DATA *Nugget*

Mangroves on the move

Featured scientists: Candy Feller from the Smithsonian Environmental Research Center and Emily Dangremond from Roosevelt University

Research Background:

All plants need nutrients to grow. Sometimes one nutrient is less abundant than others in a particular environment. This is called a **limiting nutrient**. If the limiting nutrient is given to the plant, the plant will grow in response. For example, if there is plenty of phosphorus, but very little nitrogen, then adding more phosphorus won't help plants grow, but adding more nitrogen will.

Candy (right) and Emily (left) measure the height of a black mangrove growing in the saltmarsh.

Saltmarshes are a common habitat along marine coastlines in North America. Saltmarsh plants get nutrients from both the soil and the seawater that comes in with the tides. In these areas, fertilizers from farms and lawns often end up in the water, adding lots of nutrients that become available to coastal plants. These fertilizers may contain the limiting nutrients that plants need, helping them grow faster and more densely.

One day while Candy, a scientist, was out in a saltmarsh in northern Florida, she noticed something that shouldn't be there. There was a plant out of place. Normally, saltmarshes in that area are full of grasses and other small plants—there are no trees or woody shrubs. But the plant that Candy noticed was a mangrove. **Mangroves** are woody plants that can live in saltwater, but are usually only found in tropical places that are very warm. Candy thought the closest mangrove was miles away in the warmer southern parts of Florida. What was this little shrub doing so far from home? The more that Candy and her colleague Emily looked, the more mangroves they found in places they had not been before.

Teacher Note: You can take this time to connect the research to the theme of primary productivity. Primary productivity is the rate at which plants and other photosynthetic organisms produce organic compounds (biomass). In this study, the primary productivity, or amount of plant growth, is measured using plant height and percent cover.

Primary productivity can be stimulated by nutrient addition or fertilization – this is the same reason we often add fertilizer to soil to help crops grow. Candy knew that in other coastal places, extra nutrients in seawater could come in with the tides and act as fertilizers for plants by delivering their limiting nutrients. In salt marshes, the limiting nutrient can change – sometimes nitrogen (N) is the limiting nutrient, sometimes the limiting nutrient is phosphorus (P), and sometimes it is another nutrient.

Candy thought that, in addition to warmer weather, extra nutrients could be helping the mangroves live in this unexpected place. Candy expected that mangroves would grow taller and become more dominant when given their limiting nutrient, but did not know which nutrient was limiting at this particular place.

Candy and Emily wondered why mangroves were starting to pop up in northern Florida. Previous research has shown nitrogen and phosphorus are often the limiting nutrients in saltmarshes. <u>They thought that fertilizers being washed into the ocean have made nitrogen or phosphorus available for mangroves, allowing them to grow in that area for the first time</u>. So, Candy and Emily designed an experiment to figure out which nutrient was limiting for saltmarsh plants.

For their study, Candy and Emily chose to focus on black mangroves and **saltwort** plants. These two species are often found growing together, and mangroves have to compete with saltwort. Candy and Emily found a saltmarsh near St. Augustine, Florida, in which they could set up an experiment. They set up 12 plots that contained both black mangrove and saltwort. Each plot had one mangrove plant and multiple smaller saltwort plants. That way, when they added nutrients to the plots they could compare the responses of mangroves with the responses of saltwort.

To each of the 12 plots they applied one of three conditions: control (no extra nutrients), nitrogen added, and phosphorus added. They dug two holes in each plot and added the nutrients using fertilizers, which slowly released into the nearby soil. In the case of control plots, they dug the holes but put the soil back without adding fertilizer.

Candy and Emily repeated this process every winter for four years. At the end of four years, they measured **plant height** and **percent cover** for the two species. Percent (%) cover is a way of measuring how densely a plant grows, and is the percentage of a given area that a plant takes up when viewed from above. Candy and Emily measured percent cover in 1x1 meter plots. The cover for each species could vary from 0 to 100%.

<u>Scientific Questions</u>: What is the limiting nutrient for mangroves and saltwort? Is the same nutrient limiting to both species?

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 questions:

Plot	Treatment	Mangrove height (cm)	Saltwort height (cm)	Mangrove % cover	Saltwort % cover
1	Control	69	28	36	29
2	Control	80	32	47	22
3	Control	90	34	60	15
4	Control	108	41	68	9
5	Nitrogen	93	41	63	18
6	Nitrogen	105	46	78	6
7	Nitrogen	112	48	89	3
8	Nitrogen	124	51	94	0
9	Phosphorus	71	23	40	24
10	Phosphorus	81	31	55	22
11	Phosphorus	83	32	64	11
12	Phosphorus	87	38	68	12

		Mean mangrove height (cm)	Mean saltwort height (cm)	Mean mangrove % cover	Mean saltwort % cover
Means	Control	86.8	33.8	52.8	18.8
	Nitrogen	108.5	46.5	81.0	6.8
	Phosphorus	80.5	31.0	56.8	17.3
SE	Control	8.3	2.7	7.1	4.3
	Nitrogen	5.8	2.3	4.5	2.7
	Phosphorus	4.4	2.5	3.9	2.7

**Standard error (SE) tells us how confident we are in our estimate of the mean and depends on the number of replicates in an experiment and the amount of variation in the data. When there is lower replication and higher variation, SE bars are large. A large SE means we are not very confident, while a small SE means we are more confident.*

 Name____________________

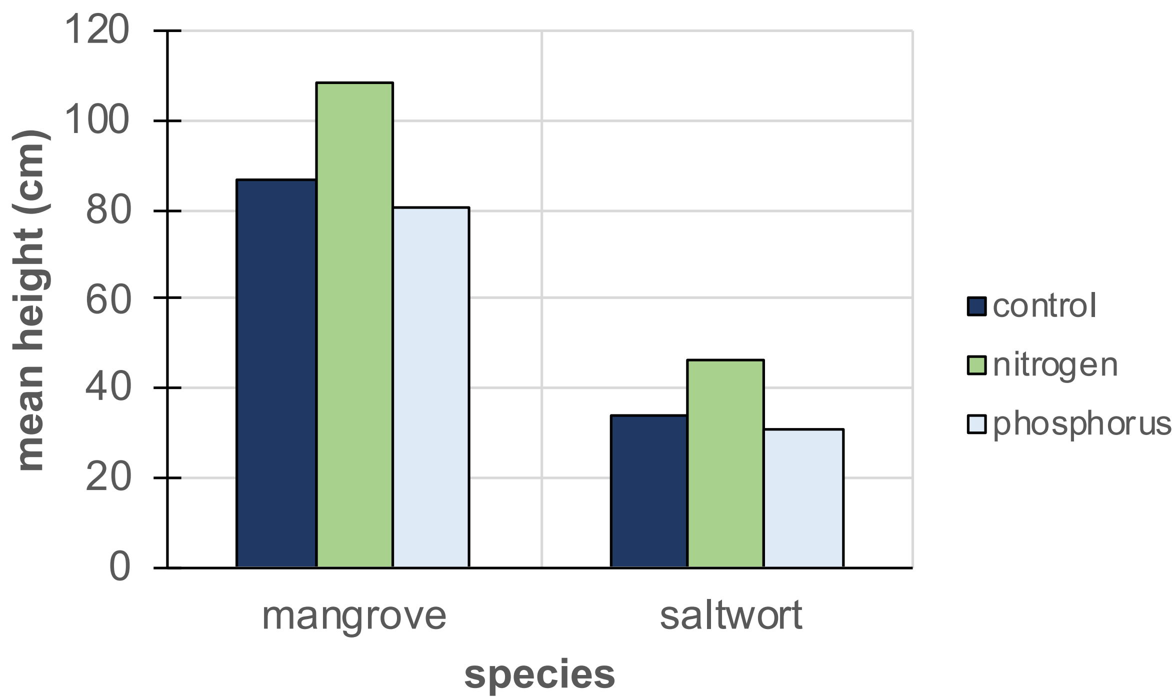
Teacher Note - Error Bars: You can have students add error bars to their graphs to deepen this discussion or remove the SE table for younger students. Error bars based on standard deviation (SD) give us information on the amount of variation in the data. They can be used to draw attention to large or small amounts of variation around the mean. Standard error (SE) is the SD divided by the square root of the study's sample size (SE=SD/√n). Unlike SD, SE reflects the uncertainty in our estimate of the mean. The larger our sample size and the less variation in the data, the more confident we can be in our estimate of the mean. Upper error bars are calculated by adding one SE or SD to the mean, and lower bars are calculated by subtracting one SE or SD from the mean.

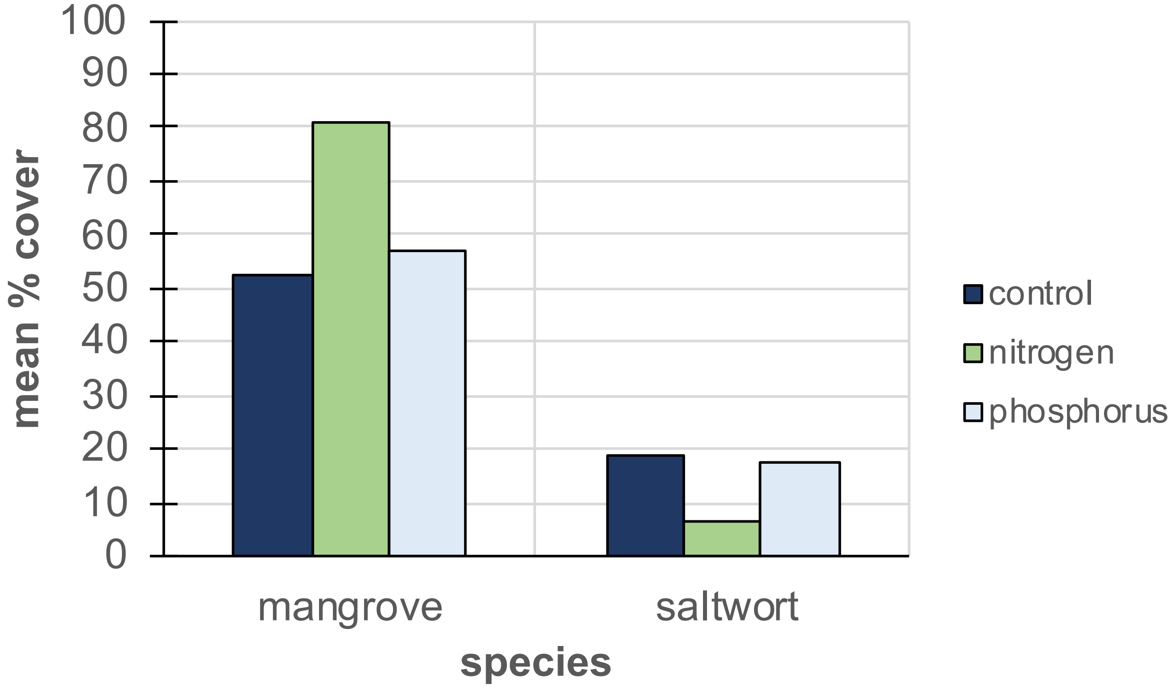
What data will you graph to answer the questions?

Independent variable(s): `nutrient treatment (control, nitrogen, or phosphorus) & plant species (black mangrove, saltwort)`

Dependent variable(s): `height (cm) and percent (%) cover`

Draw your graph(s) below: Identify any changes, trends, or differences you see in your graph(s). 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 each of the scientific questions.

Nitrogen is the limiting nutrient in this site. The same nutrient is limiting to both species of plants.

What evidence was used to write your claims? Reference specific parts of the tables or graph(s).

Teacher Note: To support their claims, students should use mean values for each treatment, and compare across treatments within one species. Students calculate these values and they're found in the second table.

The mean height of mangroves in the nitrogen treatment was 108.5 cm tall, whereas the mean height of mangroves in the control was 86.8 cm and 80.5 cm in the phosphorus plots. Saltwort plants showed a similar trend with mean heights of 33.8 cm (control), 46.5 cm (nitrogen), and 31.0 cm (phosphorus).

The mean percent cover of mangroves was highest in the nitrogen plots (81%), compared to 53% in the control and 57% in the phosphorus plots. The mean percent cover of saltwort was 6.8% in the nitrogen plots, 18.8% in control plots, and 17.3% in phosphorus plots.

Explain your reasoning and why the evidence supports your claims. Connect the data back to what you learned about how limiting nutrients affect plant growth.

Nitrogen is the limiting nutrient for both mangroves and saltwort at this site. We can tell this because adding phosphorus did not change the responses compared to the control plots, but adding nitrogen did increase growth.

Mangroves grew taller and grew more densely than saltwort with or without added nutrients. In the experiment, nitrogen increased the height of both mangroves and saltwort, but mangroves benefitted more than saltwort plants. Additionally, nitrogen causes the percent cover of mangroves to increase and the percent cover of saltwort to decrease.

In this study, the plants were growing in the same location, so these data show that nitrogen is giving mangroves an advantage over saltwort. With the arrival of nitrogen, which relieves nutrient limitation, saltmarshes in northern Florida may be converted to mangrove ecosystems.

Did the data support Candy and Emily’s hypothesis? Use evidence to explain why or why not. If you feel the data was inconclusive, explain why.

The data support Candy and Emily’s hypothesis that addition of limiting nutrients from fertilizers explains why mangroves are growing in northern Florida’s saltmarshes. The first graph shows that nitrogen helps both mangrove and saltwort plants grow taller. The second graph shows that mangroves become even more dominant (take up more space) when nitrogen was added.

However, this study only compared one other species of saltmarsh plant to mangroves, so further experiments might want to look at other species as well. This experiment also only tested one hypothesis, and there could be other reasons that mangroves have started to grow in the area.

Teacher Note: In addition to changing nutrients, another reason mangroves are taking over the saltmarsh is the changing climate. This is an alternative hypothesis that could be tested in future experiments. Northern Florida has a temperate climate with cool winters. When Candy and Emily looked at recent weather records, they realized that the saltmarsh in northern Florida had not experienced a winter freeze for many years. This, along with more nutrients, allowed tropical mangroves to survive winter in a place that is normally too cold.

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

One of the next steps would be to look at how increased nutrients affect reproductive output of mangroves and saltmarsh plants. Do nutrients affect the reproductive output of mangroves or saltmarsh? Do they produce more seeds or more stems (increased density) when fertilized? This would show how fertilizers would affect future generations, not just the plants growing in the saltmarsh at the moment.

Other species of plants could be examined to determine the competitive advantages that may exist in environments where mangroves have and have not already been established.

Another important factor is to compare the level of nutrients added in this study to the level that is observed in the coastal marsh habitats. What are the increases due to chemical runoff and how do the results from this study relate to what exists? Long-term data on nutrient availability would be useful for researchers to know how fast the limiting nutrient is increasing.

Another avenue of research could focus on climate. Will warming temperatures favor mangrove or saltmarsh growth? Which will have a competitive advantage over the other? Will warming change the reproductive output and population growth rates of one species over another? We know that mangroves have been able to grow in areas they don't usually because of fewer freezes. What happens if there is a freeze? Would all the mangroves die, or could they resprout and grow back? Are there any special adaptations in the mangrove's leaves and stems to freeze?

Additional teacher resources related to this Data Nugget:

The data presented here have been published:
https://link.springer.com/article/10.1007/s10021-019-00441-2

A video on a warming experiment in the mangrove-saltmarsh ecotone:
https://www.pbs.org/newshour/show/climate-change-pushes-floridas-mangroves-north

This experiment was set up in the Guana-Tolomato-Matanzas National Estuarine Research Reserve. For more information on this location, students can visit their website.
https://gtmnerr.org