Phytoplankton Responses During an Upwelling Cycle

PUPCYCLE II

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Lesson Development Funded by NSF
#OCE1751805

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Background Information

Scientists from 13 research institutions across the US, Canada, and Israel participated in a 2-week expedition in the North Pacific aboard the research vessel Sally Ride.

The researchers were investigating the responses of plankton to upwelling cycles along the northwest coast of the United States.

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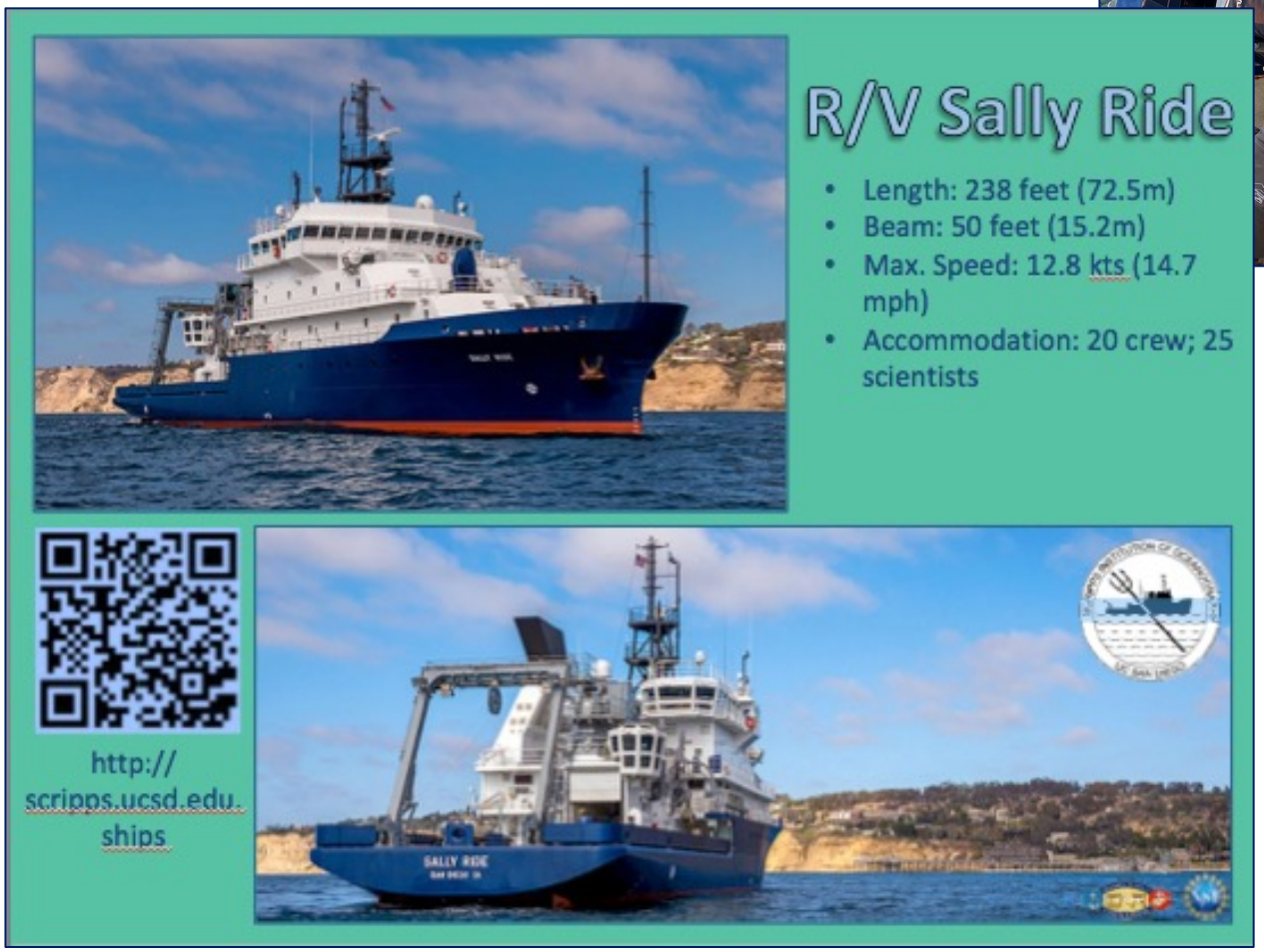
Background Information

Scientists collect seawater samples collected during a CTD cast.



Link to Video: https://youtu.be/OWz2iywtzvI

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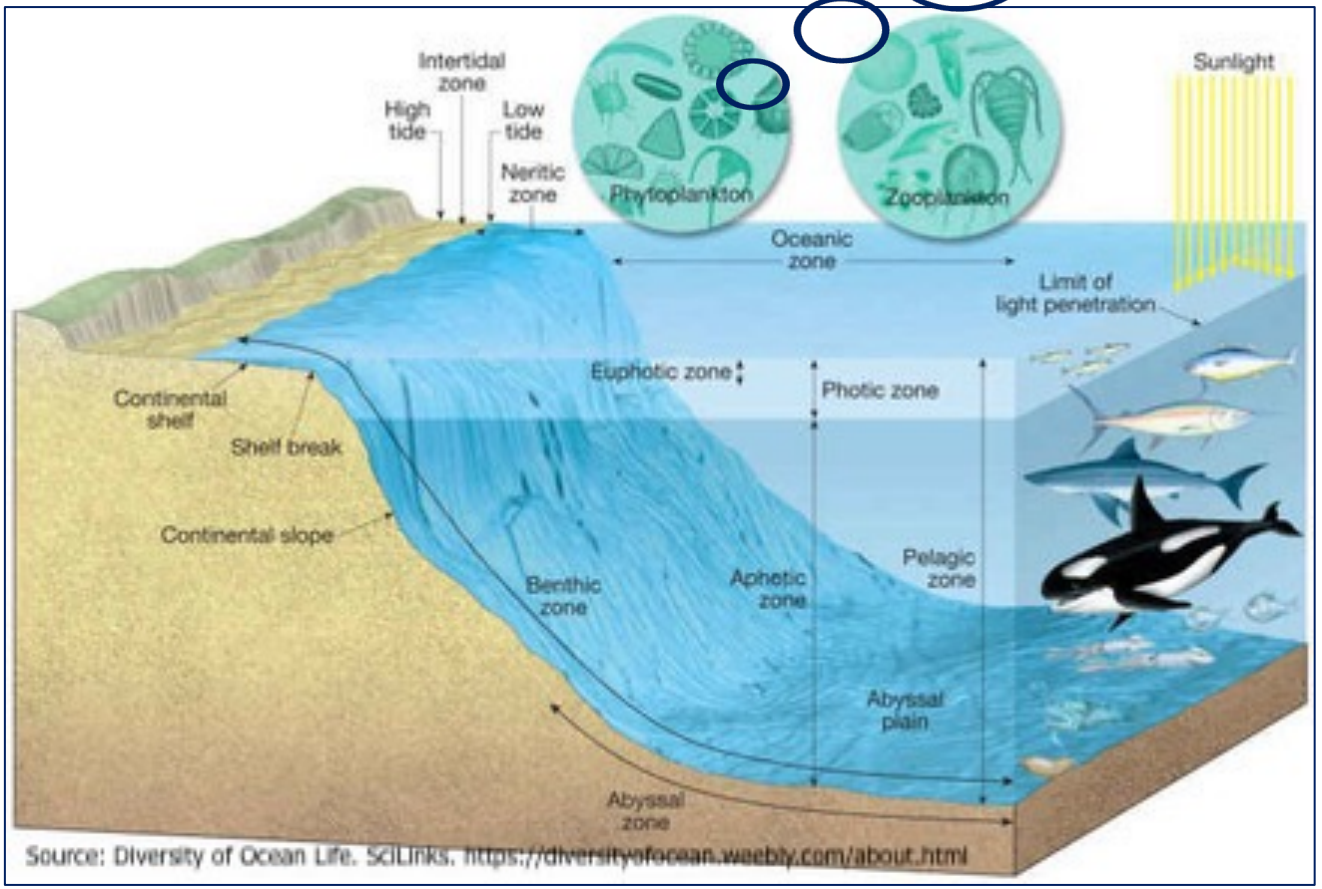
Background Information

Phytoplankton provide 50% of the oxygen we breathe!

Plankton are classified as Phytoplankton (plant drifters) or Zooplankton (animal drifters) and form the base for the aquatic food.

Like land plants, Phytoplankton need sunlight to perform photosynthesis.



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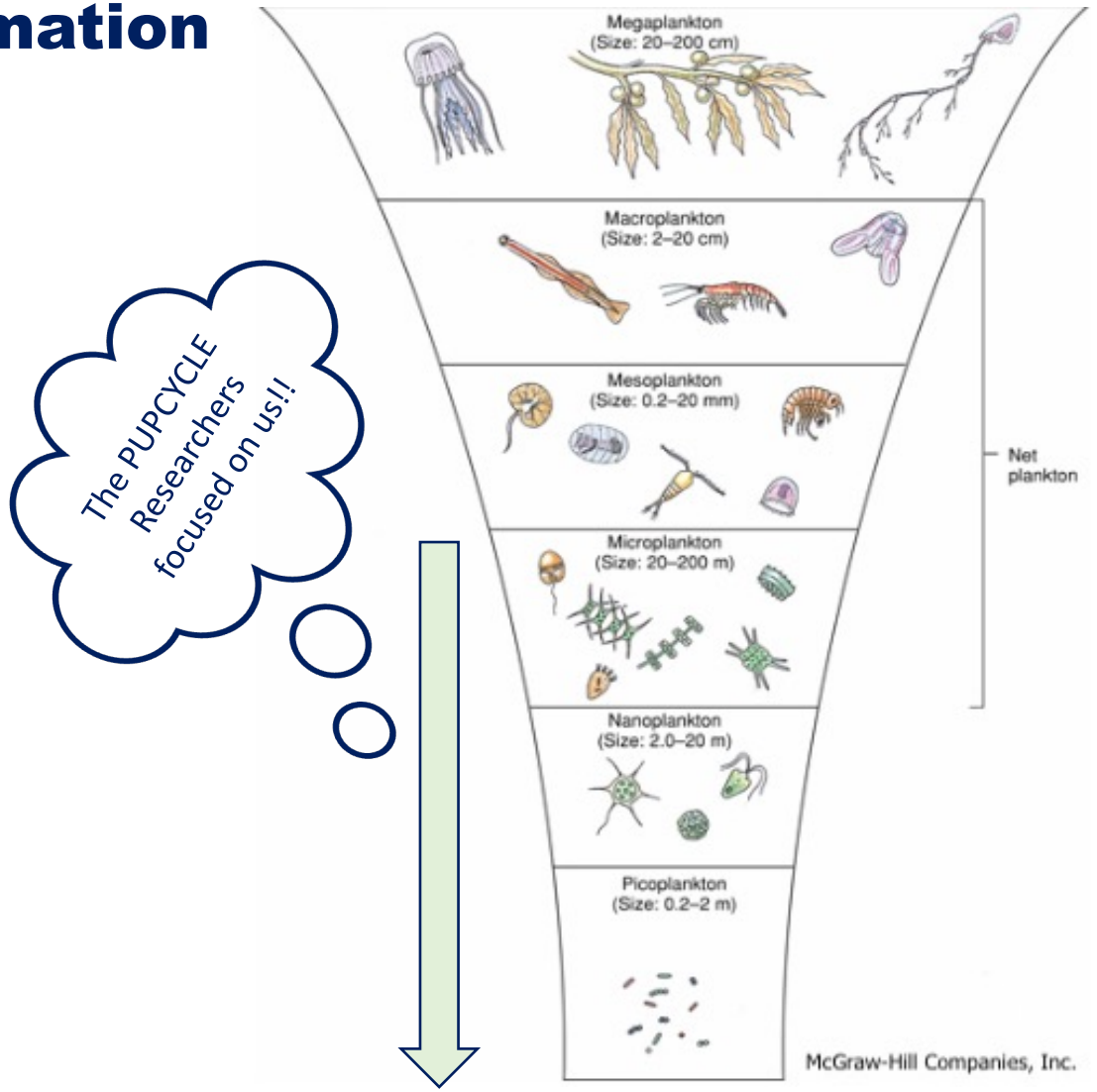
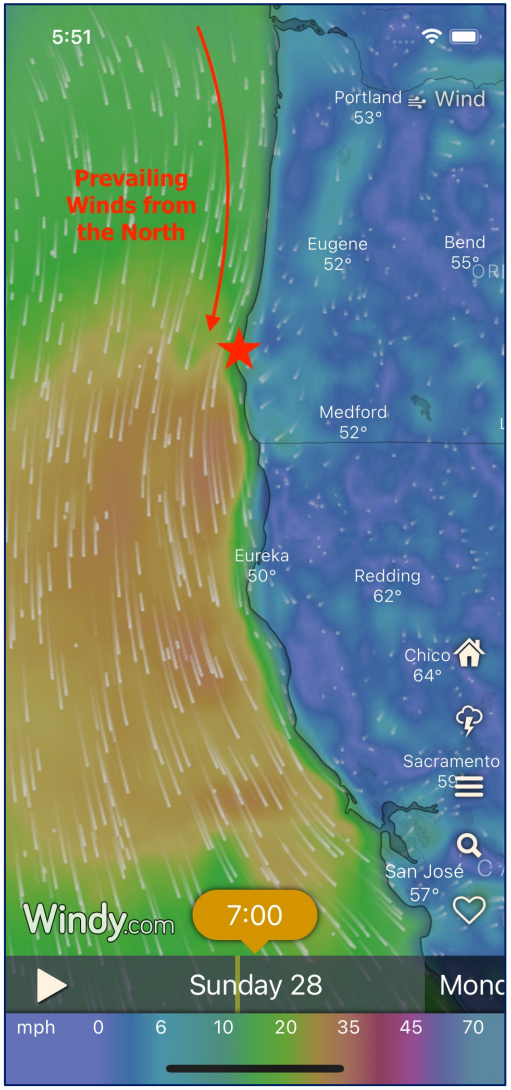
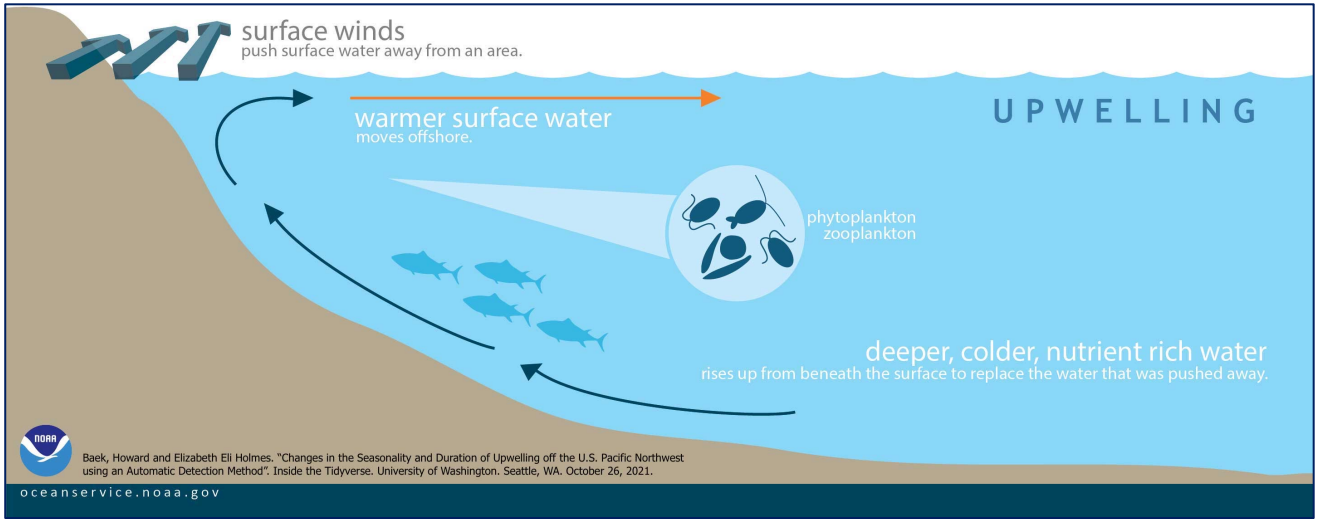
Background Information

"Plankton" means drifter. Phytoplankton and Zooplankton drift with the ocean currents and are found in a variety of sizes.



Background Information





Winds blowing along the shore push warm surface water away and allow the deeper, colder water to reach the surface.

Deeper waters have more nutrients.

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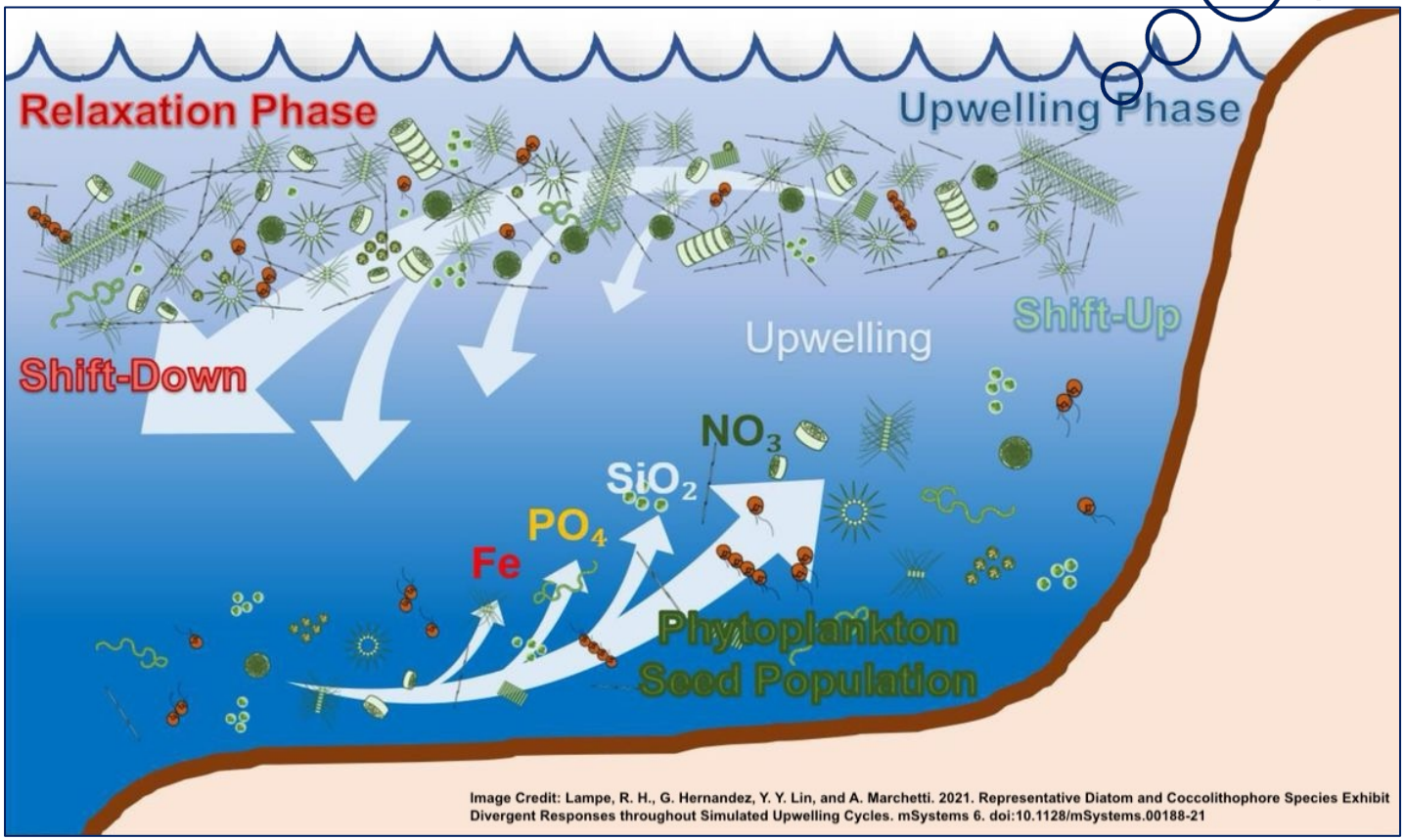
Background Information

Here comes the Nutrient Buffet!!!

Buffet is over!



Upwelling brings nutrient-rich water toward the surface

Phytoplankton Responses During an Upwelling Cycle

Data Collection

Each research team is analyzing samples of seawater for specific nutrients and phytoplankton.

Seawater Samples Collection

Phytoplankton Responses During an Upwelling Cycle

Different size filters are used to trap the specific organisms (”cells”) being analyzed by the researchers.

Phytoplankton (Cells) Filtration

Link to video: https://youtu.be/1Vae50UEOMo

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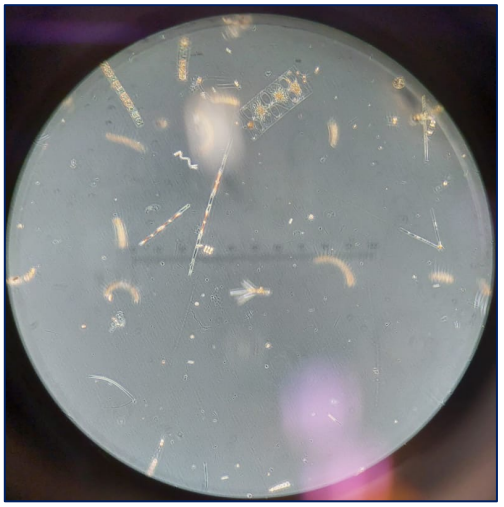
Phytoplankton Responses During an Upwelling Cycle

The cells/phytoplankton trapped on the filters will be frozen and stored onboard for RNA analysis back at the university.

RNA analyses will tell the scientists how the phytoplankton are responding to the nutrients provided during the upwelling cycle.

We make art on the filters!!



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Phytoplankton Responses During an Upwelling Cycle

Chlorophyl is an indicator of primary productivity by phytoplankton. High levels of chlorophyl (CHLA) = High levels of photosynthesis.

Chlorophyl Filtration

Link to Video: https://youtu.be/O_t5XOWl7Bc

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Phytoplankton Responses During an Upwelling Cycle

Data Analysis

Some of us build our homes with Silicates

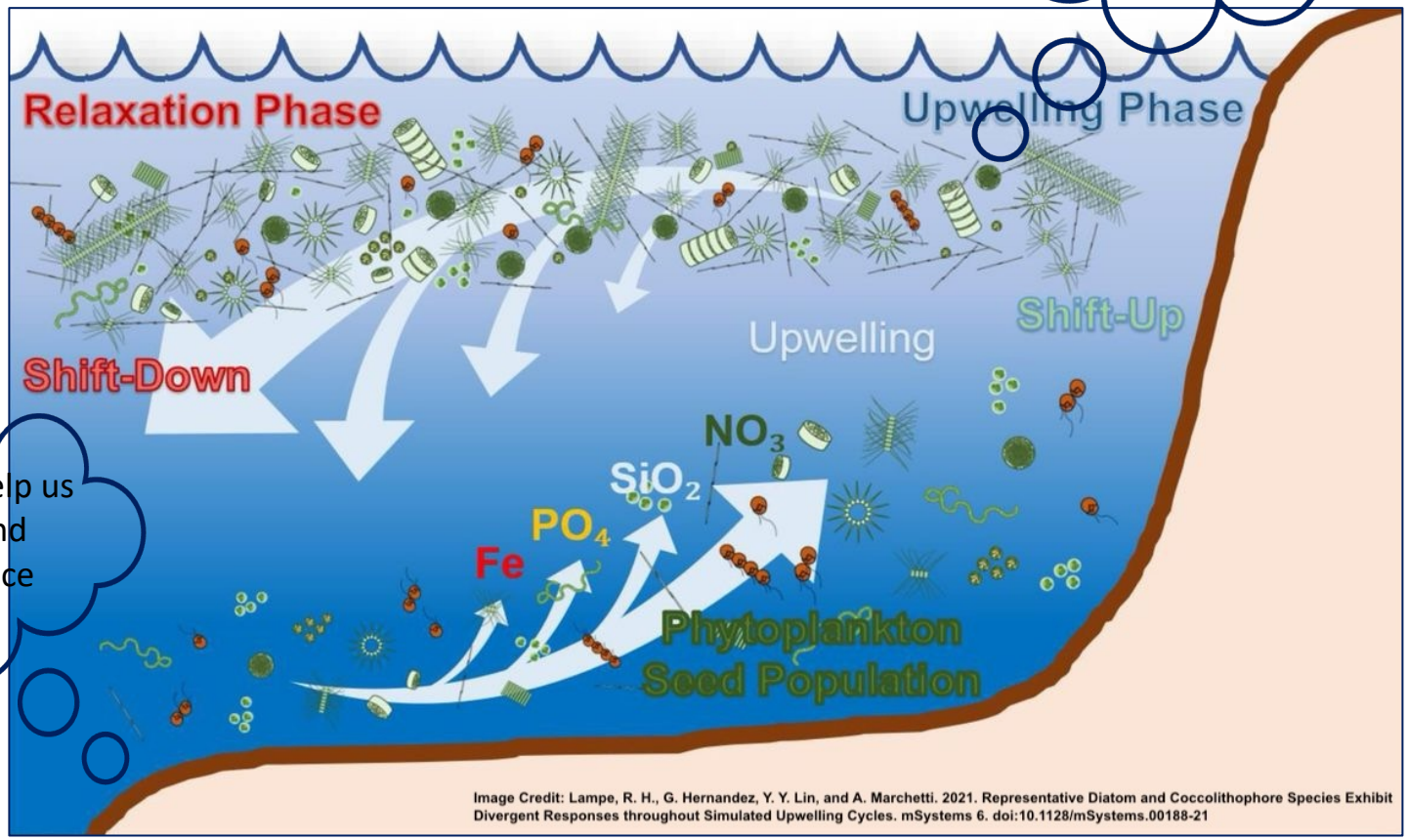


Image Credit: Lampe, R. H., G. Hernandez, Y. Y. Lin, and A. Marchetti. 2021. Representative Diatom and Coccolithophore Species Exhibit Divergent Responses throughout Simulated Upwelling Cycles. mSystems 6. doi:10.1128/mSystems.00188-21

Nitrates help us grow and reproduce

Phytoplankton Responses During an Upwelling Cycle

Data Collection

CTD* Data Collected During an Upwelling Cycle

Data collected during a the PUPCYCLE II Research Cruise aboard the R/V Sally Ride (May-June 2023)

Station	Date	Latitude	Longitude	Depth (m)	Depth (ft)	PO4 (uM/L)	NO3 (uM/L)	Silicate (uM/L)	Total_Chla (ug/L)
1	29-May	43.0452	-124.552	11.7	38.4	1.81	14.6	21.3	7.93
1	29-May	43.0452	-124.552	19.5	64.0	2.56	23.5	29.3	1.49
1	29-May	43.0452	-124.552	28.5	93.5	2.67	25.15	32.25	0.31
1	29-May	43.0452	-124.552	53.4	175.2	2.85	27.76	38.4	0.18
2	31-May	42.94262	-124.58048	11.8	38.7	1.43	7.49	14.3	12.98
2	31-May	42.94262	-124.58048	18.9	62.0	2.21	18.68	26.7	13.95
2	31-May	42.94262	-124.58048	26.7	87.6	2.47	21.98	32.1	9.55
2	31-May	42.94262	-124.58048	48.2	158.1	2.81	27.55	35.8	2.21
3	1-Jun	42.84549	-124.6693	7.7	25.3	1.53	8.97	9.61	7.01
3	1-Jun	42.84549	-124.6693	14.6	47.9	1.34	6.09	9.2	14.33
3	1-Jun	42.84549	-124.6693	22.3	73.2	1.72	12.1	18.65	16.70
3	1-Jun	42.84549	-124.6693	45.5	149.3	2.79	26.4	31.05	0.93

*CTD is a large instrument that is tethered and wired to the ship. CTDs are lowered to various ocean depths to collect seawater and information (Conductivity, Temperature, and Depth) to analyze the chemical composition and microscopic organisms found at the selected depth. Each Station shown in the table includes data collected from seawater at 4 different depths at each station location.

Phytoplankton Responses During an Upwelling Cycle

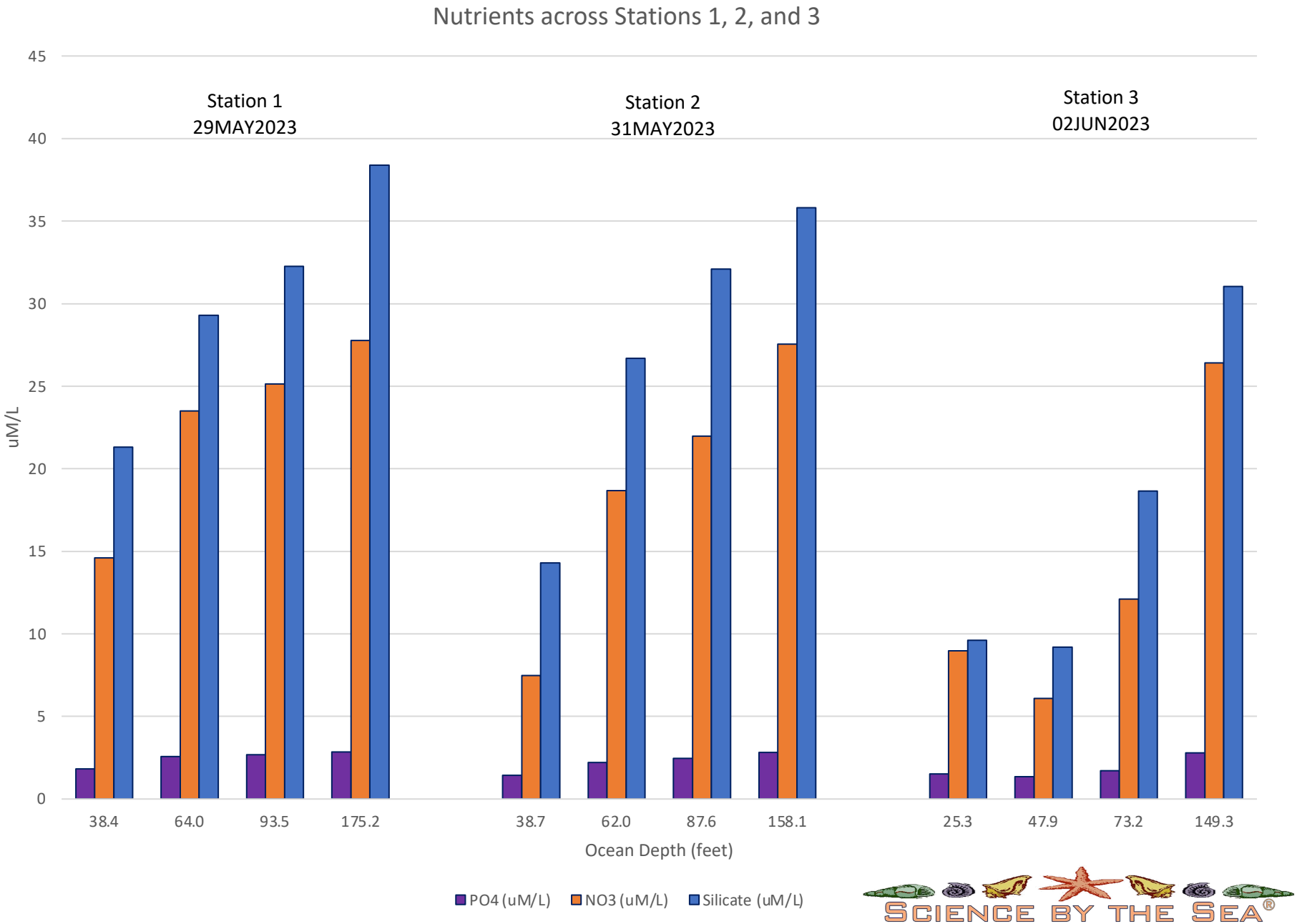
Data Analysis

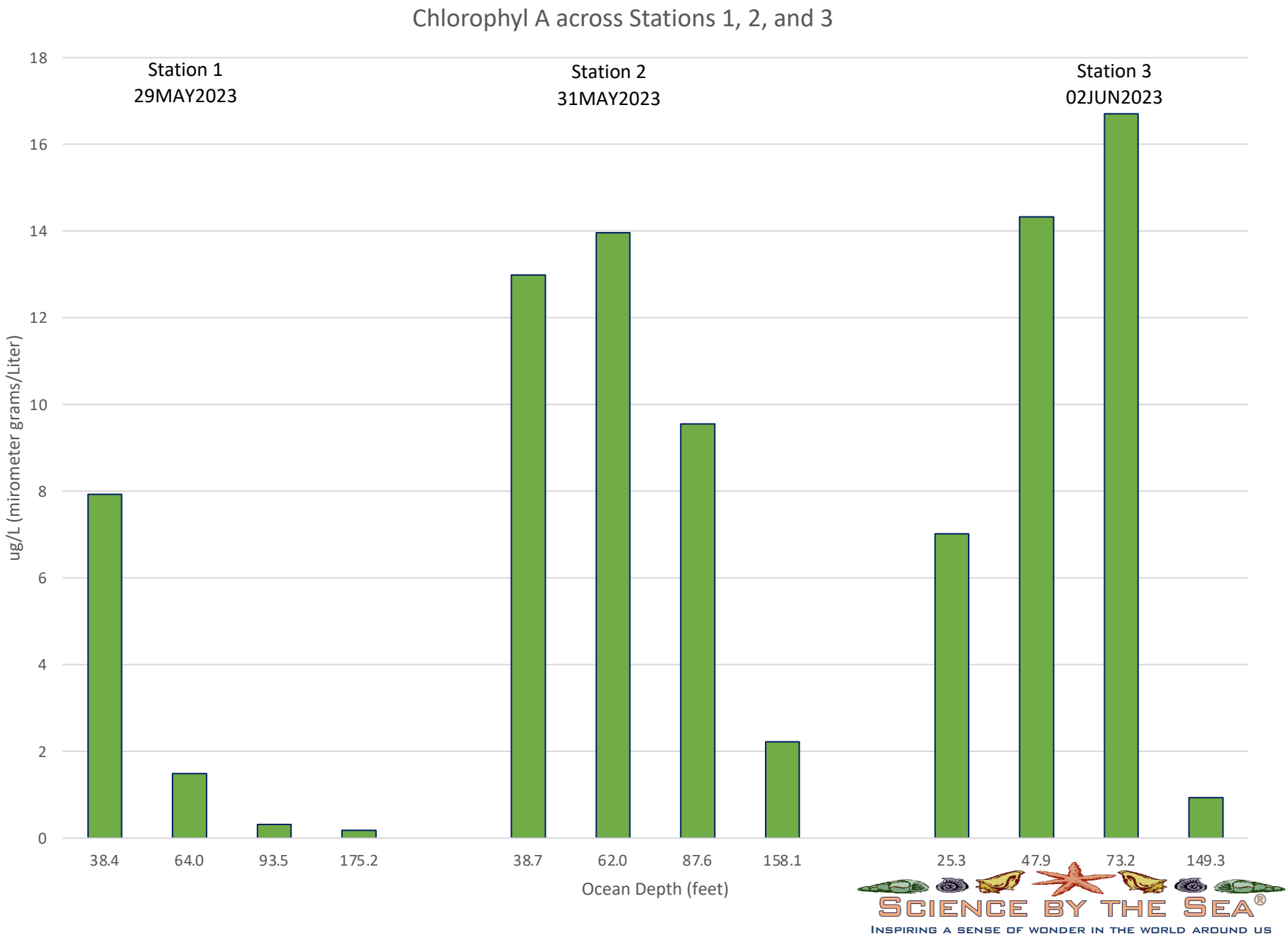
Steps for Graph #1: Nutrients across Stations 1, 2, and 3

- Select Cells G2 – G15 through I2 – I15 and generate a graph
- Edit your graph to label each of the following:
  - Edit the X-axis to the depths for each sample.
    - Edit the X-axis from 1, 2, 3, 4: Click on the X-axis; Click the "Select Data" menu button; Click the "Horizontal (Category) axis label" box; Select Cells F2 – F15 and Click the "Horizontal (Category) axis label" box again.
    - Label the X-axis "Ocean Depth (ft)".
  - Label the Y-axis "uM/L".
  - Label the Graph "Nutrients across Stations 1, 2, and 3.

Steps for Graph #2: Chlorophyl A across Stations 1, 2, and 3

- Select Cells J2 – J15 and generate a graph
- Edit your graph to label each of the following:
  - Edit the X-axis to the depths for each sample.
    - Edit the X-axis from 1, 2, 3, 4: Click on the X-axis; Click the "Select Data" menu button; Click the "Horizontal (Category) axis label" box; Select Cells F2 – F15 and Click the "Horizontal (Category) axis label" box again.
    - Label the X-axis "Ocean Depth (ft)".
    - Label the Y-axis "ug/L".
    - Label the Graph "Chlorophyl A across Stations 1, 2, and 3.




Chlorophyl A across Stations 1, 2, and 3
Station 1
29MAY2023
Station 2
31MAY2023
Station 3
02JUN2023
ug/L (mirometer grams/Liter)
0
2
4
6
8
10
12
14
16
18
38.4
64.0
93.5
175.2
38.7
62.0
87.6
158.1
25.3
47.9
73.2
149.3
Ocean Depth (feet)
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Phytoplankton Responses During an Upwelling Cycle

Data Analysis and Summary of Findings

Analyze your data set and graphs to respond to the following analyses questions.

1. At what depth are Silicates at their highest concentration?
2. Is there an observable trend in the Silicates data set? If so, describe the observed trend in Silicates across the 3 stations.
3. At what depth are Nitrates at the highest concentration?
4. Is there an observable trend in the Nitrates data set? If so, describe the observed trend in Nitrates across the 3 stations.
5. At what depth did we observe the highest concentration of Chlorophyl A?
6. Is there an observable trend in the Chlorophyl A data set? If so, describe the observed trend in Chlorophyl A across the 3 stations.
7. The phytoplankton's response to upwelling is:
   A. Immediately observed in the data set.
   B. More apparent on Day 2 of the upwelling event.
   C. Identical to the abundance of nutrients available during the upwelling event.
8. At what depths of the ocean does most primary productivity occur? Why?
9. At what depth of the ocean are most of the nutrients found?
10. How does ocean upwelling support primary production?
11. Describe the relationship between primary productivity responses to the upwelling of nutrients.

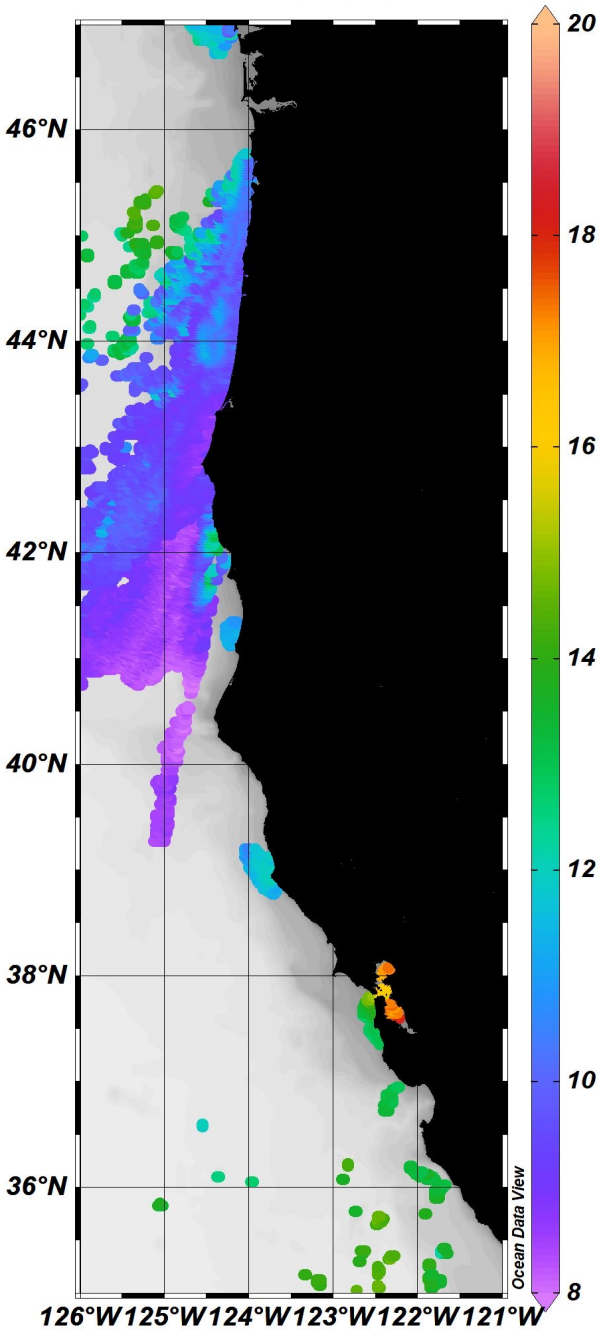
Phytoplankton Responses During an Upwelling Cycle

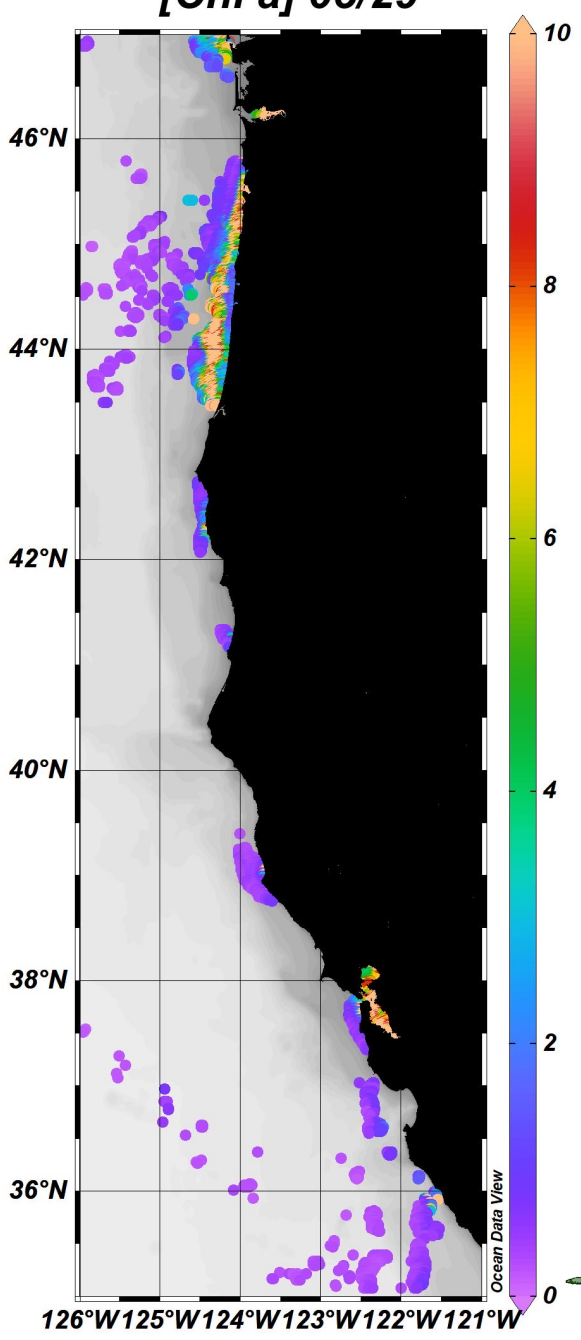
EXTENSION ACTIVITY

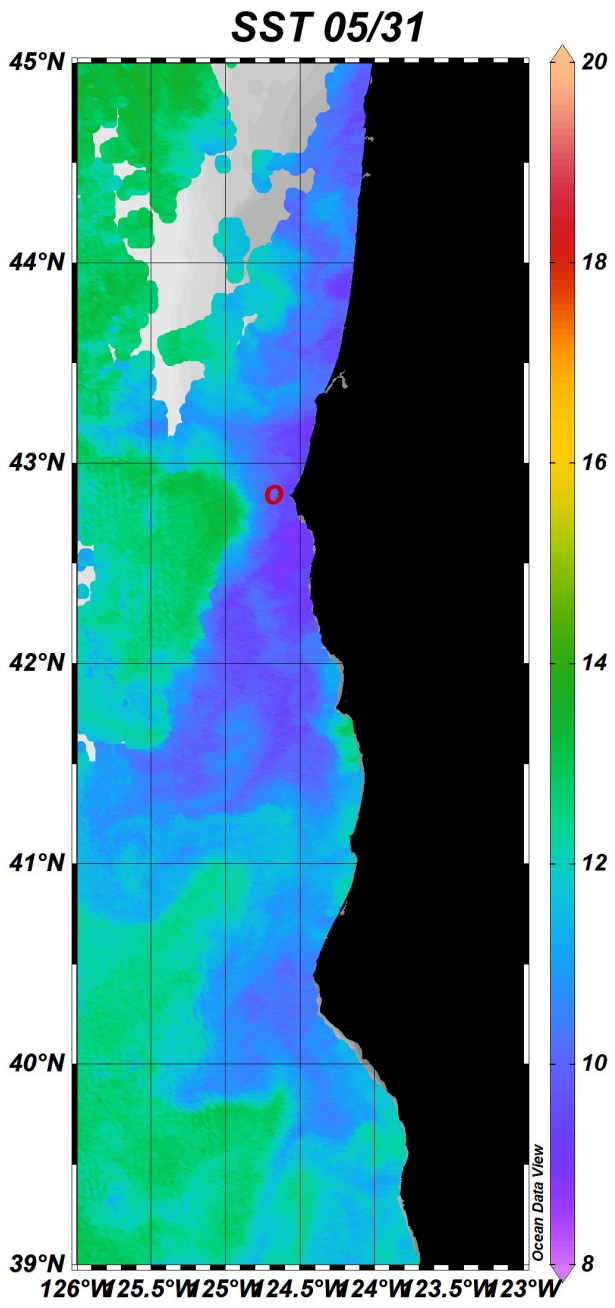
Additional Application of Knowledge – This section allows students to identify Stations 1, 2, and 3 on the Satellite maps used to assist the researchers in locating the ocean upwelling cycle.

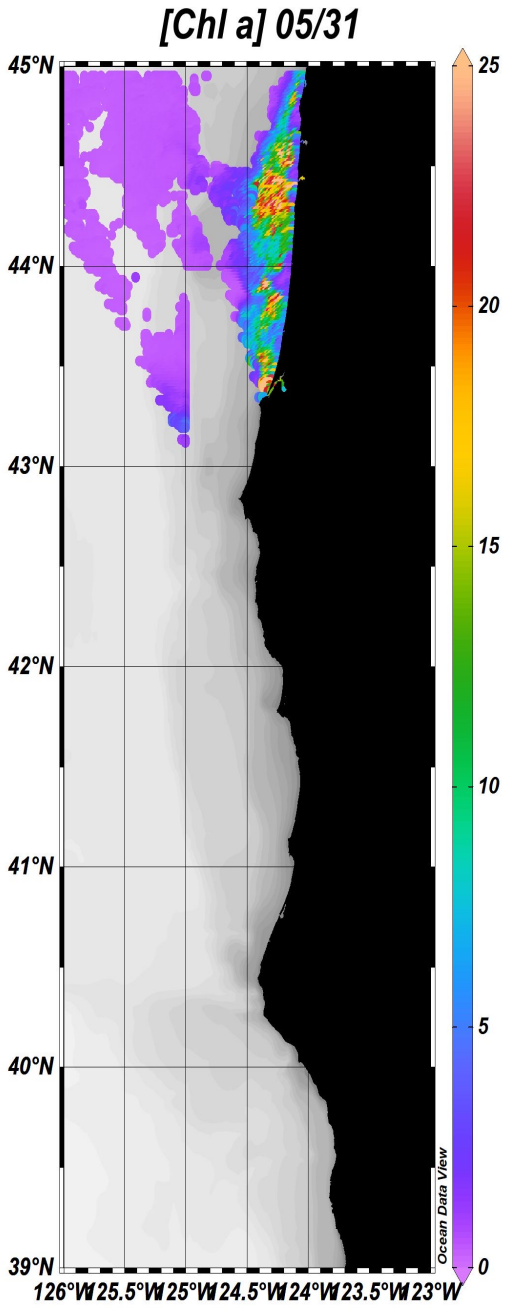
a. Distribute the Satellite maps for each Station (Slide #19 – May 29; Slide #20 – **May 31**; and Slide #21 – **June 01**) and use the Latitude/Longitude data (on the data table, Slide 13) to assist students in plotting each of the following:
   i. **Station 1** on the SST/CHLA page dated May 29.
   ii. **Stations 1 and 2** on the SST/CHLA page dated May 31.
   iii. **Stations 1, 2, and 3** on the SST/CHLA page dated June 02.
   iv. **(Option)** Include the SST/CHLA Satellite images for the dates between each station (SLIDE #25 – May 30 and SLIDE #26 – June 01) for additional satellite data during the data collection dates.

b. Facilitate a class discussion on the location of the upwelling cycle observed by the scientists and the direction in which the upwelling current was moving (e.g., north, south, east, or west).









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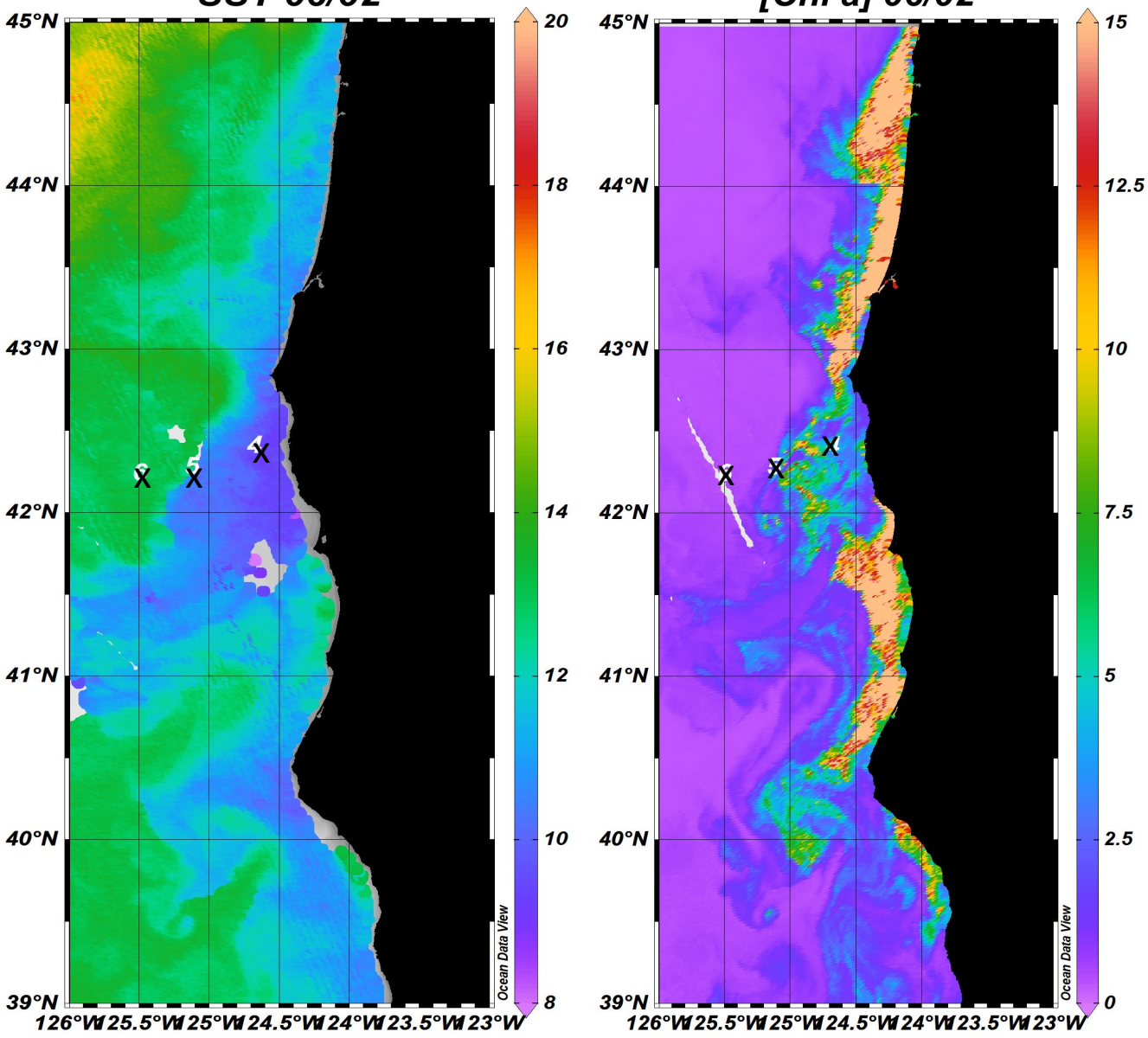
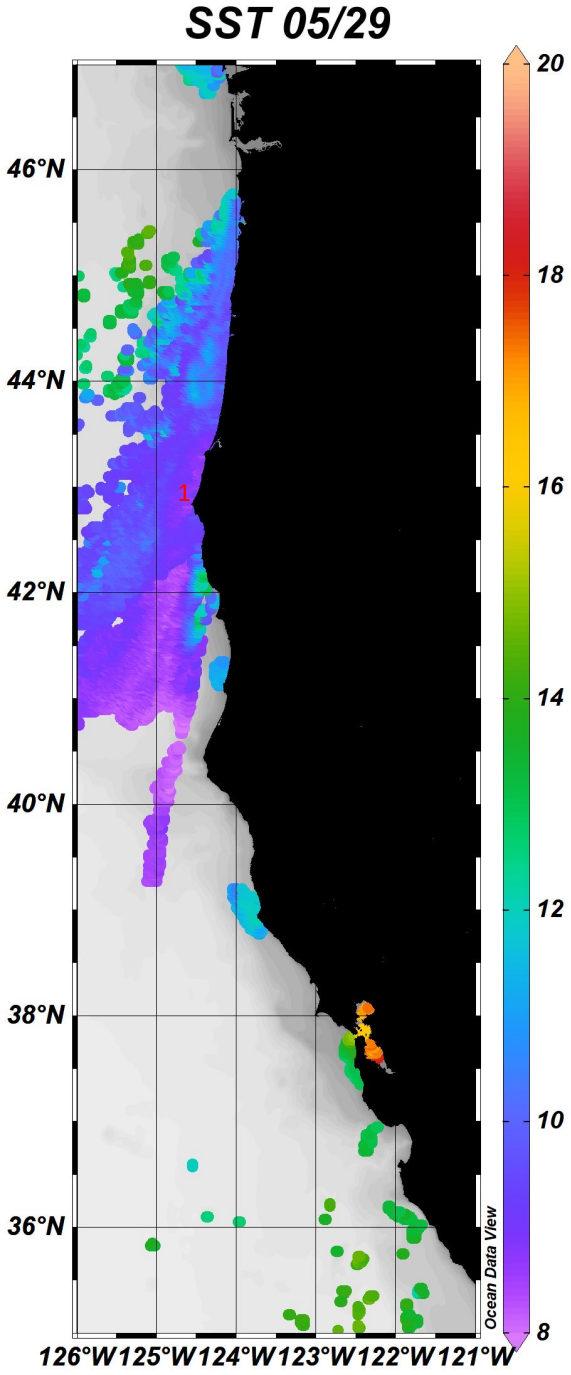
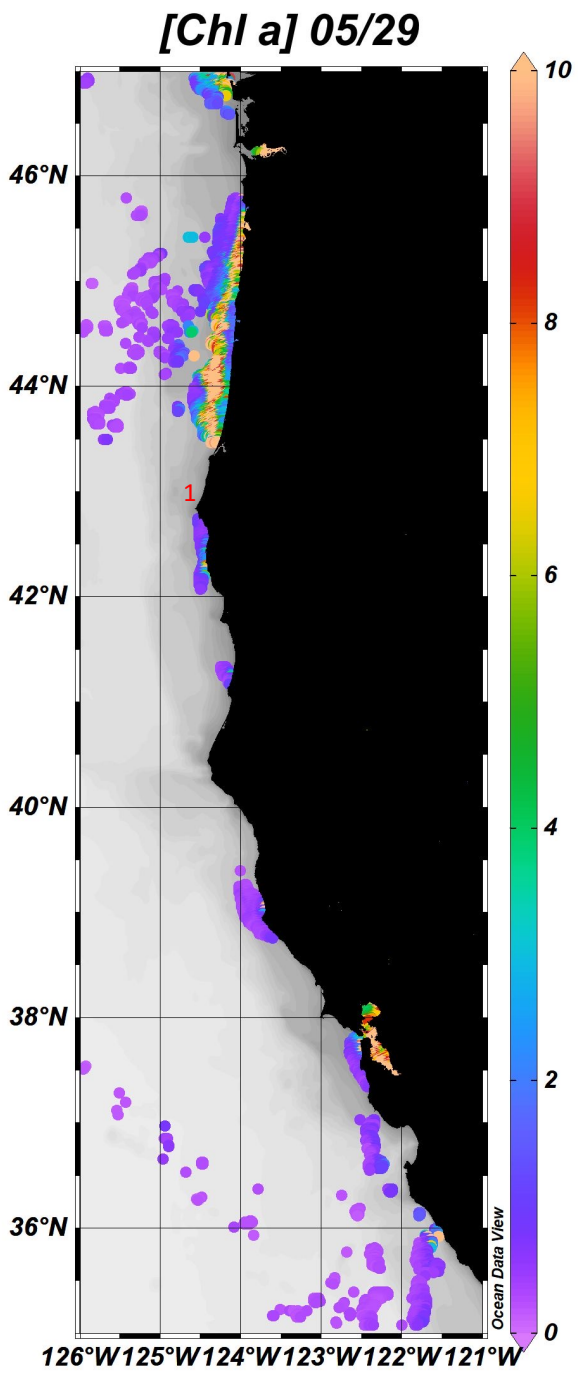
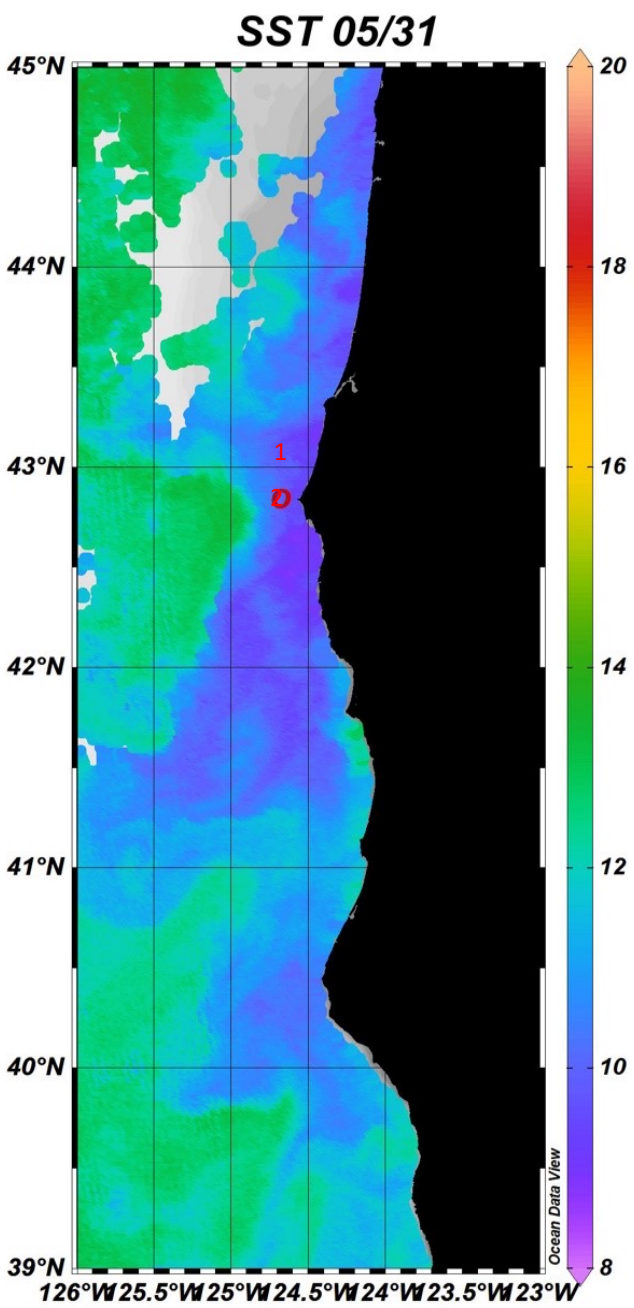


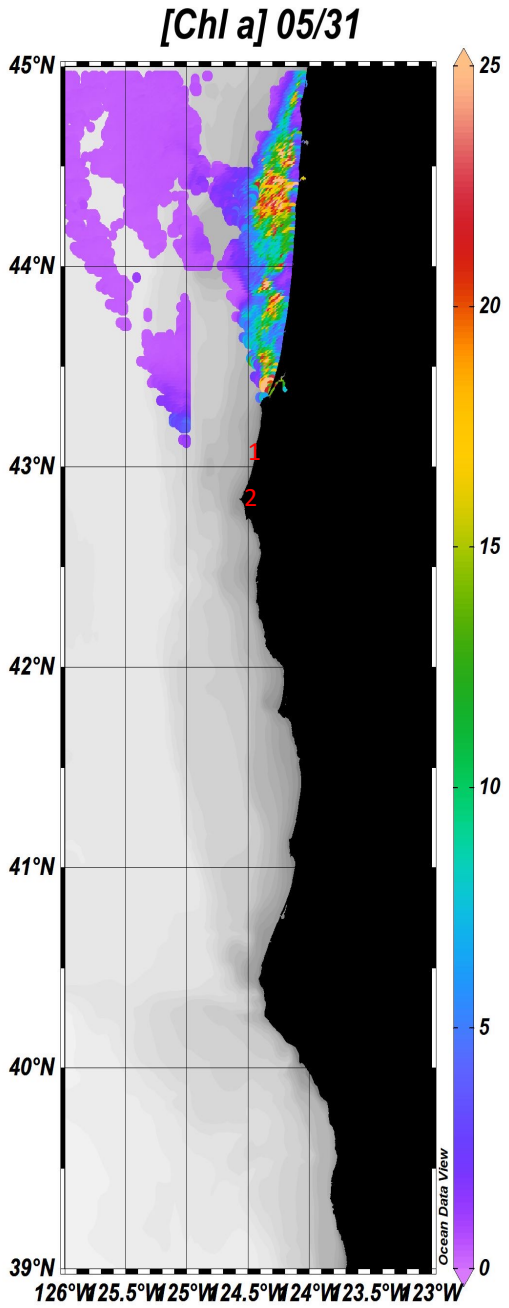




TEACHER KEY

Important Note – Satellite CHLA Imagery was incomplete for May 29 and May 31. Students should rely on seawater sample data for accurate CHLA measurements.





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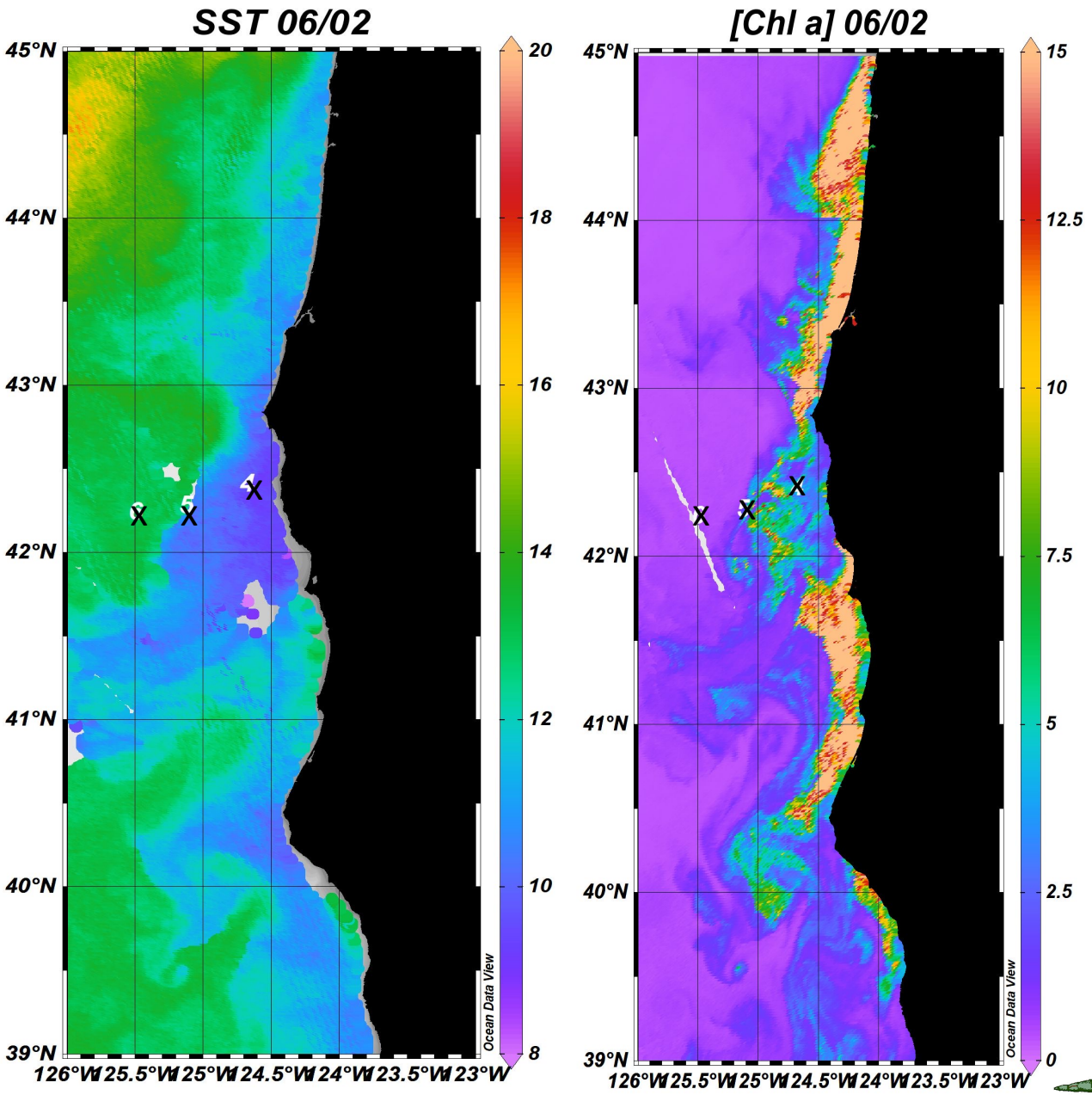
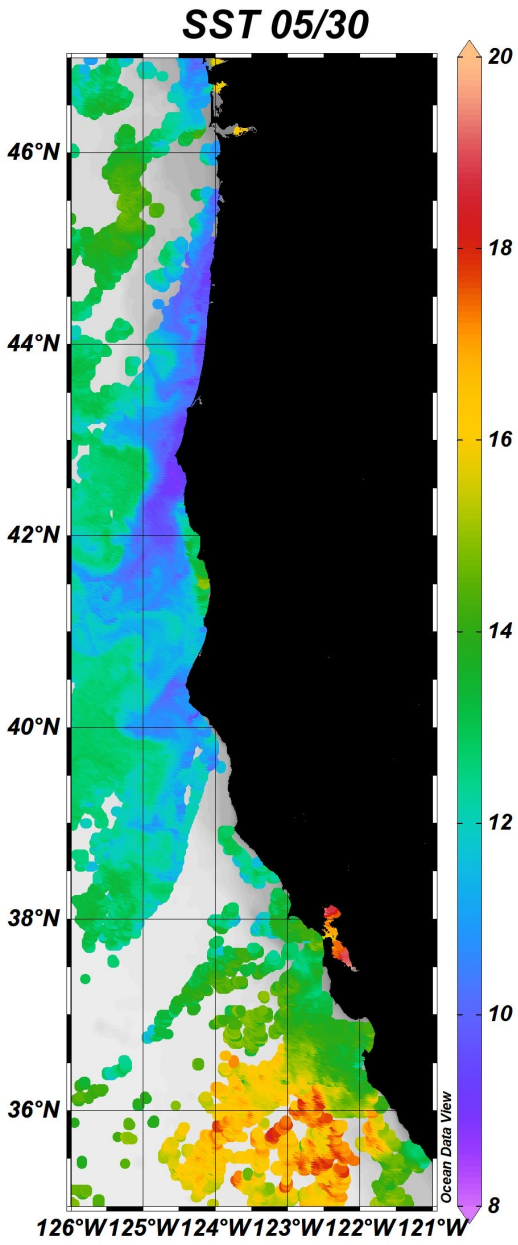
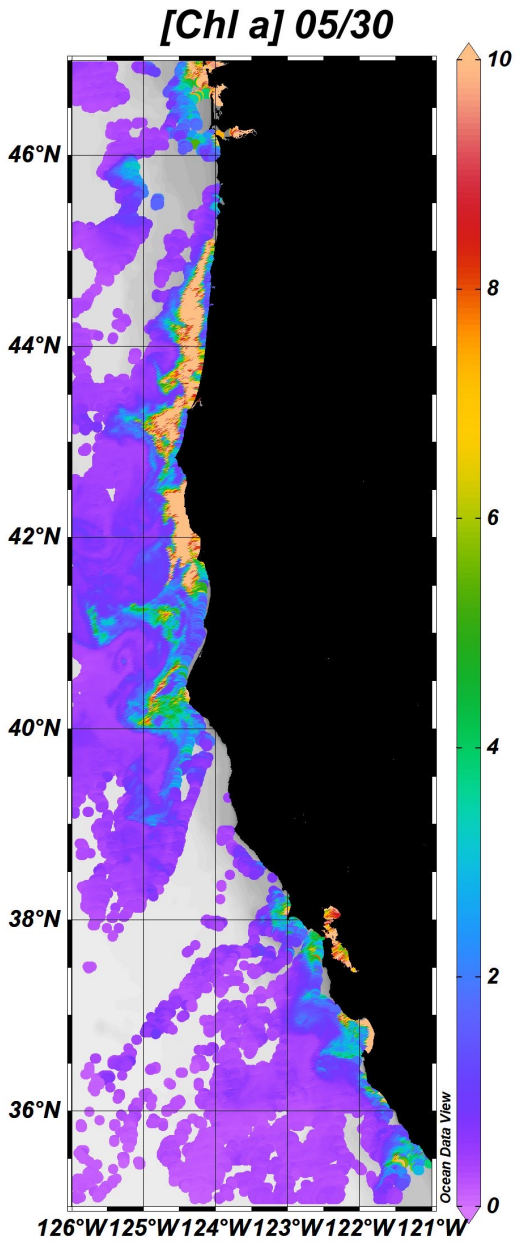


TEACHER KEY

Important Note – this is NOT where we ended up doing stations 5 and 6 (because of the weather day) so I have "x"ed them out of these.





Additional Satellite Imagery

Additional Sea Surface Temperature and Chlorophyl A Imagery for May 30

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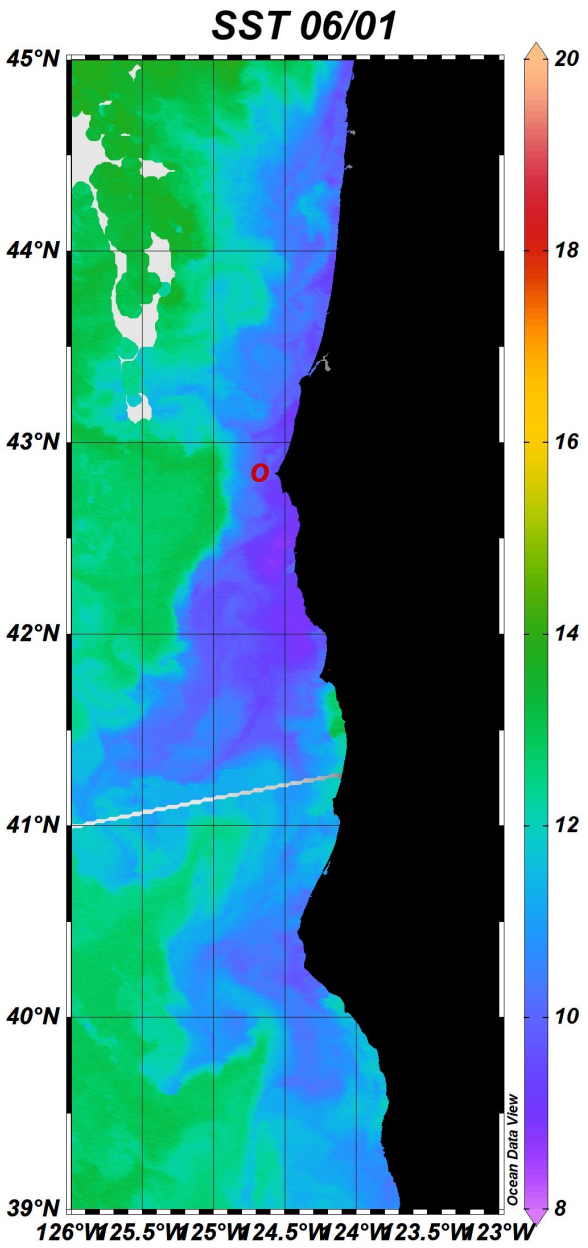

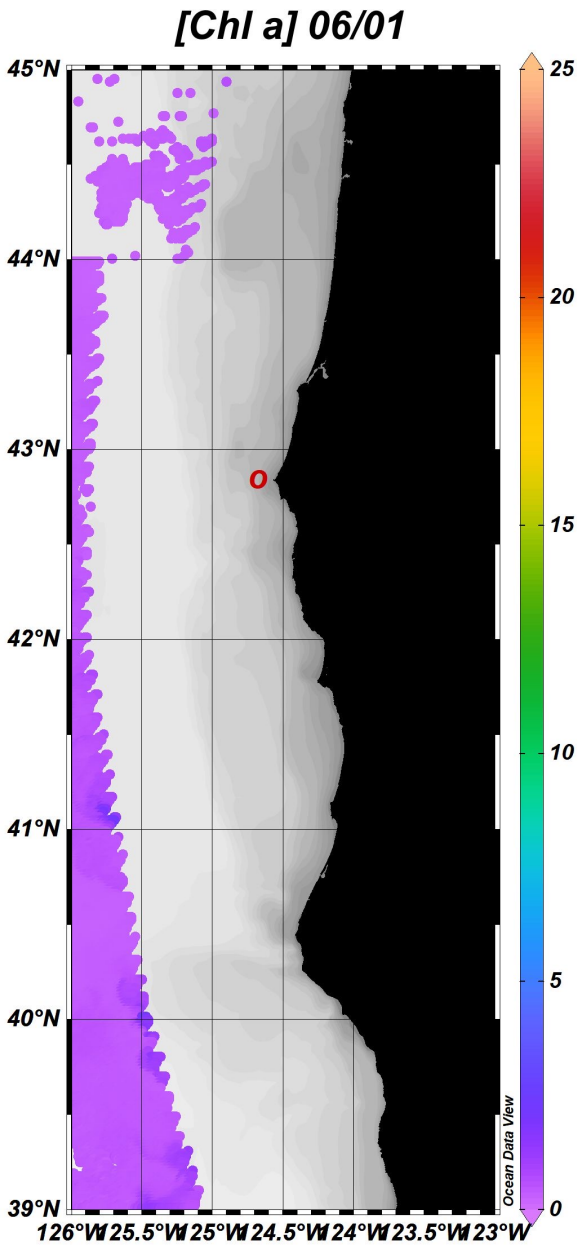

Additional Satellite Imagery

Additional Sea Surface Temperature and Chlorophyl A Imagery for June 01

LESSON NOTES: [Additional notes are included in the PPT version that is available upon request.]
Silicates and Nitrates peak at the start of the upwelling event (Station 1) and begin to decline as upwelling continues through Stations 2 and 3.

Phosphates show minimal changes across all 3 stations.

CHLA levels are at their lowest at the start of the upwelling event (Station 1) and increase significantly at Stations 2 and 3. CHLA concentrates at the surface where the phytoplankton can access sunlight for photosynthesis.

Phytoplankton Physiology:

- Diatoms absorb silicates from seawater to build their outer shells of glass.
- Diatoms and other phytoplankton need sunlight and nutrients, like nitrates, to assist them in photosynthesis and reproduction.

Nutrients and the Biogeochemical Cycle:

- Deep sea sediments contain large stores of nutrients that sink to the seafloor over time.
- The aquatic food web contributes to nutrient deposition and content throughout our oceans.