Faster, Farther, Deeper

Exploring Physiology of Highly Migratory Ocean Predators

Electronic tagging technologies provide scientists with unprecedented insights into fundamental questions about animals in the open ocean, like *Where do they go?* and *When do they go there?* Sensors in these tags also provide information about the environmental conditions these animals experience as they traverse the ocean, including dramatic changes in temperature, pressure, and light over the course of days, hours, or even minutes. These kinds of data can often lead to more questions than answers about these animals, leaving scientists to ask, “How do they survive that?!”

In this module, you will use the data available through Ocean Tracks to inspire your own questions and design an experiment to explore in greater depth the question:

How does physiology influence how different species use the ocean environment?

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Engage

ADAPTING TO SURVIVE

All plant and animal species that inhabit the ocean have developed their own unique set of adaptations for survival in a specific range of environmental conditions, including salinity, temperature, pressure, and light. Whales for example, have evolved over millions of years from lumbering land dwellers into streamlined marine giants, with adaptions such as echolocation, thick layers of blubber, modified lungs, better hearing, and larger arteries to not only survive, but thrive in the ocean.

Orcas (aka killer whales), perhaps best known for their incredible feats of intelligence, playfulness, and agility in aquatic theme park shows, exhibit many adaptations for survival in the wild. Found in all oceans (polar and tropical), these apex predators have adapted to survive a wide range of environmental conditions.

- Read more about some of the Orca's amazing adaptations: https://seaworld.org/en/animal-info/animal-infobooks/killer-whale/adaptations

ENGAGE QUESTION

1. What are some of the ocean conditions that orcas have adapted to survive?

2. What orca adaptation(s) did you find most surprising? Why?

Learning Objectives

- Describe physiological characteristics and adaptations of marine animals for survival in the ocean environment.
- Identify data required to answer a research question.
- Propose a research experiment to study adaptations of a marine animal.

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Explore

PART 1: COMPARING SPECIES

Electronic tagging technologies provide scientists with new information about animal movement in the open ocean and the environmental conditions they encounter along their journeys via sensors that measure and record things like temperature, pressure, and light.

With Ocean Tracks, you can explore some, but not all of these kinds of data. In this section, you will look at location, distance, speed, and depth data for four different species to lay the foundation for additional research into their physiology and adaptations for survival.

- Go to http://oceantracks.org/map. By default, elephant seal track #302 is displayed on the map.
- Open the **Data & Tools** tab and click **+** to expand the **Tracks** menu. In addition to Elephant Seal #302, also **Show**:
  - Laysan Albatross #278
  - Bluefin Tuna #508400
  - White Shark #501600
- Click **+** to expand the **Tools** menu and explore data graphs for Elephant Seal #302.
- Make and complete a table like Table 1 on Slide 6 to record depth, speed, and temperature data for all 4 animals. When gathering data for each animal, remember to select **Graph** to activate the track and generate data plots under **Tools**. When a track is active, track points on the map will be highlighted for the selected time range (See Slide 4).
- Use the annotated images on Slides 4 and 5 for additional tips on how to use the Ocean Tracks interface to find and gather all the data you need for your table.

Explore

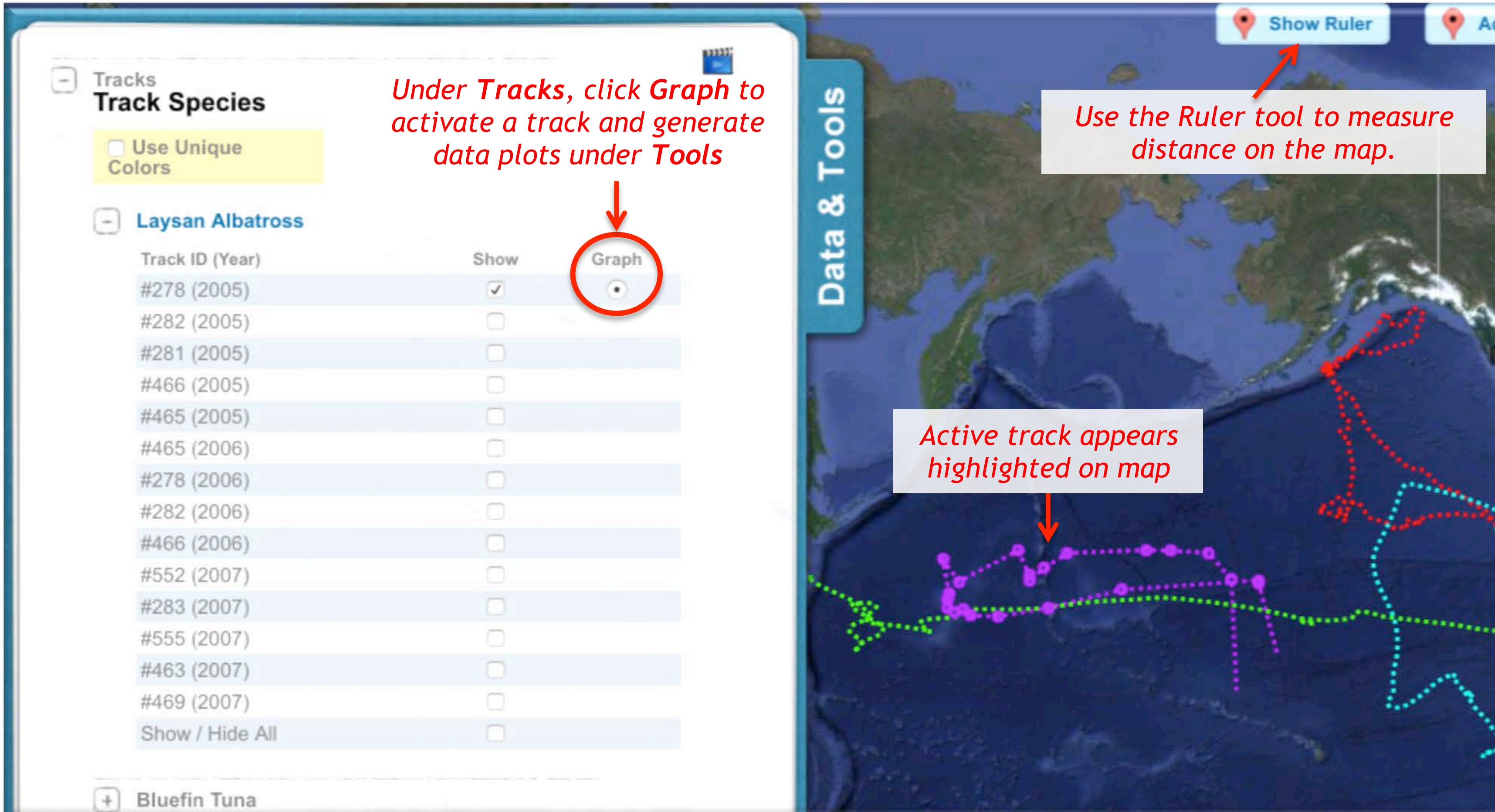


Figure 1. How to Graph/Activate a track.

Explore

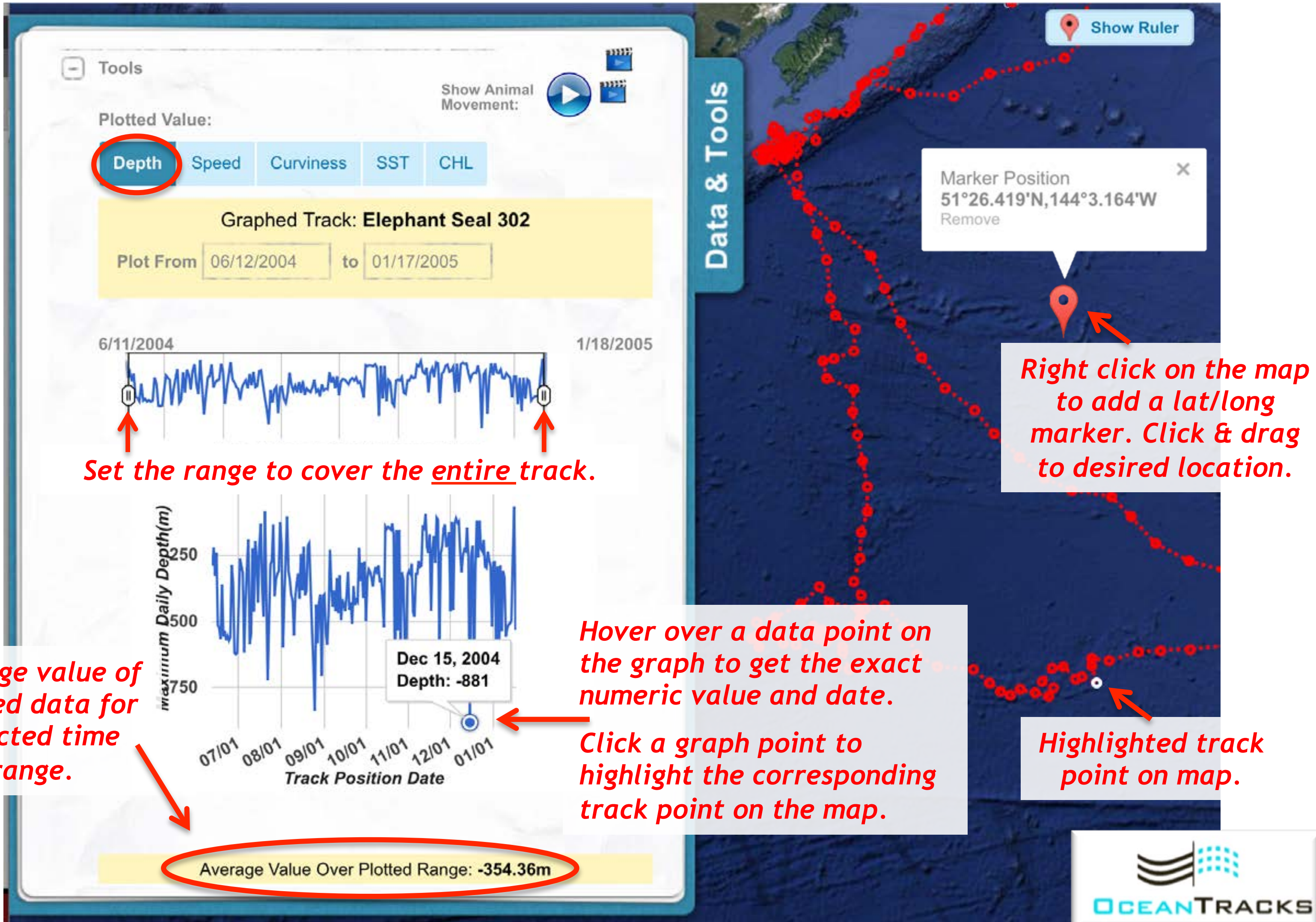


Figure 2. Tips for exploring Ocean Tracks data.

Explore

Table 1. Depth, Speed, & Temperature Data

Animal Species/ ID	Avg. depth (m)	Deepest dive (m)	Date & Lat./Long. of deepest dive	Avg. speed (km/h)	Fastest speed (km/h)	Date & Lat./Long. of fastest speed	Avg. SST along track (˚C)	Max. SST along track (˚C)	Min. SST along track (˚C)
Elephant Seal #302	-351.59		12/15/2004; 43˚18.5'N 143˚15.7'W		5		12.59		
Laysan Albatross #278	NA	NA	NA						
Bluefin Tuna #508400								24.1	
White Shark #501600				1.67					

Explore

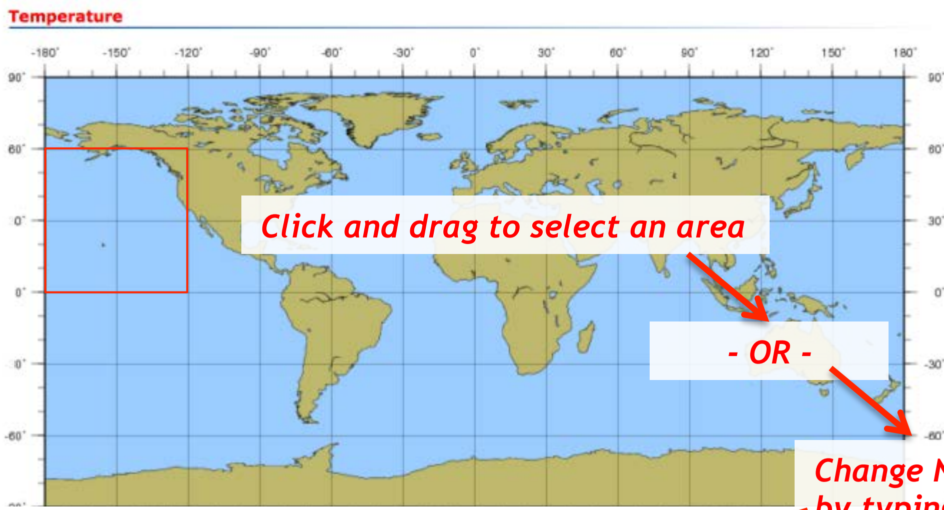
EXPLORE PART 1 QUESTIONS

1. *An animal's physiological adaptations are particularly important at the extremes of the conditions that animal encounters. From your data table, identify the animals and data values (including units) for the following:*
   a. *deepest dive*
   b. *fastest speed*
   c. *largest range of SST along track*
2. *Using depth data from your table, determine the greatest pressure in pounds per square inch (psi) experienced by each of the four animals. For reference, pressure at the surface (atmospheric pressure) is 14.5 psi and increases by approximately 14.5 psi per 10 meters of depth in the ocean.*
3. *Sunlight keeps the top layer of the ocean relatively warm compared to deeper water. Animals diving deep below the surface will encounter a wider range of temperatures than what we see in the SST data. Use the World Ocean Atlas (http://tinyurl.com/oceanatlas) to find the temperature at the approximate location and depth of each animal's deepest dive (**see slides 8 and 9 for information about how to use the World Ocean Atlas**). Record the following information for each animal:*
   - *Species/Track ID*
   - *Depth of deepest dive*
   - *Latitude and Longitude of deepest dive location*
   - *Approximate temperature at depth of deepest dive (in °C)*

OCEANTRACKS

Explore

Set all map and data parameters and then click Show Figure button at bottom left.



Change N,S,W,E edge boundaries by typing in boxes. Click Zoom to show just the selected map area.

Northern edge 60

Western edge -180 Zoom or Redraw World Map -120 **Eastern edge**

Southern edge 0

Grid one-degree quarter-degree

Figure Type Data distribution — *Choose Data distribution*

Time Span 2005-2012 years — *Set time span that best matches track data*

Time Period December — *Choose month of deepest dive*

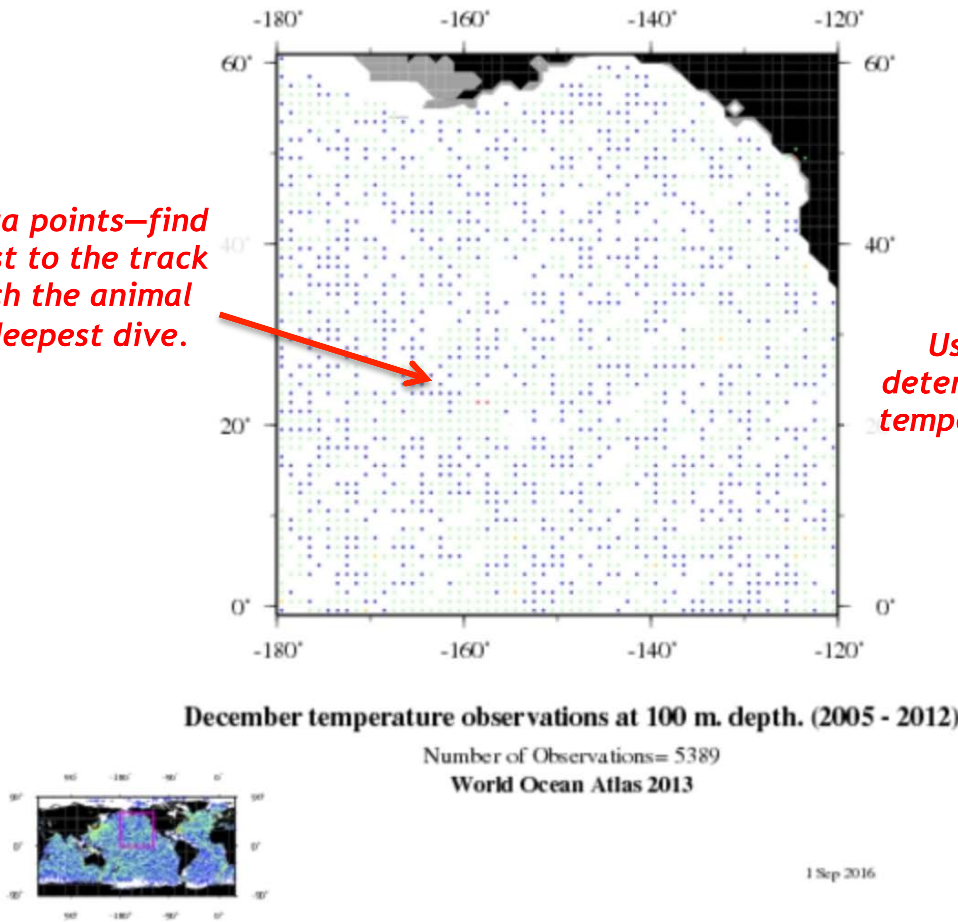
Depth 100 meters — *Select depth*

Show Figure Please, CLICK ONLY ONCE, it may take a while before figure is shown.

Figure 3. How to use World Ocean Atlas

Explore

Individual data points—find the one closest to the track point for which the animal recorded its deepest dive.



Use the color scale to determine the approximate temperature at the location of interest.

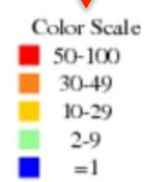


Figure 4. Interpreting World Ocean Atlas Temperature Data

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PART 2: COMPARING ANIMALS OF THE SAME SPECIES

Looking at data from multiple animals within the same species can help us better understand the animals' environmental preferences and tolerance limits.

- Choose one species to explore further. Turn off tracks for all other species.
- Add more rows to the bottom of your data table to record depth, speed, and temperature data for **3 more** tracks of your chosen species. Select tracks from different years if possible.
- On the map, use the **Add Marker** tool to label your map with the name of the species you chose. Save a screenshot of your map showing the tracks you explored for your chosen species.

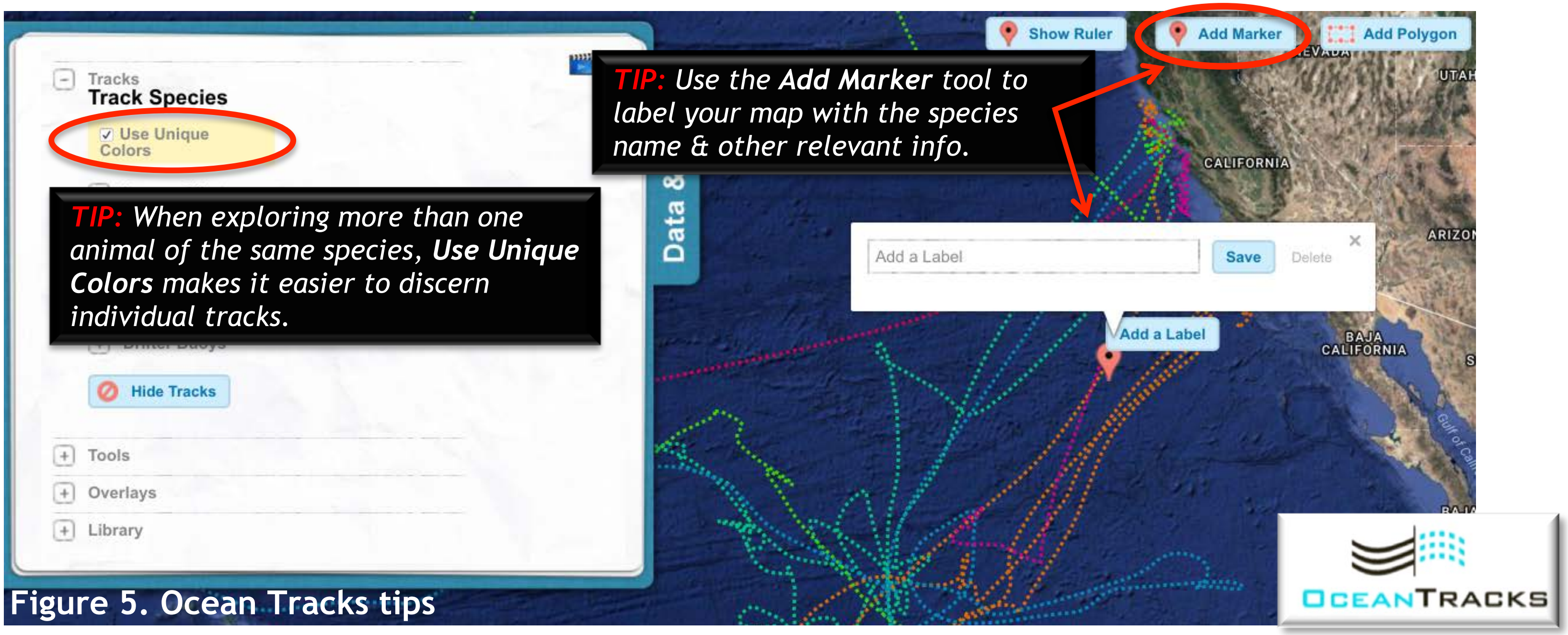


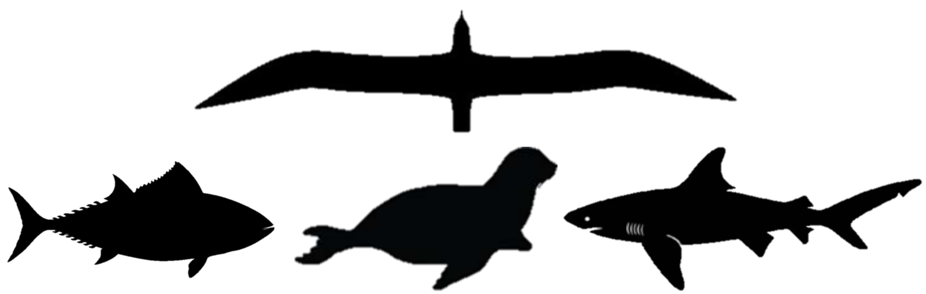
Figure 5. Ocean Tracks tips

Explore

EXPLORE PART 2 QUESTIONS

1. *What species did you choose to explore further? How did the data for the three new tracks compare to the first track you looked at for this species? What values, if any, stood out to you as being noticeably different for one animal compared to the others of that species?*

2. *What questions do these data raise for you about your chosen species that cannot be answered with Ocean Tracks data alone?*



Explore

EXPLORE PART 3: LEARN MORE ABOUT YOUR CHOSEN SPECIES

In this section, you will use the Ocean Tracks Library and primary literature to do some research about your chosen species to learn more about what kinds of adaptations these animals have and what other research has been done with tracking technology to study them.

- Using the Ocean Tracks Library (http://oceantracks.org/library/), the Additional References below, and/or the internet, research adaptations of the species you chose to investigate further.

ADDITIONAL REFERENCES

- **Elephant Seal:**
  - Friends of the Elephant Seal: http://www.elephantseal.org/
  - Boeuf, Burney J. Le, et al. "Prolonged, continuous, deep diving by northern elephant seals." *Canadian Journal of Zoology* 67.10 (1989): 2514-2519. http://mirounga.ucsc.edu/leboeuf/pdfs/LeBoeuf.1989.prolongeddiving.pdf
- **Laysan Albatross:** The Albatross-The Master of Dynamic Soaring: http://tinyurl.com/nld7swl
- **Bluefin Tuna:** Graham, J. B., & Dickson, K. A. (2004). Tuna comparative physiology. *Journal of experimental biology*, *207*(23), 4015-4024: http://jeb.biologists.org/content/207/23/4015.full
- **White Shark:** Del Raye, G., Jorgensen, S. J., Krumhansl, K., Ezcurra, J. M., & Block, B. A. (2013). Travelling light: white sharks (Carcharodon carcharias) rely on body lipid stores to power ocean-basin scale migration. *Proceedings of the Royal Society of London B: Biological Sciences*, *280*(1766), 20130836: http://rspb.royalsocietypublishing.org/content/280/1766/20130836

Synthesize

WRITE A RESEARCH PROPOSAL

Based on the data you explored in Ocean Tracks and the reading you did on the species of your choice, come up with a question you have about how the species you've selected is able to do what you observed in the tracking data. Your assignment is to write a hypothetical research proposal to obtain the data you would need to explore the question you've asked.

EXAMPLE: ***How do body temperature and water temperature affect the heart function of marlins?***

A marlin researcher sees that marlin appear to avoid water warmer than 23°C, and she would like to know why. She suspects that it is because their hearts can't work above that temperature, so she proposes to build a surgically implantable tag with sensors to measure external water temperature, internal body temperature, and heart rate. She will implant these in 100 marlin, in the hopes that at least 10 will be re-captured and the tags recovered for data analysis. Once recovered, she will download and review the data from the tags, looking to see how internal body temperature relates to external body temperature, as well as how it relates to heart function.

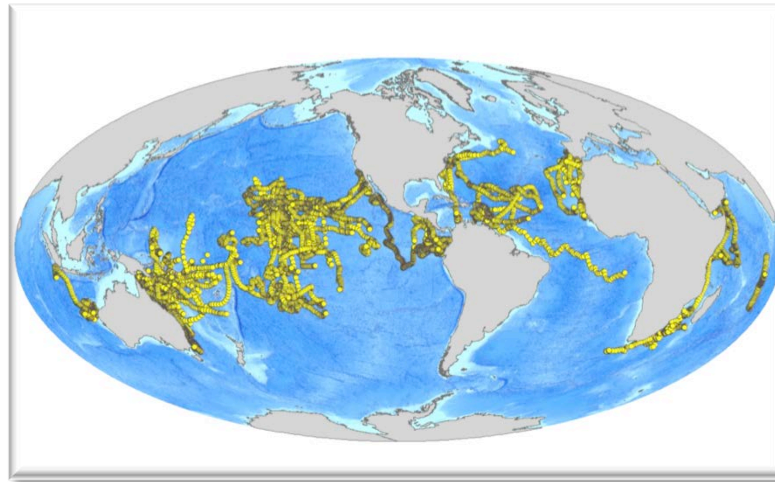


Figure 6. Marlin tracks. Image courtesy of Stanford University and IGFA.

CONTINUED…

Synthesize

PROPOSAL GUIDELINES

Your proposal is not intended to be a fully-realized research proposal, but rather a summary that includes the following key components, which can be captured in 1 well-focused paragraph (or PowerPoint slide) per section:

- **Title**: Interesting and informative enough to convey the nature of the proposed work, but brief.
- **Background**: What did you observe in the Ocean Tracks data that led to your research question? What else would someone reading your proposal need to know to understand your proposed research idea? Include relevant screenshots, Ocean Tracks data, and/or citations.
- **Statement of the Problem:** What is the research question you want to answer? Why is it important or interesting?
- **Proposed Approach:** What will you measure? How will you measure it?
- **Expected Outcomes:** What experimental outcomes would you expect to see from this research? What would each of these results mean?

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