Creating and Analyzing a Phoenician Navigational Safety Zone

—by Jeff Blossom

Introduction

Problem

How would you use land visibility to map an ancient civilization's navigational safety zone?

The Phoenicians excelled at maritime trading, sailing the Mediterranean Sea between 1500 and 300 AD (Markoe 2000). These remarkable seafaring people, credited with spreading the alphabet, occupied small enclaves in port towns that served as their bases of operations both religious and economic. These ports of call defined the Phoenician geographic footprint and grew to include many locations along hundreds of kilometers (km) of the eastern Mediterranean coast. Sailing safely from port to port was essential to the Phoenicians' livelihood.

Navigating within sight of land is the safest way to sail and remained the Phoenicians' preferred method, even when navigation using celestial bodies became better understood. Exactly how far out to sea could they sail and still be in sight of land? In other words, what was the Phoenicians' navigational safety zone? Landmark visibility while at sea depends on the coastal land's height above sea level (elevation), the distance of inland elevated features from the coast, and air clarity. Using a digital elevation model (DEM), observer point locations, and parameters available in geographic information system (GIS) software, you can model this landmark visibility and map the navigational safety zone within which an enterprising ancient people sailed for more than a thousand years.

Location

Eastern Mediterranean Sea

Keywords: visibility; landmarks; historic; coastal topography

Time to complete the lab

Two hours

Prerequisites

Cursory familiarity with ArcGIS® software

Data used in this lab

- Shuttle Radar Topography Mission (SRTM) 90-meter (m) elevation data; country and ocean boundaries; latitude and longitude locations
- Geographic coordinate system: WGS 1984
- Datum: WGS 1984
- Projected coordinate system: UTM, Zone 36N

Student activity

You will use the data and software in this lab to reconstruct a model of a vital aspect of an ancient maritime trading culture and then use that model to analyze it further. The Phoenicians' economic model for existence was based on trade along coastal cities with established societies (Markoe 2000). The mariners prayed to gods of the sea for safe passage and erected temples of worship on promontories along trade routes (Brody 1998). Fixing their position in relation to known landmarks was critical to safe, successful navigation between economic and religious destinations.

What was the nature of the coastal area the Phoenicians frequented? What landmarks were used for navigation? How prominent must a mountain have been to be used for navigation? Coastlines with elevations that rapidly increase as one travels inland are more visible farther out to sea than coastlines with low relief. By inspecting a DEM and accounting for the curvature of the earth, you will be able to make an educated guess as to how far off the coast land remains visible.

Evidence points to a Phoenician presence in the cities of Arwad, Byblos, and Tyre—all major economic centers—and the port of Kition on the island of Cyprus (Markoe 2000), to which the Phoenicians eventually expanded their trade. The city of Ugarit was also important to Phoenicians; it contained a shrine to one of their gods, Baal (Brody 1998). To familiarize yourself with these cities and the surrounding vicinity, you will make an overview map. Then you will create an elevation map and analyze it to determine prominent landmarks on the coast. Finally, you will calculate viewsheds (areas visible from an observation point) and produce a navigable safety zone map showing area waters from which seafarers could count on spying land.

In this lab, you will do the following:

- **Prepare the data**
  - Copy the DEM and coastline data.
  - Map the locations of Arwad, Byblos, Tyre, Ugarit, and Kition based on their latitude and longitude values.
- **Create maps**
  - Create an overview map of the eastern Mediterranean Sea and Phoenician ports.
  - Create an elevation map using hypsometric shading.
  - Create a viewshed map from the high point along the coast.
  - Create a maritime navigable safety zone visibility map.
- **Analyze results**
  - Determine the navigable safety zone for a ship sailing the eastern Mediterranean coast.
  - Determine whether it is possible to sail within sight of land to reach the island of Cyprus from the eastern Mediterranean coast.
  - Identify areas of high and low sailing risk as defined by the width of the navigable safety zone.

PREPARE YOUR WORKSPACE

1 Create a ***SpatiaLABS*** folder and a ***Phoenician*** subfolder under the *C:* folder.

2 Locate *Phoenician.zip* and put it in the *C:\SpatiaLABS\Phoenician* workspace.

3 Examine all the data in the *Phoenician* folder (you should have *Phoenician_sites.xlsx* and *Phoenician.gdb*, which contains *World_Countries*, *ocean*, *High_Point*, *High_Points*, *E_Med_Poly*, and *E_Med_DEM*).

CREATE A PHOENICIAN OVERVIEW MAP

1 Launch ArcMap™ and use the *Add XY Data* command (click *File » Add Data » Add XY Data*) to convert the coordinates in workbook sheet 1 of the *Phoenician_sites.xlsx* Microsoft Excel file into a shapefile named ***Sites***. These coordinates are in the WGS 1984 geographic coordinate system.

Question 1: *In what modern-day countries are these sites located? How did you determine this?*

2 Load the *World_Countries* and *ocean* feature classes from the *Phoenician* geodatabase and create a location map of these sites similar to map 1 below.

Map 1: Location map of the Phoenician civilization

3 The map document should contain three data frames: one for the global overview, one for the Mediterranean overview, and one for the eastern Mediterranean. For the global overview, use the *ocean* and *World_Countries* feature classes. For the Mediterranean and eastern Mediterranean maps, the *ocean* polygon coastline is not detailed enough to use. For these two maps, set the data frame background to blue and add *World_Countries*. The result will display blue (for water) where there is no land.

4 Include city and country labels, a scale bar, and a north arrow.

5 Use the *Measure* tool to get a feel for the distances between these sites and from the sites to the island of Cyprus.

Question 2: *What is the distance from Kition to Byblos in kilometers?*

Create an elevation map

1 Add the *E_Med_DEM* map layer. This is a digital elevation model that contains elevation readings in meters above sea level at 90 m apart.

Question 3: *What are the minimum and maximum elevations of E_Med_DEM?*

Question 4: *What are the northernmost, southernmost, westernmost, and easternmost coordinates of E_Med_DEM in latitude and longitude?*

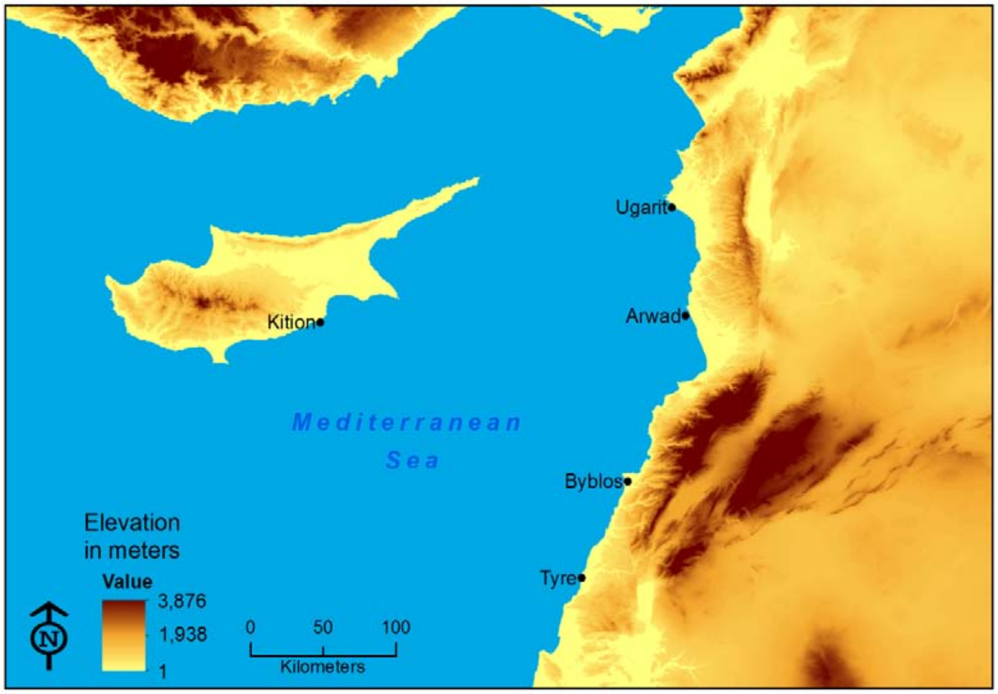
Hypsometric shading is the cartographic technique of coloring like values or groups of values using the same color to enable the map reader to visualize a range of different values across the map. This technique is commonly used with elevation raster datasets. Symbolizing a raster dataset by using the stretched classification method in ArcMap results in hypsometric shading.

2 Apply this symbology to the DEM using intuitive colors.

3 Add the *E_Med_Poly* feature class (water areas) and symbolize in blue.

4 Add a legend to your map.

Your map should look similar to map 2 below:



Map 2: Elevation map of the eastern Mediterranean coastline

Question 5: *Interpreting the elevation map, describe the coastal topography from north to south along the eastern coast of the Mediterranean Sea. Make sure to mention any prominent features (high points) near the coast.*

CREATE A VIEWSHED MAP

A viewshed is the visible area from an observation point. The *E_Med_DEM* dataset contains cells (squares) of equal size, each tagged with an elevation value.

1 Zoom in very close so you can see these squares and measure the width of a cell.

Question 6: *What is the width of the cell in meters? Are these perfect squares?*

Whether or not a cell is visible from another single observation cell on the map is determined by computing the altitude angle to the cell center using the altitude angle of the local horizon (ArcGIS for Desktop Help). The local horizon is computed by considering the intervening terrain between the point of observation and the cell being analyzed. If the point lies above the local horizon, it is considered visible.

The viewshed command takes an input observation point and calculates whether all other cells in the DEM are visible from this point. If visible, the cell is assigned a value of *1* in the output raster layer; if not visible, the output value is *0*.

The viewshed command defaults to using a flat surface, which the earth certainly is not. Therefore, the viewshed command contains an option that adjusts for the curvature of the earth. The rate of curvature of the earth is such that when moving across land or water of equal elevation, the local horizon is not visible after a distance of 5 km if the observation point is 1.7 m high. As the elevation of the observation point increases, the viewable distance also increases. In terms of what can be seen, it is possible to see high points, such as mountaintops, that are much farther away than lower features that may be closer.

In terms of a sea coast, the more drastic the relief, the farther out to sea the land is visible. To determine how far out to sea the land on the eastern Mediterranean is visible, observer points could be placed at increasing intervals moving westward out to sea, and testing could be done to see if the resultant viewsheds intersect the land. This might involve the placement of many points and subsequent viewshed generations to find the spot at which land is not visible. A more efficient way to do this is to determine the high points that are nearest to the coast and create viewsheds of these. This will reveal all areas that these high points are visible from, creating a boundary out in the water outside which land is not visible.

2 Add the *High_Point* feature class, which contains the highest point of the DEM.

The high points in elevation have been determined by querying the DEM.

3 Add an attribute named ***OFFSETA*** of type *Double* to this feature class.

4 Calculate the *OFFSETA* value as equal to *4*.

Entering this offset distance will effectively raise the elevation of the observer point 4 m off the ground and ensure that your viewshed is not affected by minor inconsistencies in the DEM.

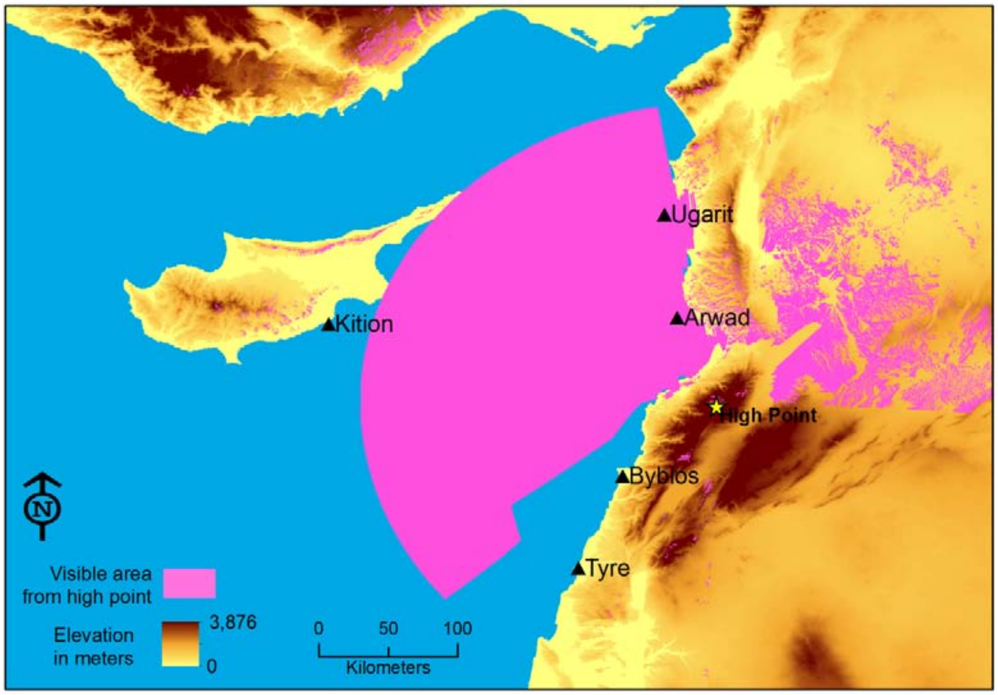
5 In ArcToolbox™, use the *Viewshed* tool (*Spatial Analyst » Surface » Viewshed*) to create a viewshed from this point, being sure to select the *Use earth curvature corrections (optional)* check box.

6 Symbolize the resultant viewshed raster so all nonvisible (null) areas have no color.

7 Symbolize visible areas using a color that contrasts with the background map.

8 Make a map of the high point viewshed, making sure to include a legend, scale bar, and north arrow.

The map should look similar to map 3 below:



Map 3: The viewshed from the coastal high point of the DEM

Question 7: *How far out to sea is the high point visible?*

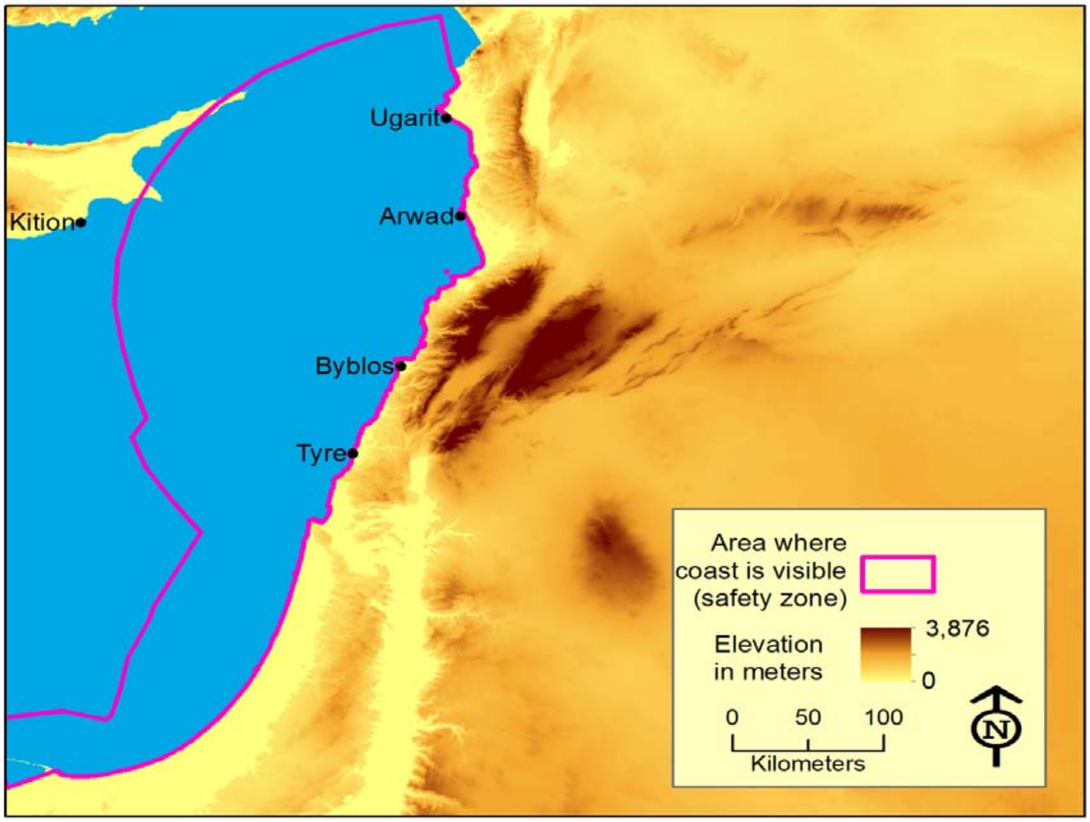
CREATE THE PHOENICIAN NAVIGATION SAFETY ZONE MAP

1 Create another viewshed along the coast from the *High_Points* feature class. These are additional high points extending south along the coast.

2 Display the visible areas of the resultant viewsheds. Create a polygon feature class and digitize a polygon to enclose the visible areas from the two viewsheds.

3 Make a map with this coastal visible area displayed. This is the Phoenician navigable safety zone.

The map should look similar to map 4 below:



Map 4: Phoenician navigation safety zone.

4 Examine this safety zone.

Question 8: *How does the shape of the safety zone change as you move south? Why?*

Question 9: *Is land visible the entire time if you are sailing from the eastern Mediterranean coast to the island of Cyprus? How might this have affected the economic importance of Cyprus to the Phoenicians?*

Question 10: *If a Phoenician sailor wanted to extend his trading area for economic gain, would there be a larger navigable safety zone sailing north from Ugarit or south from Tyre? What other factors would affect economic opportunities in either scenario?*

Question 11: *What environmental conditions may have changed between the Phoenician time period and now that could make the use of a modern DEM ineffective? How could these discrepancies be fixed or accounted for?*

Question 12: *For what other purposes could viewshed creation analysis be used? List at least three.*

Submit your work

Submit the following:

- Map 1: Overview map of the eastern Mediterranean Sea and Phoenician sites
- Map 2: Elevation map of the eastern Mediterranean coastline
- Map 3: Viewshed from the coastal high point
- Map 4: Safety zone (coastal visible area) map
- Answers to questions 1–12

Credits

Data

High_Point and High_Points data were created by the author. Other data for this activity courtesy of NASA, NGA, USGS EROS, and Esri; source: Esri Data and Maps, 2008.

Instructor resources

Context for the lab

This SpatiaLAB is written primarily for undergraduates studying history or geography.

The lab shows how to use modern-day geographic information to analyze historic phenomena. It is intended to promote thinking about how geographic data and software can be used to reconstruct models of past environments and then use these models to perform analyses.

Instructors may engage students to discuss the limitations of using the modeling techniques in this lab, how the results might be misinterpreted, and how these viewsheds can be compared against actual conditions on the ground.

Using a spatial approach, GIS can be one of the most useful tools to explore historic spatial data, data analysis, and mapping.

This lab uses elevation, latitude and longitude, coastal, and political boundary data.

Students are asked to answer 12 questions, perform GIS analyses, and make four maps.

Analysis and visualization tools

ArcGIS 9 or 10 using the Spatial Analyst extension is required to complete this lab.

Answers to questions

Question 1: *In what modern-day countries are these sites located? How did you determine this?*

Answer: These sites are located in Lebanon, Syria, and Cyprus. You can determine this by looking at what country each city fell into on the location map (map 1).

Question 2: *What is the distance from Kition to Byblos in kilometers?*

Answer: The distance from Kition to Byblos is 205 km.

Question 3: *What are the minimum and maximum elevations of E_Med_DEM?*

Answer: The minimum elevation is 1 m, and the maximum elevation is 3,876 m.

Question 4: *What are the northernmost, southernmost, westernmost, and easternmost coordinates of E_Med_DEM in latitude and longitude?*

Answer: The northernmost coordinates are 40.212; southernmost, 29.812; westernmost, 29.601; and easternmost, 40.909. They were obtained by using the Project Raster command on the E_Med_DEM, projecting it into the WGS_1984 geographic coordinate system, right-clicking the result, clicking Properties, and then looking at the Extent values on the Source tab.

Question 5: *Interpreting the elevation map, describe the coastal topography from north to south along the eastern coast of the Mediterranean Sea. Make sure to mention any prominent features (high points) near the coast.*

Answer: At the very northernmost end of the coast, there is a mountain range that rises steeply up to about 1,700 m above sea level and extends eastward about 20 km . The land inland of the coast is much gentler from about 50 km north of Ugarit to about 50 km south of Arwad. There is a singular mountain peak about 50 km north of Ugarit. At about 50 km south of Arwad, the elevation quickly rises to peaks as high as 3,000 m. This ridge of high mountains extends to the south for about 120 km and east into the land for several hundred kilometers. The coastal topography then becomes much gentler, starting at approximately 30 km north of Tyre. From there, the topography remains gentle, rising very little along the inland stretches to the southernmost extent of the DEM.

Question 6: *What is the width of the cell in meters? Are these perfect squares?*

Answer: The cell width is 87 m. Yes, these are perfect squares. The answer is found by right-clicking E_Med_DEM, clicking Properties, and reading the cell size value.

Question 7: *How far out to sea is the high point visible?*

Answer: The high point can be seen at approximately 212 km.

Question 8: *How does the shape of the safety zone change as you move south? Why?*

Answer: It becomes narrower. This is because of lower coastal elevations and gentler topography in the south.

Question 9: *Is land visible the entire time if you are sailing from the eastern Mediterranean coast to the island of Cyprus? How might this have affected the economic importance of Cyprus to the Phoenicians?*

Answer: Yes, land is visible the entire time. This would enable the Phoenicians to sail within sight of land from the coast to Cyprus. This made Cyprus of potentially high economic importance to the Phoenicians.

Question 10: *If a Phoenician sailor wanted to extend his trading area for economic gain, would there be a larger navigable safety zone sailing north from Ugarit or south from Tyre? What other factors would affect economic opportunities in either scenario?*

Answer: The larger navigable safety zone would be north from Ugarit, because land is visible to a greater distance out to sea. Other factors to consider include the water depth of the port (how easy it is to dock a boat near shore), the willingness of the population at the port to participate in economic activities, and the total population in the port city and its access to economic resources (timber, minerals, and the like).

Question 11: *What environmental conditions may have changed between the Phoenician time period and now that could make the use of a modern DEM ineffective? How could these discrepancies be fixed or accounted for?*

Answer: Changing environmental conditions that could affect the use of a modern DEM include sea level rise or fall and events that change the shape of the land, such as volcanic activity or human leveling or building up the land. To fix these inconsistencies, elevations in the DEM could be edited manually to account for the differences.

Question 12: *For what other purposes could viewshed creation analysis be used? List at least three.*

Answer: Viewshed analysis could also be used to (1) create a map of the viewsheds from which a proposed radio tower or wind turbine is visible, (2) model the viewable land from fire observation towers, and (3) analyze the impact of a proposed building or neighborhood on the viewsheds of the surrounding countryside.

References

ArcGIS for Desktop Help.
`http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009z000000v3000000.htm`

Brody, Aaron J. 1998. *Each Man Cried Out to His God: The specialized religion of Canaanite and Phoenician seafarers*. Atlanta, GA: Scholars Press.

Markoe, Glenn. 2000. *Peoples of the Past: Phoenicians.* London: British Museum Press.

Data information

The dataset Phoenician.zip contains the E_Med_DEM, E_Med_Poly, High_Point, High_Points, ocean, and World_Countries feature classes and the Phoenician_sites spreadsheet.

Data sources

Eastern Mediterranean DEM, **Country, ocean, E_Med_Poly, High_Point, and High_Points feature classes:** Esri Data & Maps 2008

The E_Med_DEM was clipped from the ArcGIS 9.3 Elevation & Imagery Data\srtm_void_filled\elevation dataset. The country boundary feature class was exported from the

ArcGIS 9.3 Data & Maps\world\data\country.sdc dataset. The ocean boundary feature class was exported from the ArcGIS 9.3 Data & Maps\world\data\ocean.sdc dataset. E_Med_Poly was created by reclassifying E_Med_DEM into all values < 1 and then converting the result into a polygon. The High_Point and High_Points feature classes were created by manually querying the DEM and digitizing points.

Phoenician_sites.xlsx locations: maps.google.com/ (accessed February 2011)

The latitude-longitude values in this spreadsheet were obtained by entering the city names into Google Maps, one of several free geocoding services on the Internet. The resultant locations were then slightly refined, placing the locations right on the coast. Many of the ideas behind the Phoenician exercise were conceived during conversations with Jeff Howry, PhD, research associate at the Harvard Semitic Museum. His help during these brainstorming sessions is much appreciated.