What’s UP in the Pacific Ocean?

Connecting productivity and tuna migration

In this module, you’ll follow a bluefin tuna on a spectacular migratory journey up and down the west coast of North America and back and forth across the Pacific Ocean. You will analyze the track patterns of this animal and use Sea Surface Temperature (SST) and Chlorophyll concentration (CHL) data to identify evidence of upwelling in an attempt to determine what might be driving these incredibly long migrations as you explore the question:

How does marine productivity influence the migration patterns of Bluefin Tuna #201000?

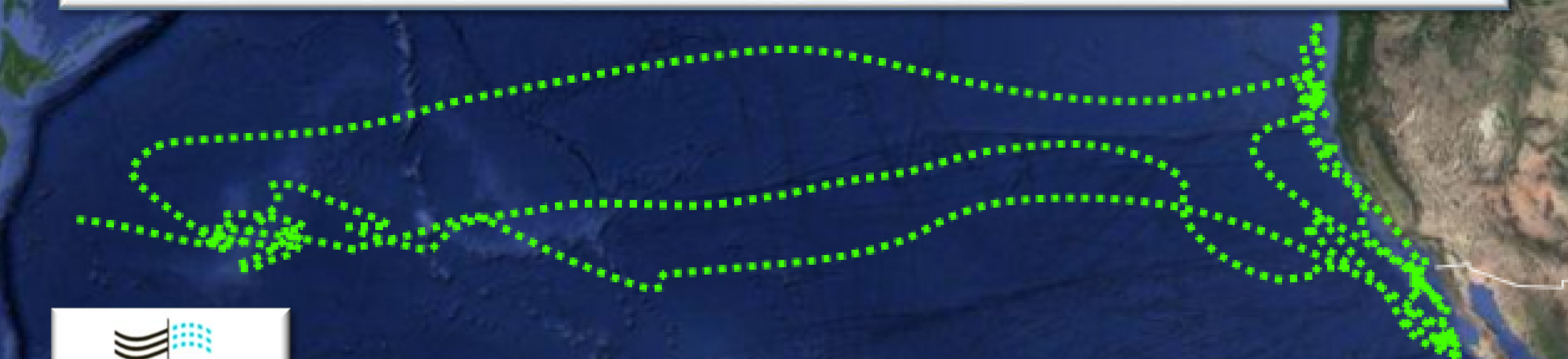
Engage

Electronic tagging has given scientists unprecedented insight into how large marine species like tunas and sharks use the ocean environment and how incredibly far these migratory animals travel in their lifetimes.

The image below shows the spectacular 41,830.41 km journey of a Bluefin tuna from August 8, 2002 to May 31, 2004. In less than two years, this animal not only traveled up and down the west coast of North America several times, but also crossed the Pacific Ocean three times! After seeing tracks like this, scientists began to wonder: what drives these animals to make such incredible migrations?

Learning Objectives

- Interpret color maps
- Use data to identify and describe coastal upwelling
- Integrate information from color maps and tracking data
- Use data to make and support claims about relationships between oceanographic conditions and animal behavior



OceanTracks

Engage

- Go to http://oceantracks.org/map.
- **Show** and **Graph** Bluefin tuna track #201000.
- Animate the track by clicking the **Show Animal Movement** icon under **Tools**.
- Observe where the tuna goes over its nearly two year journey.

CLASS DISCUSSION

As a class, discuss some reasons why marine species migrate and what factors might influence migration patterns. Specifically:

1. *What oceanographic processes and/or conditions might influence where and when species migrate?*
2. *What biological processes might influence migration patterns?*
3. *Where does Tuna #201000 spend most of its time: along the coast or in the open ocean?*
4. *What might the tuna be doing in those regions? Include some possible explanations based on your discussions (and/or the OT Library: http://oceantracks.org/library), for why the animal traveled or lingered where it did.*

Next, you'll explore sections of the tuna track as well as Sea Surface Temperature (SST) and Chlorophyll concentration (CHL) data to help you determine what factors might be influencing this animal's incredibly long migration.

Explore

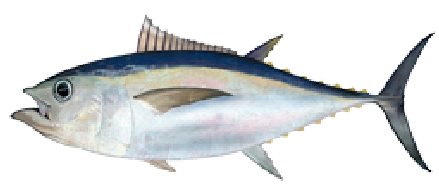
Food can be a powerful motivator. Without it, animals cannot survive. Since primary production forms the base of the food web, we might reasonably expect that areas of high primary production will attract zooplankton and other organisms at higher trophic levels (like tuna!), and may be a driving factor behind observed migration patterns for these animals.

In this section, you'll use Ocean Tracks data to test three hypotheses relating to the question: ***How does marine productivity influence the migration patterns of Bluefin Tuna #201000?***

Hypothesis 1: Bluefin tuna #201000 spends most of its time along the coast of North America because there is strong coastal upwelling in this region.

Hypothesis 2: Bluefin tuna #201000 moves up and down the coast of North America in response to seasonal variation in coastal upwelling.

Hypothesis 3: Bluefin tuna #201000 migrates to the area offshore of Japan because oceanic productivity is high in this area.



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Explore

All three hypotheses include something about productivity or upwelling, so let's take a look at how you can identify these processes in Ocean Tracks.

Chlorophyll concentration (CHL) at the surface of the ocean is used as a proxy for primary production by phytoplankton. Satellites measure the amount of green light reflected from the ocean's surface to generate maps of global chlorophyll concentration.

In Ocean Tracks, CHL is represented using color map overlays. Each color corresponds to a different range of chlorophyll concentrations. Areas that are dark red have the highest concentrations (20-30 mg m^{-3}), and areas that are purple have the lowest concentrations (0.1-0.03 mg m^{-3}). Areas with data gaps (i.e., where you can see the underlying bathymetry layer) result when clouds and/or ice obstruct the satellite's view of the surface of the ocean.

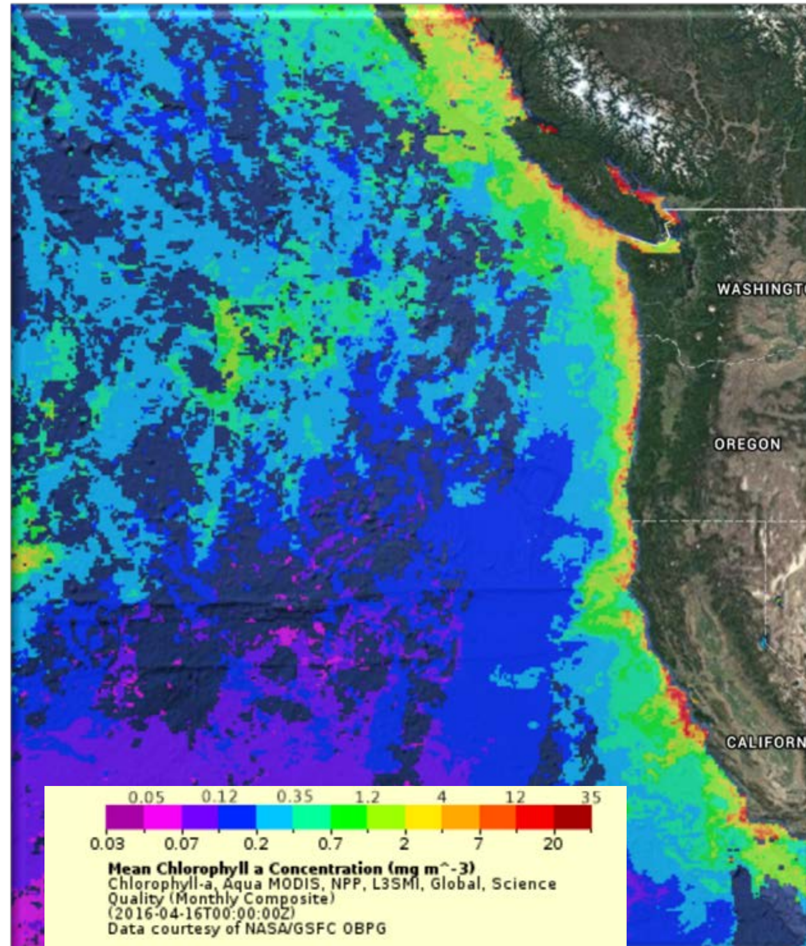

Figure 1. Map showing chlorophyll concentrations for the western coast of North America in June 2010.

(See http://oceantracks.org/library/oceanographic-factors/chlorophyll/ for more information about chlorophyll and CHL maps.)

Explore

Sea Surface Temperature (SST) is another important oceanographic property to consider when looking for evidence of productivity or upwelling.

SST influences the distribution of animal and plant life in the ocean. Each species has its own individual temperature tolerance based on physiological processes. Temperature is also linked to the concentration of nutrients in the water, which together with the amount of solar radiation influence the amount of primary production at the surface of the ocean.

Because of this, scientists use temperature maps to help predict where species go and where primary production is highest in the ocean.

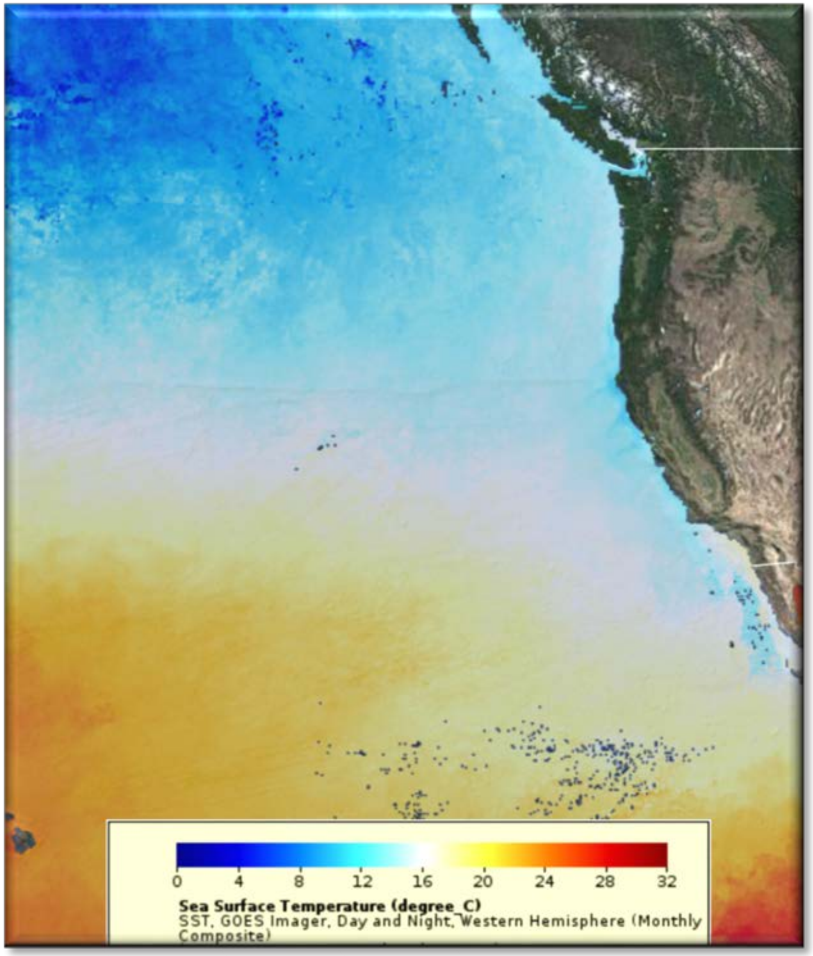

Figure 1. Map showing sea surface temperature for the western coast of North America in June 2010.

(See http://oceantracks.org/library/oceanographic-factors/sea-surface-temperature/ for more information about sea surface temperature and SST maps.)

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Explore

PART 1: IDENTIFY EVIDENCE OF COASTAL UPWELLING

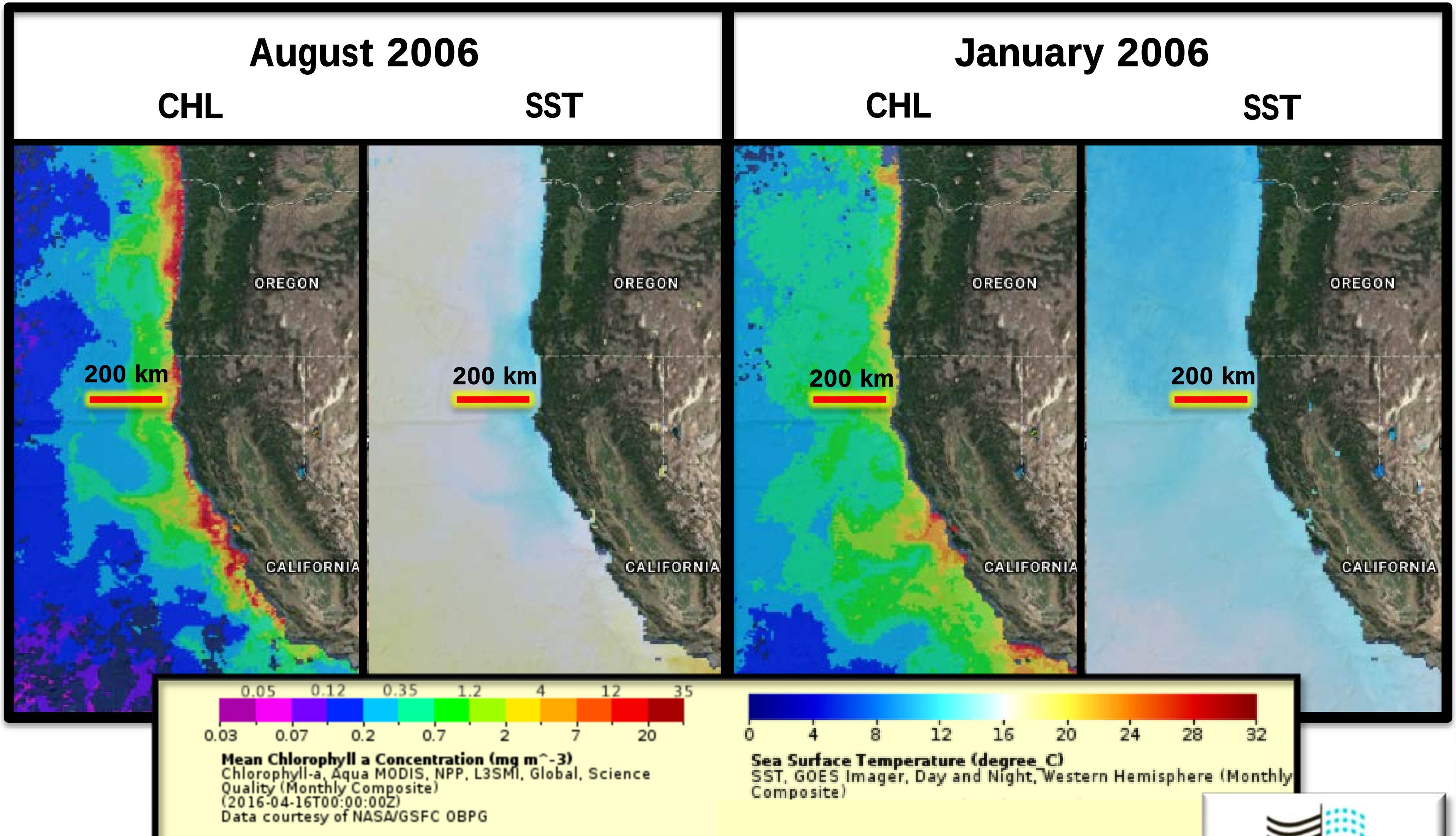
Coastal upwelling occurs when winds blowing across the ocean surface push water away from an area and **cold**, **nutrient-rich** water rises up from below to replace the displaced surface water. This process also stimulates primary production by phytoplankton, which means we would expect to see colder sea surface temperatures and higher chlorophyll concentrations **compared to areas further offshore** during a coastal upwelling event.

- Look at the example maps on the next page that show CHL and SST overlays side by side for 2 different months in the same year (August and January, 2006).
- Carefully examine the data values inshore (within ~200 km of coastline) and offshore (~200-500 km) to look for patterns that provide evidence for upwelling. NOTE: In addition to looking at the static images, you might find it helpful to also look at these maps and explore the overlay data on the Ocean Tracks interface.

EXPLORE PART 1: QUESTIONS

1. *Which month (August or January, 2006) best indicates that coastal upwelling is occurring? Describe the conditions observed in that set of maps, including a comparison of the ranges of SST and CHL values inshore (within ~200 km of shore and offshore (from 200-500 km offshore).*

Explore



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Explore

Hypothesis 1: Bluefin tuna #201000 spends most of its time along the coast of North America because there is strong coastal upwelling in this region.

PART 2: TEST HYPOTHESIS 1

Now that you know what the signature of strong upwelling looks like in the data, let's revisit ***Bluefin Tuna track #201000*** to to test Hypothesis 1 by looking for evidence of upwelling.

- Go to http://oceantracks.org/map.
- **Show** and **Graph** Bluefin Tuna track #201000.
- Explore the SST and CHL conditions during time periods when the tuna is returning to shore (August, 2003), and when it is near shore (September, October, and November 2003).
- Under the **Tools** menu:
  - Use the "Plot from" boxes to enter the start and end dates for the section of the track that corresponds to the tuna's movements during each of these months.
  - Use the tabs to select SST or CHL. NOTE: Average values for the plotted time range are shown below the graph, highlighted in yellow. To find individual values, hover your cursor over the graph. The corresponding track point will change color on the map to show you the animal's position on that date.

Explore

Hypothesis 1: Bluefin tuna #201000 spends most of its time along the coast of North America because there is strong coastal upwelling in this region.

EXPLORE PART 2 QUESTIONS:

- *When you have a month selected, record the following information in a table like the one below:*
  - *The **tuna's location**, including the nearest state or province, whether it was near the northern, central, or southern part of that state. Also, use the **Show Ruler** tool to measure the approximate distance the tuna was from shore on the first and last day of the month, and record those distances as part of the tuna's location.*
  - *The **maximum and average CHL** values for that section of the track.*
  - *The **average SST** value for that section of the track.*

Show Ruler

Table 1.

Month	Tuna's Location	CHL max from track (mg/m^3)	CHL avg. from track (mg/m^3)	SST avg. from track(°C)
August 2003	~2395 km offshore of S. Oregon on 8/1 heading east, then moving up the coast to ~130 km offshore of N. Oregon on 8/31.	1.3	0.13	16.67
September 2003				
October 2003				
November 2003				

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Explore

Hypothesis 1: Bluefin tuna #201000 spends most of its time along the coast of North America because there is strong coastal upwelling in this region.

- Next, take a look at the SST and Chlorophyll map **Overlays** for August, September, October, and November 2003. These can be selected in the Overlays dropdown, or by clicking on a track point on the map that is in that month and selecting “Show CHL Map” or “Show SST Map.”
- Inspect the SST and CHL maps to determine how these parameters vary from inshore areas (within ~200km of the coastline) to offshore areas (~200-500 km) along the stretch of coast adjacent to the tuna’s track for each month. Record ranges of data values for SST and CHL for inshore and offshore areas in the table below.
- To determine how strongly these maps show that upwelling is occurring, pay attention to a) the presence of a gradient from inshore to offshore in your data tables, and b) how big this gradient is. Based on this information, indicate in the table below whether the evidence for upwelling is “strong,” “moderate,” or “weak.”

Table 2.

Month	Inshore CHL range (mg/m^3)	Offshore CHL range (mg/m^3)	Inshore SST range (°C)	Offshore SST range (°C)	Strength of evidence for upwelling
August 2003	0.2-35	0.03-0.7	15-16	17-18	Moderate
September 2003					
October 2003					
November 2003					

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Explore

Hypothesis 1: Bluefin tuna #201000 spends most of its time along the coast of North America because there is strong coastal upwelling in this region.

EXPLORE PART 2 QUESTIONS

Use your data tables to help you answer the following questions.

1. *How strongly do the data in Tables 1 and 2 support Hypothesis 1? Hint: think about oceanographic conditions when the tuna is lingering along the coast vs. travelling onshore or alongshore.*

1. *List two alternative explanations for why tuna might spend time along the western coast of North America.*

1. *What additional information or data would you need to explore Hypothesis 1 further?*

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Explore

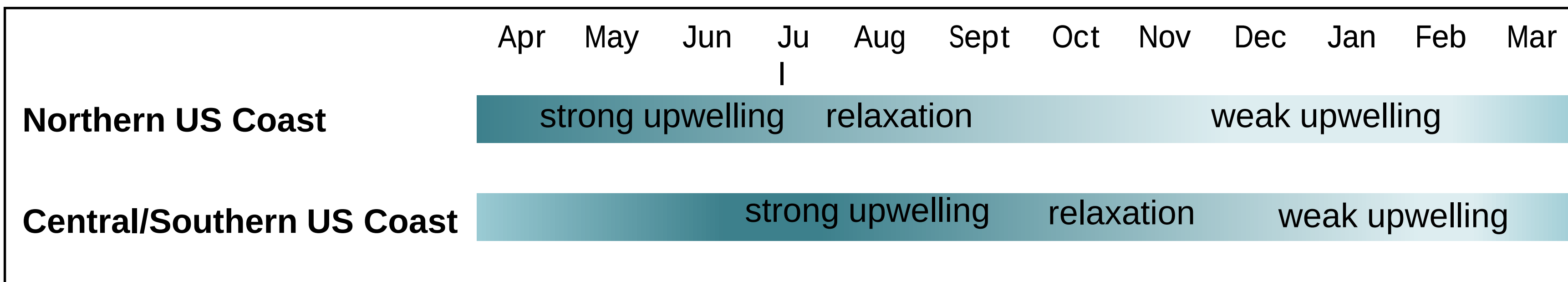
Hypothesis 2: Bluefin tuna #201000 moves up and down the coast of North America in response to seasonal variation in coastal upwelling.

PART 3: TEST HYPOTHESIS 2

To test Hypothesis 2, we'll compare SST and CHL map overlays between the months of August, September, October, and November 2003, when the tuna is returning to the western coast of North America, lingering along the the coast of Oregon and Northern California, and then moving down the coast to Baja California.

The intensity of upwelling along the west coast of the US varies across geographic locations and through time. The diagram below depicts typical seasonal patterns along the Northern (north of San Francisco) and Southern (south of San Francisco) portions of this coastline, showing approximate timing of strong upwelling, weak upwelling, and relaxation (when upwelling-favorable winds diminish or reverse).

Figure 1.



Explore

Hypothesis 2: Bluefin tuna #201000 moves up and down the coast of North America in response to seasonal variation in coastal upwelling.

EXPLORE PART 3 QUESTIONS

1. *Using the data in Table 2, how strongly do the CHL and SST data from August-November 2003 exhibit the typical seasonal patterns for the northern part of the western US shown in the Figure 1 graphic?*

2. *Using Table 1, think about where tuna #201000 was traveling during this time in relation to the SST and CHL conditions along the coast. How strongly do the data you collected in Tables 1 and 2 suggest a relationship between the tuna's movement and seasonal variation in coastal upwelling?*

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Explore

Hypothesis 3: Bluefin tuna #201000 migrates to the area offshore of Japan because oceanic productivity is high in this area.

PART 4: TEST HYPOTHESIS 3

Now, let's compare the section of the track you've just analyzed to a section of the track where the tuna is offshore of Japan (May 1- June 30, 2003). Making this comparison will help us evaluate whether or not this tuna migrates to this area because of high oceanic productivity.

- Display the SST and CHL **Overlay** maps for May and June, 2003.

EXPLORE PART 4 QUESTIONS

1. *Describe the ranges of SST and CHL in the vicinity of the tuna during these months using specific data values.*

2. *How strongly do these maps and data values indicate high productivity in the area where the Bluefin tuna is during this time period?*

3. *Why else might the tuna migrate to this area of the ocean? Provide two alternative explanations (see http://oceantracks.org/library/species/northern-bluefin-tuna/ for more information).*

4. *What additional data or information would you need to understand what the tuna is doing in this location during this time? NOTE: don't limit yourself to what is available on the Ocean Tracks interface.*

Explore

PART 5: MAKING COMPARISONS

Next, let's compare these findings to a larger sample size (more tunas) studied by a group of scientists at Hopkins Marine Station.

- Click on the link below to open the article *Movements of pacific bluefin tuna (Thunnus orientalis) in the Eastern North Pacific revealed with archival tags* by Boustany et. al.

- Read the abstract, which summarizes the results of their analysis.

http://www.tagagiant.org/media/Boustany%20et%20al_PBFT.pdf

ELSEVIER
Progress in Oceanography
journal homepage: www.elsevier.com/locate/pocean

Movements of pacific bluefin tuna (*Thunnus orientalis*) in the Eastern North Pacific revealed with archival tags

Andre M. Boustany [a,*], Robyn Matteson [a,1], Michael Castleton [a], Charles Farwell [b], Barbara A. Block [a]

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Explore

EXPLORE PART 5 QUESTIONS

1. *What seasonal migration patterns are described for Pacific Bluefin tuna in the abstract?*

2. *What explanation do the authors provide for why the tuna might not always migrate to areas of high productivity?*

3. *Does Bluefin Tuna #200100 follow the patterns described in this paper? List one way in which this tuna's movement patterns are similar and one way in which it is different.*

1. *Display all of the tuna tracks on the Ocean Tracks interface. List two common patterns among the tracks displayed. How do these patterns compare to those of the 143 tuna tracks analyzed in the paper?*

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Synthesize

Write a 300 word scientific abstract summarizing your answer to the question:

How does marine productivity influence the migration patterns of Bluefin Tuna #201000?

Your abstract should include:

- A brief background statement about ocean productivity and/or bluefin tuna migrations. (1-2 sentences)
- Your research question/objective. (1 sentence)
- A description of your methods. (1-2 sentences)
- Your main results/conclusions relating to each hypothesis, referring to specific data values (i.e., numbers). As you develop your conclusions, consider the temporal (time-dependent) relationship between primary productivity and food availability for predators such as bluefin tuna. (2-3 sentences) NOTE: You don't have to re-state the hypotheses in the abstract.
- A summary statement of your findings, or sentence to connect these findings to a broader context like the research findings of Boustany et. al. (1 sentence)

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