

Lesson 3: Tracking the Gentle Giants– Student Version

Lesson Objectives: At the end of the lesson, students will be able to

- Use basic GeoMapApp skills and mapping software functionality to explore real world scientific data sets collected by marine mammal biologists and oceanographers.
- Examine distribution and movements of blue whales, bowhead whales and Right whales based on satellite telemetry data collected with satellite tags and the ARGOS satellite system.
- Add oceanographic features, including Sea Surface Temperature and Primary Productivity and analyze whale locations and oceanographic habitats in relation to these variables.

Background: Most scientists conducting research follow a process called the **scientific method**. A way for scientists to learn more about a topic is by doing research, or a carefully planned study following the steps of the scientific method (Figure 1).

Research begins with a question that a scientist would like answered or a problem that needs to be solved. Next, the researcher makes a plan for collecting information. This usually includes making observations, conducting background research to learn what other scientists have discovered related to the same topic or scientific question. Then, using the information collected, they construct a hypothesis and devise a research plan. Then the scientist implements the research plan and collects data. Scientists then examine and analyze the data and test their hypothesis. Finally, a conclusion is made and the results are reported. The process does not end there, and is often an **iterative** or repetitive process, with new hypothesis being formed and the process continuing on, often by other researchers (Figure 1).

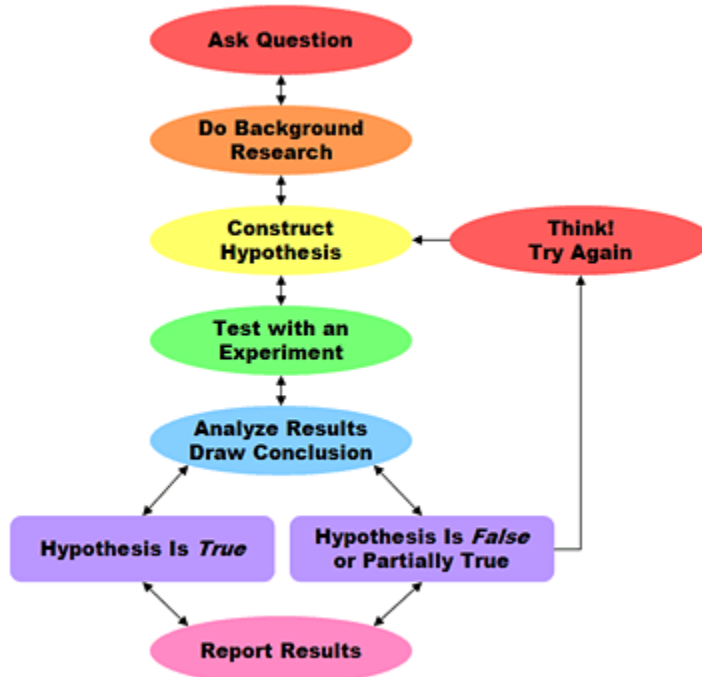


Figure 1. Steps used in the scientific method. The process is iterative, and is often repeated many times.

Have you ever wondered where whales are found in the ocean? Do you think about the habitats or **ecosystems** in the ocean that a whale calls home? **Cetacean researchers** are scientists who want to learn more about these marine mammals and their oceanic environments.

This lesson will highlight the work of Dr. Bruce Mate and the Marine Mammal Institute, located at Oregon State University's Hatfield Marine Science Center. Dr. Mate and his team of researchers collect data on the movements and behaviors of whales fitted with satellite tags. The Marine Mammal Institute has tracked some of the largest and most mysterious animals on our planet, including the blue whale, bowhead whale and North Atlantic Right Whales, the subjects of this lesson.

Blue Whale, *Balaenoptera musculus*



Figure 2. Aerial photograph showing a blue whale in the water next to a tagging vessel, a 15 foot long Zodiac.

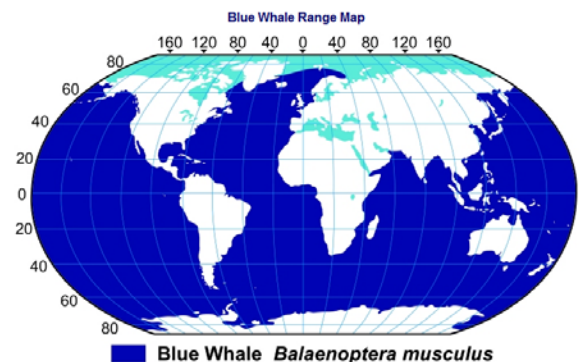


Figure 3. Map showing the distribution of blue whales around the world.

The blue whale is the largest mammal, possibly the largest animal to have ever inhabited the earth. The longest blue whale ever recorded was a 108 foot female caught in whaling efforts off the coast of Antarctica. Blue whales can weigh as much as 150 tons (136,000 kg). This species of whale, a member of the rorqual family, is able to attain such large sizes because of its aquatic existence, where gravity is not a factor and the buoyancy of the water supports the body weight, and the availability of a large food supply. The blue whale feeds on small swarming crustaceans called euphausiids or krill. During the summer feeding season, a blue whale can consume up to 4 tons of krill, or 40 million individual animals a day. Blue whales migrate to calving/breeding grounds located in tropical-to-temperate waters for reproduction. The blue whales may be found in all oceans of the world, and can feed in polar, temperate or

tropical waters. Blue whales are fast, strong swimmers, and capable of reaching 30mph (48.3 km/hr). Their average cruising speed is approximately 12 mph (19.3 km/hr).

Bowhead Whale, *Balaena mysticetus*



Figure 4. Image of a Bowhead whale diving in icy Arctic Waters.

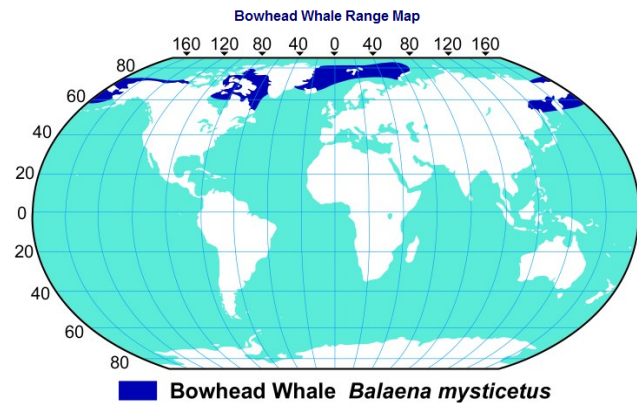


Figure 5. Global distribution of bowhead whales.

The bowhead whale, formerly known by Yankee whalers as the Greenland right whale, is a upper jaw that somewhat resembles the shape of an archer's bow. Its head is immense; it makes up nearly one-third of the bowhead's total body length. Its mouth can be as long as 16 feet (4.9 m), 12 feet (3.7 m) high, and 8 feet (2.4 m) wide and its tongue weighs about 1 ton (907 kg) and adults reach lengths of 60 feet (18.3 m). Bowheads live at the southern edges of the Arctic ice during winters and move into leads through broken & melting ice during summers. Bowhead whales have been an important subsistence item for Arctic native hunters for centuries, with the blubber (*muktuk* in Alaskan Inuit), muscle, & certain internal organs used as valuable energy-rich food; the baleen used to make implements, baskets (from the hairy fringes), & works of art; and the bone used as materials for housing construction, and handles of tools. Bowhead whales feed on planktonic organisms including copepods, amphipods, euphausiids, and various other crustaceans. They consume about 2 tons (1800 kg) of food each day.

North Atlantic Right Whale



Figure 6. Image of a submerged Right Whale.

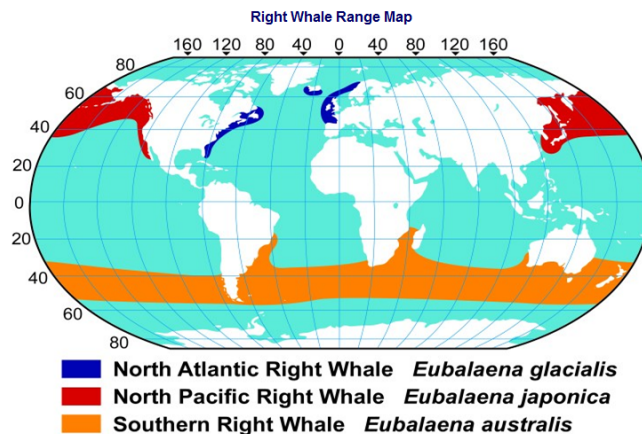


Figure 7. Map showing distribution of three species of Right whales

Adult right whales are generally 35-55 feet (10.7-16.8 m) long. This whale's diet is less varied than that of many other baleen whales. They feed on planktonic organisms including shrimp-like krill and copepods. The right whale may have received its name from whalers who thought that it was the "right" whale to kill because it was correct commercially (oil came from whales in those days), or because it was considered "proper" or "true" which meant typical of whales in general. They were easy targets, if you could ever call going out in small boats with harpoons and lances an 'easy' business. Right whales swim slowly and float when dead, which was important in those days. The exploitation of the right whale began in the Bay of Biscay in Spain by the 12th century and continued, especially in the North Atlantic, for many centuries. Despite being protected since the 1930s, the right whale is today the most endangered of all the great whales.

The whale data used in this lesson was collected by scientists at the Marine Mammal Institute of Oregon State University, using satellite transmitters attached to individual whales, and the ARGOS Satellite Data Collection System.

How Argos Works

Scientists attach transmitters to the dorsal surface of a whale. Transmitters send signals to satellites on dedicated frequencies. Polar orbiting satellites collect the signals as they fly over a transmitter (Figure 9). Then, ground antennas relay recorded and real-time signals from the satellites to processing centers. The

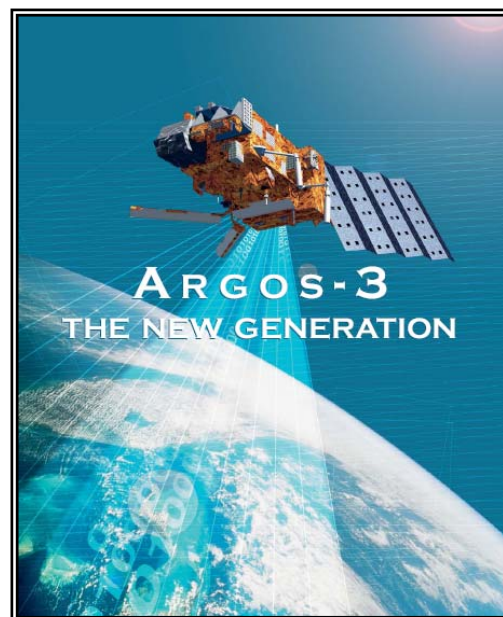
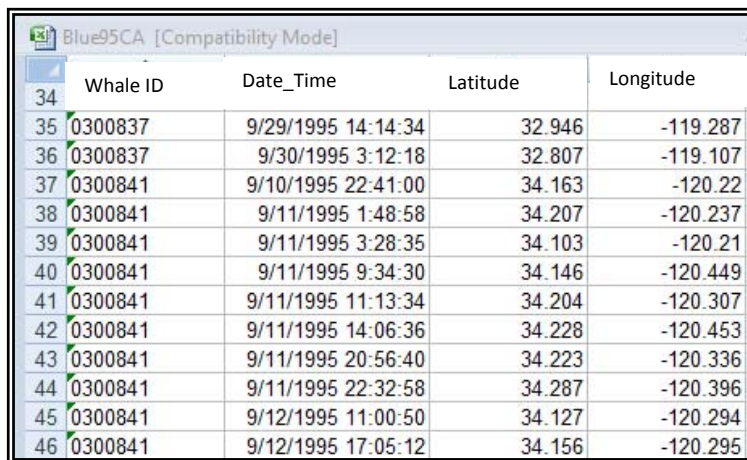


Figure 8. Image of an ARGOS satellite

two processing centers in France and the USA process the signals and send them out as data to users to incorporate into maps, tables or files. ARGOS users all over the world access their data on-line, by email, fax, CD-Rom or directly through mapping software.



	Whale ID	Date_Time	Latitude	Longitude
34				
35	0300837	9/29/1995 14:14:34	32.946	-119.287
36	0300837	9/30/1995 3:12:18	32.807	-119.107
37	0300841	9/10/1995 22:41:00	34.163	-120.22
38	0300841	9/11/1995 1:48:58	34.207	-120.237
39	0300841	9/11/1995 3:28:35	34.103	-120.21
40	0300841	9/11/1995 9:34:30	34.146	-120.449
41	0300841	9/11/1995 11:13:34	34.204	-120.307
42	0300841	9/11/1995 14:06:36	34.228	-120.453
43	0300841	9/11/1995 20:56:40	34.223	-120.336
44	0300841	9/11/1995 22:32:58	34.287	-120.396
45	0300841	9/12/1995 11:00:50	34.127	-120.294
46	0300841	9/12/1995 17:05:12	34.156	-120.295

Figure 9. Telemetry data collected with ARGOS Satellite System on locations of a blue whale.

Exercise 3: Tracking the Gentle Giants

In this exercise, you will learn how to use real world data sets collected by scientists to study the habitats and movements of 3 species of whales, blue whales, bowhead whales and North Atlantic right whales. You will use GeoMapApp tools and functionality to explore the oceanic areas these whales call home.

1. Launch GeoMapApp. Double click on the GeoMapApp icon  on your desktop.

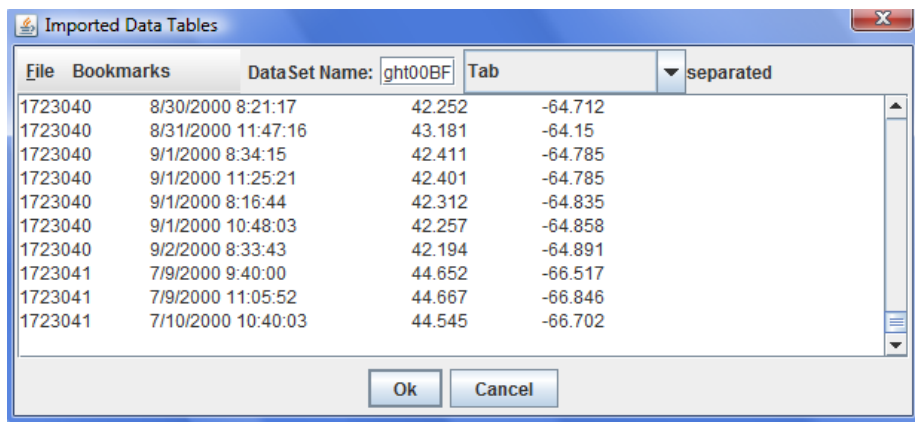
2. Choose a map projection. Select the appropriate projection for the datasets you will use and the area of the world you are most interested in viewing. For this exercise, select the projection option, 'Mercator'.

3. Maximize your GeoMapApp session. Move your mouse over the corner of your map window until it turns into a double headed arrow, click and drag to resize the window.

4. Add whale data to your map.

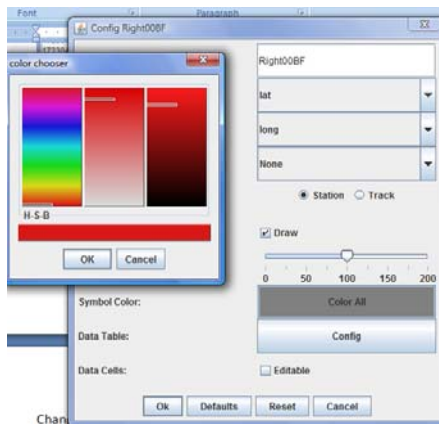
A. Add shapefile data from a folder stored on your system. Select File → Import Shapefile → From Local File System... Navigate to the Lesson 3 data folder and select Blue94CA.shp shapefile.


B. Add spreadsheet data from an Excel File stored on your system. Select File → Import Table or Spreadsheet → From Excel formatted (.xls) file... Navigate to the Lesson 3 Data Folder and choose the Right00BF.xls file. Click Open. The 'Imported Data Tables' Window Opens.

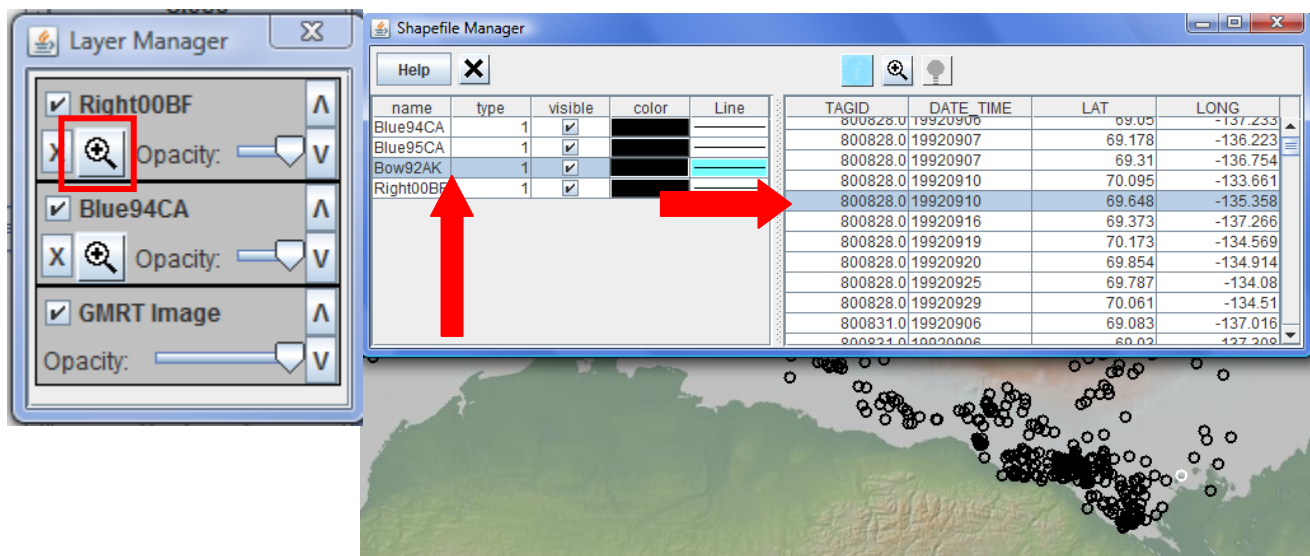


Click OK. The Config data dialog box opens.

C. Change the symbol color of your data. Click on the 'Color All' bar. Use the Color Chooser window that opens up to select a color for your data. Choose a shade of red for the Right Whale Data. Click OK. Click OK again.



5. Zoom to the data layer you added. Locate the 'Layer Manager' dialog box. It may be docked in the bar at the bottom of your window. Click on the name tab to open the box. Click on the Zoom In Tool  next located in the Right00BF layer. This will focus the map view on the best scale for viewing that particular data set, and the map view will center the layout to feature the data set you added.



6. Highlight a record in the Shapefile Manager box and on the map simultaneously. Locate the Shapefile Manager box. Highlight the data set you have zoomed in on by clicking in the column with the 'name' heading. The Bowhead data is highlighted above. Click on a record in the data table and notice the corresponding symbol in the map appears highlighted (a white circle appears around your data). Click on a symbol in the map and notice the corresponding record in the data table is also highlighted.

7. Change the opacity of your data. Click on the Opacity slider bar and slide it left and right. Observe the change in your map view.

8. Add more than one shapefile at a time. Select File → Import Shapefile → From Local File System... Navigate to the Lesson 3 Data Folder. Holding the shift key and clicking on the top record and then the bottom record selects all the records. Holding the 'Ctrl' key and simultaneously clicking on the individual file name one at a time selects the files. Add all of the whale shapefile data sets (all of the files in the Lesson 3_Whales folder).

9. Change the color of your whale datasets. In the 'Shapefile Manager' dialog box, change the color of each whale data set. Double click on the rectangle under the 'color' column to open the 'color chooser' box and select a color that will contrast with the land and ocean floor displays.

10. Explore the whale habitats. Use the Zoom In Tool in the 'Layer Manager' dialog box and zoom in to the whale habitats, one species at a time.

Question 1. Describe the location of the North Atlantic Right Whale.

Question 2. Describe the location of the Bowhead Whale.

Question 3. Describe the location of the Blue Whale.

Note: refer back to the introduction, and examine the range maps of each species.

Question 4. Why do you think the data only covers a small area compared to the range maps presented in the introduction of this lesson? Hint: Look at the dates of the data.

Satellite tags are designed to withstand a variety of environmental conditions, but it can be rough seas out there. Tagging devices fall off animals or fail for a variety of reasons. The life expectancy of a tag on a marine mammal can be a few days to a few months, and is an element of uncertainty in any **telemetry** research project. Tagging marine animals is expensive, and the tags range from \$2,000 to \$5,000 per tag, and that does not include the ship costs and data retrieval costs of subscribing to the ARGOS data collection system.



Figure 10. Satellite tag designed for marine animals.

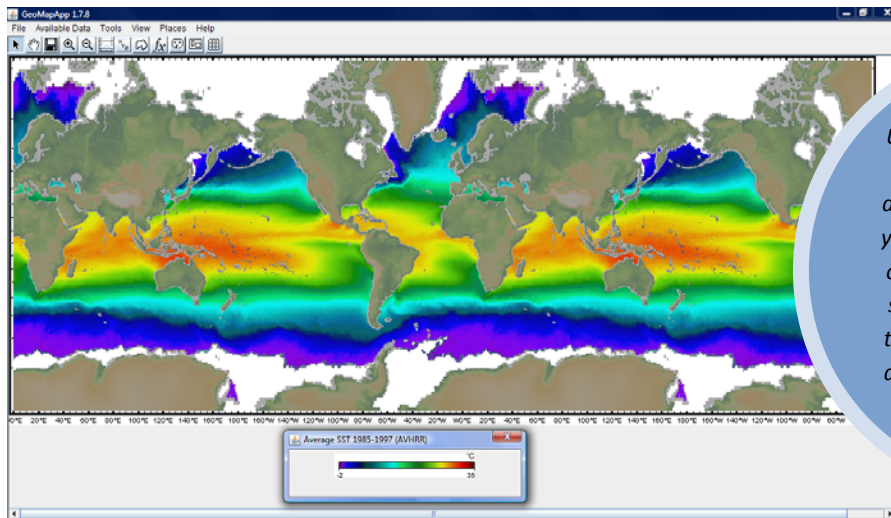
Question 5. How many months were researchers able to collect satellite data for each species? Fill in the table below. For geographic range, use the cursor and notice the latitude and longitude information that displays in the GeoMapApp window.

	Geographic Range	Temporal Range (dates of tagging data)
Right Whale		
Bowhead Whale		
Blue Whale94		
Blue Whale95		

Question 6. Based on these data sets, estimate which tagged whale species covered the largest geographic range?

11. Zoom out to Global Scale. Select Bookmarks → Zoom out to Global Scale.

12. Add Oceanographic Data. Select Basemaps → Sea Surface Temperatures → Average SST 1985 – 1997 (AVHRR).



User Tip: The scale bar may be docked in your windows docking bar at the bottom of your window. Find the name of the scale bar (if you don't see it in your map view, it is the same as the name of the data set, and double click on it.

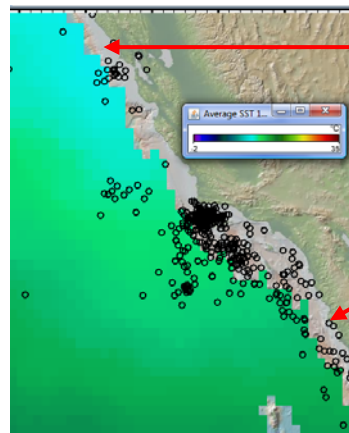
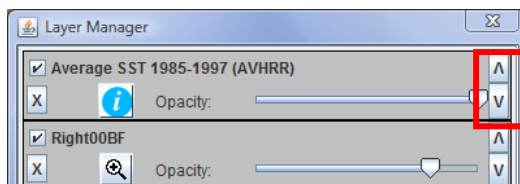
13. Examine the Sea Surface Temperature layer and compare the whale data in relation to this oceanographic variable. Notice the general pattern of temperature variation.

Question 7. How is temperature displayed visually on the map? Hint: What information does the color bar give you?


Question 8. Where are warmer ocean waters located?

Question 9. Where are cooler ocean waters located?

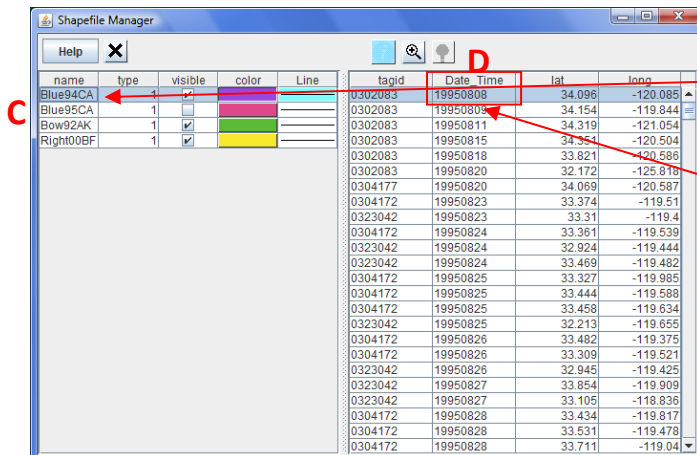
14. Zoom into to the whale data. Zoom into the whale data and examine the whales species' locations relative to temperature. You may need to move the Sea Surface Temperature layer down so that it lies underneath the whale data. Click the down arrow next to the Average SST data layer in the Layer Manager box until it is the bottom layer. You may notice that the SST layer is not filled in near the shoreline in some areas. This is due to the nature of satellite data collection and the difficulty of obtaining accurate data in near shore areas.



Gray areas near the coast represent gaps in sea surface temperature data.

A. Zoom into the Blue Whale data. You may need to use the Zoom Out Tool  one time to see the full range of the data. One of the data sets collected satellite data for 4 months. Let's examine this data set.

B. Open and maximize the Shapefile Manger Dialog Box.



C. Click on the Blue 95 data record.

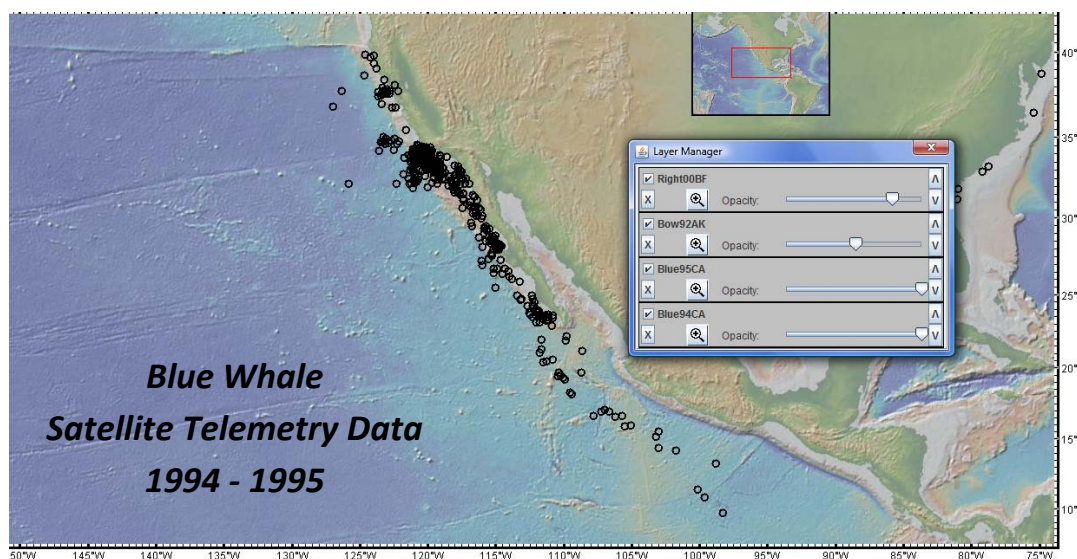
D. Click on the 'Date_Time' Column heading. This orders all data records by that category. The first record is listed as 19550808. This means the first data point was collected on August 8, 1995.

E. Use the blue slider bar on the right side of the window to scroll down to the last record.

Question 10. What was the last date of data collected in 1995? Approximately how many months was data collected on blue whales in this year?

15. Turn off the Blue95CA layer. Click the check mark in the Blue95CA layer in the Layer Manger Dialog Box.


16. Use the highlight function to determine where the whales were at the beginning and end of data collection. Click on the data record in the data table, and the data record is highlighted on the map with a white circle outline on the map. Scroll to the end of the data set to find the last data point recorded.



Question 11. Label the map above with an “S94” near the start date for the BlueWhale94 data and an “E94” near the end data point for the BlueWhale94 data. Do the same using “S95” and “E95” for start and end points of the blue whale data collected in 1995.

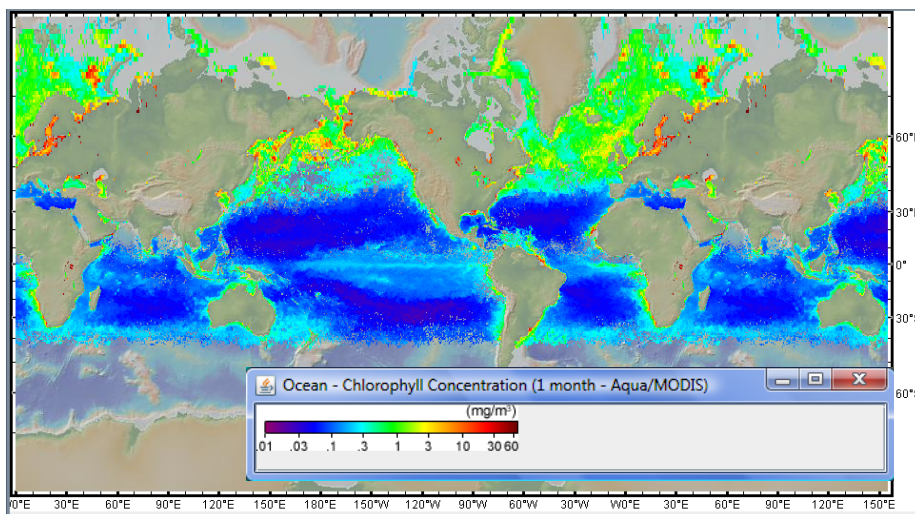
Question 12. What range of temperatures did the blue whales travel through?

Question 13. Using the scientific method and the data you have examined, propose a hypothesis about blue whale migratory movements and possible reasons for them.

17. Explore more information about the layer. Click on the Internet Information button  next to the layer name (Average SST) in the Layer Manager Dialog Box. A website launches with more information about the Sea Surface Temperature data.

18. Turn off the Average SST layer. Click the check mark next to the layer name in the Layer Manager Dialog Box.


19. Add the Primary Productivity Layer. Select Basemaps → Ocean Primary Productivity → Ocean Chlorophyll Concentration (1 month AQUA/MODIS). This is a composite raster image based on one month of data collection by the AQUA/MODIS satellite system. This system measures chlorophyll amounts in surface ocean waters and computer technicians apply a color scale to represent the different measured levels of chlorophyll.



20. Examine the Scale Bar for the Primary Productivity (Ocean- Chlorophyll Concentration. Hint: The scale bar may be docked in the bottom windows tray. Maximize the scale bar by double clicking on the name in the tray.

Question 14. What are the units of primary productivity?


Question 15. What range of primary productivity is found in the world’s oceans?

21. Explore metadata (information about your data). Use the internet Information button  next to the Ocean – Chlorophyll Concentration data layer and navigate to the NASA Earth Observations website. Click on the ‘About NEO’ link (upper right hand corner).

Question 16. What is the mission of the NEO?

22. Close the NEO website and Zoom Out to the World Extent in GeoMapApp. Select Bookmarks → Zoom to World Extent.

Question 17. Use the Ocean-Chlorophyll Concentration Scale Bar and describe the pattern of Primary Productivity around the world. Describe the general patterns of relative concentrations (use the terms equator, polar regions, near shore, open ocean).

23. Zoom In on the Right Whale data. Use the zoom tools or the Shapefile Manager. You may need to change the color of your right whale data and/or move the Ocean – Chlorophyll layer down using the down arrow next to the layer name to see both data sets. To change the color of your data, click on the Shapefile Manager button , then double click on the rectangle in the Color column. Use the slider bars to change the color of the data points on the map layout.

Question 18. Are Right Whales found in areas of high or low chlorophyll concentrations?

Question 19. Describe the chlorophyll concentrations (primary productivity) in the Right Whale habitat. Hint: Notice that there are areas of high productivity (orange and red pixels). Where are these areas located?

Question 20. Examine the blue whale data. Describe the range of chlorophyll concentrations in the areas where blue whales traveled.

Question 21. Examine the bowhead whale data. Describe the range of chlorophyll concentrations in the areas where bowhead whales traveled.

Key words: Cetacean Researcher, scientific method, ecosystems, iterative, satellite tags, telemetry, primary productivity, chlorophyll concentration, metadata.



Diving in Deeper - Extending the Lesson

1) Meet the man behind the data! Read this newsletter by Dr. Bruce Mate, the lead scientist for the Whale Telemetry group at the Marine Mammal Institute.

http://mmi.oregonstate.edu/sites/default/files/2009_Feb_Newsletter_color.pdf

The data collected on the blue whale is featured by National Geographic on this website <http://channel.nationalgeographic.com/episode/kingdom-of-the-blue-whale-3302>. There are videos, photos, exploratory sections using Google Earth Ocean, and even interactive games to tag and track blue whales! The TV documentary on the blue whale, 'Kingdom of the Blue Whale' features the same data used in this GeoMapApp lesson, and would make a great addition to your classroom activities, and it is available for purchase from National Geographic.

2) Read the following articles from scientific journals. These articles feature the same data sets used in these lessons and are included in the Lesson 3 folder, listed under the pdf title name given below. Reading these articles will give students a better sense of how scientists communicate results of their research in professional formats, scientific journals.

1. pdf title – BlueWhale_Satellite

Scientific Reference - Lagerquist, B.A., K.M. Stafford and B.R. Mate. 2000. *Dive characteristics of satellite-monitored blue whales (Balaenoptera musculus) off the central California coast*. Marine Mammal Science 16(2):375-391

2. pdf title - Bowhead_Diving

Scientific Reference- B. R. Mate, G. K. Krutzikowsky and M. H. Winsor. 2000. Satellite-monitored movements of radio-tagged bowhead whales in the Beaufort and Chukchi seas during the late-summer feeding season and fall migration . *Canadian Journal of Zoology*. 78:1168-1181 (2000).

3. pdf title - Bowhead_Satellite

Scientific reference - G.K. Krutzikowski and B.R. Mate. 2000. Dive and surfacing characteristics of bowhead whales (*Balaena mysticetus*) in the Beaufort and Chukchi Seas. *Canadian Journal of Zoology*. 78:1182-1198 (2000).

4. pdf title - RightWhale_Satellite

Scientific Reference - Baumgartner, Mark F.; **Mate**, Bruce R. Summer and fall habitat of North Atlantic right whales (*Eubalaena glacialis*) inferred from satellite telemetry. *Canadian Journal of Fisheries & Aquatic Sciences*, Mar2005, Vol. 62 Issue 3, p527-543.

3) Read more about satellite tags

http://whale.wheelock.edu/whalenet-stuff/sat_tags_work.html .

4) Learn more about other cetacean species. The American Cetacean Society Whale Fact Packs are great learning tools and can be found at <http://www.acsonline.org/factpack/index.html> .

5) Explore the scientific method in more detail. Science Buddies has a complete section on the steps of the scientific method, including detailed help for each step http://www.sciencebuddies.org/science-fair-projects/project_scientific_method.shtml.

References and Web Searches for Students and Teachers Websites

1) Whale Habitat Maps www.acsonline.org

2) Right whales and hydrophones

<http://www.wired.com/wiredscience/2008/05/hydrophones-hel/>

3) Marine Mammal Institute <http://mmi.oregonstate.edu/>

Whale Telemetry Group at Marine Mammal Institute, OSU, <http://mmi.oregonstate.edu/wtg>