and proportions.

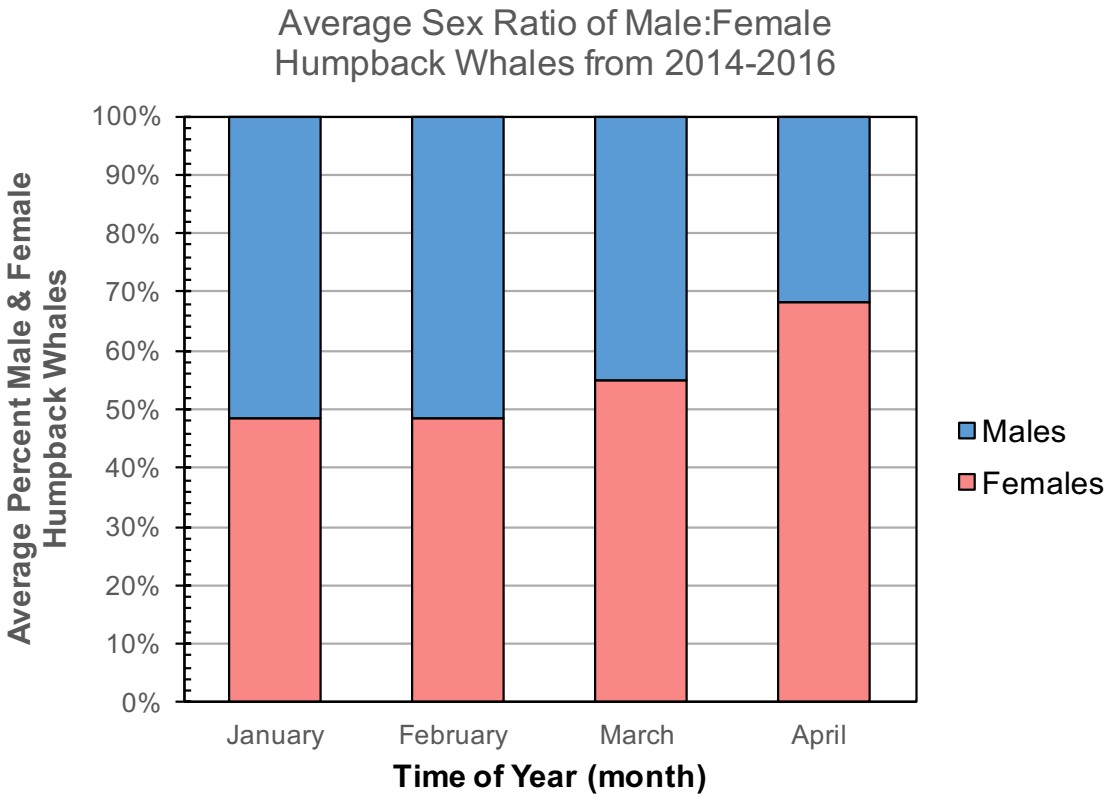
**Teacher Note:** For this activity, students will have to make two different graph types. First, a stacked bar graph can be used to best show the sex ratio and how percent males and females changes over time. Second, a line graph can be used to show how whale abundance changes over time. Students may choose to make up to six graphs – three stacked bar graphs to show sex ratio, one for each year of data collection, and three line graphs to show abundance, one for each year of data collection (Tables 1-3). Or, students can condense these data down into two graphs by using the averaged data across all years (Table 4). You may choose to use the jigsaw method again at this point and have students return to their groups to make the graphs that they worked with to make the tables earlier.

Because stacked bar graphs may be unfamiliar to students you may want to pause and discuss what a stacked bar graph is and why it is useful in examining percentages within categories. Using stacked bars lets students visualize the percentages as part of a whole (for example, 100%) more easily. Students may choose to graph sex ratios (males:females) or percent male and female. Both convey the same data, but percentages may be easier for students to interpret.

**Teacher Copy, Level 4** Name_____

*Draw your graphs below*: Identify any changes, trends, or differences you see in your graphs. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



*Interpret the data:*

Make a claim that answers the scientific question.

As the season changes from Summer (January) to Fall (April) the number of whales, and the percent male and female whales, changes over time. There are the most whales overall in January in the WAP. The sex ratio is mostly balanced from January to March.

What evidence was used to write your claim? Reference specific parts of the tables or graphs.

- The number of whales biopsied along the WAP decreased from January – March in 2014 (Females: 33 to 13, Males: 45 to 14) and 2015 (Females: 50 to 8, Males: 45 to 11).
- The number of whales biopsied along the WAP increased in 2016 from January – April (Females: 15 to 41, Males: 14 to 19).
- In 2016 the scientist team was able to stay into April (early fall) and collect more samples, which we know because they have data from that month.
- In January 2016 they biopsied fewer whales than in 2014 and 2015, but they biopsied more whales in both February and March 2016 than in previous years.
- In April 2016 there were 41 females sampled, which is roughly 10 more than in February or March of that year.
- There are more males in January 2014 & 2015 than females.
- There are more females in March 2015 & 2016 than males.
- The percentage of males decreased from January – March 2014 while the percentage of females increased.
- The percentage of males decreased from January –April 2016 while the percentage of females increased.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the importance of the WAP for whale populations during their yearly migration.

Female whales appear to be staying the WAP longer to feed, compared to male whales who return to the equator earlier in the year and don't stay as long to feed. As the year progresses from summer to fall, there are more females in the WAP, and the population also has a lower male:female ratio. This trend is clear for the averaged data. The trend is not present in the 2015 data, but is seen in 2014 and 2016. The pattern in the data is predominantly driven by one year of April data collected in

2016. Similar data were not collected in 2014 and 2015 and so we do not have the same level of support that we have for months where there are three years of data collection.

Did the data support Logan's hypothesis? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

The data follow Logan's predictions that female whales are staying in the WAP later in the year, which supports the hypothesis that this is because females need to feed longer and build up stores of energy and nutrients that they will use to feed/nurse their babies in the winter by the equator. The reason this could be occurring is because the females that are present are either pregnant and staying longer to feed to sustain their pregnancy prior to traveling back towards the equator to give birth or they have a calf with them that they are nursing or are trying to "fatten up" to sustain the journey back. Logan's observations are not able to tell us conclusively why there are more females in the WAP later in the year, but it is consistent with this hypothesis. Also, more data points in April would make this data more convincing.

**Teacher Note:** After students have begun to discuss limitations in the data, and whether they found the experiment conclusive, integrate a conversation about the complications and difficulties of studying a species such as the humpback whale.

- Because they are such a sensitive species, and populations in the WAP are so important to their recovery from the effects of whaling, research must be done in a safe and humane way. Today whales are still facing the dual challenges of recovering from near extinction in a rapidly changing ecosystem.
- Unpredictable weather along the WAP causes huge restrictions in when scientists can go out into boats and conduct their sampling. February 2015 has fewer number of whales biopsied than any other month or year sampled due to inclement weather conditions which prevented the scientists from collecting samples, rather than from there not being many humpback whales present around the WAP.
- Estimating numbers of sea organisms that are foraging is difficult. Whales may be under water feeding when the scientists are in the area. Some whales may be more curious and surface more when boats are in the area, and thereby get biopsied more than once, which would not be known until the sample is brought back to the lab and a genetic fingerprint is run.

**Teacher Note:** Before moving on to the next section, have a class discussion about the significance of scientists collecting long-term data. This research took place at the Palmer Station Long Term Ecological Research (LTER) site. Whale scientists, marine mammologists, working on the Palmer LTER project are interested in "understanding the life history, population structure, and foraging ecology of these krill predators. Through a combination of visual surveys, photographic identification, skin and blubber biopsy sampling, long-term satellite-linked tagging, and short-term multi-sensor behavioral tagging we will begin to understand the recovery of these ocean giants and their ecological role in a changing environment."

Ask students to look at the three years of data. Would their conclusions differ if they only had one year of data instead of three? Do they think more data would be needed to fully address Logan's questions, like more data in April? This could be a good way to transition to their ideas on the questions that they would like to ask next in this system.

*Your next steps as a scientist:* Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer your question?

Since Logan is interested in the recovery of the species he also wants to know if the females are pregnant when they are feeding in the WAP. To determine this, he is examining the biopsy samples he collects for signs of pregnancy indicated by increased levels of progesterone. Knowing the number of pregnant females will help Logan better understand the recovery of Humpback whales.

While we can see general trends, it is important to remember that we are only able to analyze 3 years of data, and in one of those years data were collected for an extra month when it wasn't collected in previous years, meaning it is impossible to compare those data with data from the past. If it was possible for Logan to remain at Palmer Station in the WAP later in the year, he could determine how many males and females remained later in the season.

Logan is therefore also analyzing the data collected of hormone levels collected from tissue samples for pregnancy rates. These data will give an indication to the number of pregnant females present in April along the WAP. In future seasons, it would be beneficial to try and stay for the month of April and possibly May to help with our understanding of humpback whale foraging behavior in relationship to their life cycles (pregnancies). Logan plans to do this as long as the weather cooperates!

An isotope analysis could also be completed on the whales to determine if they are primarily eating krill as previously

thought or if another food sources is important to their diet along the WAP for longer periods of time.

Sea ice data could be analyzed in conjunction with the number of krill present (krill are sea ice dependent for development). This could be compared to the amount of krill a whale eats.

Whales from several breeding grounds travel to the WAP to forage January- April. Analysis of their genetic makeup might give insight into which populations of humpback whales are recovering the fastest since the ban of commercial whaling in 1982.

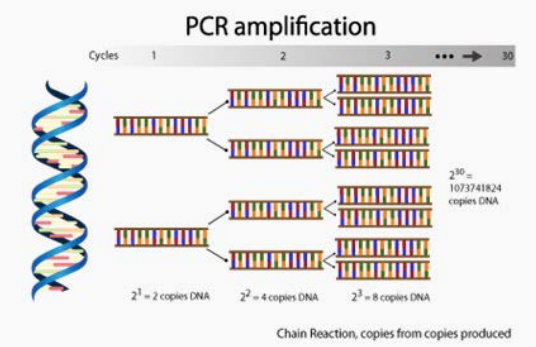
In future years tagging devices could be placed on whales biopsied in January that geo-locate them through the summer season and on their journey back towards the equator. From this information future research teams could see:

- Where the whales are feeding – is WAP sea ice retreat and decrease in krill affecting their foraging habits as greatly as expected?
- How long do individuals stay along the WAP? When do they begin to migrate back towards the equator?
- Which breeding grounds do they travel back to?

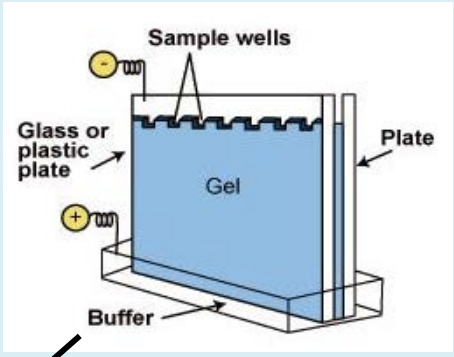
**Teacher Note:** This activity can be easily integrated as part of a molecular unit on DNA. For example, it can be easily paired with a lab activity where students extract DNA from strawberries or bananas. This activity further allows the teacher to illustrate how scientists might use a particular lab technique that students are learning in class. For example, Logan's use of polymerase chain reaction (PCR) and Gel Electrophoresis to understand the recovery a species.

In addition, this activity can help address student misconceptions that arise when learning about DNA sequences and mutation. Often when DNA and molecular genetics are taught the focus is on "mistakes/negative mutations" or crime scene investigations. Students can see in this data that variation in DNA code helps Logan distinguish individual whales from each other, as well as determine whether an individual is male or female. The mutations are not deleterious in any way; they simply represent the DNA sequence that an individual inherited and the random mutations that occur when cells divide.

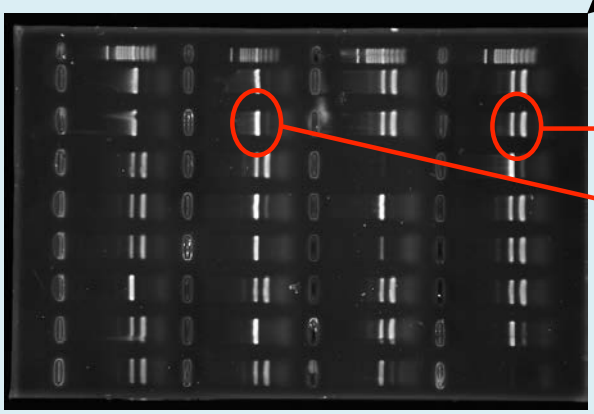
For details on how Logan uses PCR on his biopsy samples, you can have students read the following passage: *To determine the sex of the whale, sex specific markers of DNA are amplified using polymerase chase reaction (ZFY for males and ZFX for females). ZFY and ZFX are transcription factors that code for sex specific genes on the Y and X chromosomes that can be amplified. The polymerase chain reaction used in biotechnology is a synthetic process that mimics DNA polymerase used to replicate our DNA prior to cell division taking place (Step 1). The process of PCR is able to create hundreds of copies of a small section of DNA very quickly. Once the DNA is amplified it is placed into an agarose gel, which has an electrical current run through it (Step 2). DNA is negative and will migrate towards the positive side of the agarose gel. Females are XX and males are XY, on the gel this will appear as two distinct bands for males and only band for females (Step 3).*




Step 1: PCR the biopsied sample




Step 2: run the sample through an agarose gel




Step 3: analyze gel to determine the sex of each biopsy sample.

**Additional teacher resources related to this Data Nugget:**

To see more images of humpback whales, and the Palmer Research Station in the WAP where Logan works, check out this PowerPoint. This can be shared with students in class after they read the Research Background and before they move on to the data: http://datanuggets.org/wp-content/uploads/2017/11/Palmer-LTER-whale-images.ppt

More data from this region can be found on the DataZoo, Palmer LTER's online data portal. To access data on this portal, follow instructions found on the following "cheat sheet". For files that have been compiled for educators, check out the following Google Drive folder:

- DataZoo cheat sheet - https://docs.google.com/document/d/1X5yQjJwKH39Vy3Jv1-aeOI2zD6kkjtlKIqoBr7MP9ic/edit?usp=sharing
- Google Drive folder of data - https://drive.google.com/drive/folders/0B53yDSDFWmzSc2dRdTdfQU0tWlk

For his research, Logan has traveled to United States Antarctic Programs' Palmer Research Station on the WAP during the austral summer and fall and will be departing again for the WAP in January 2018. He is part of a team of scientists interested in Palmer Long Term Ecological Research (http://pal.lternet.edu/), which is funded through the National Science Foundation, documenting changes on in the Antarctic ecosystem.

For more information on whale research at Palmer Station LTER and the WAP: http://pal.lternet.edu/research/components-labs/cetacean-component

For additional classroom activities dealing with Palmer Station LTER data: http://pal.lternet.edu/education/instructional-materials-resources/data-in-the-classroom

The International Whaling Commission (IWC) was created in 1946 in Washington D.C. in hopes to provide conservation to whale stocks around the world. In 1982, the IWC placed a moratorium on commercial whaling. Fore more information on the IWC and humpback whales, check out their website: https://iwc.int/home