Get Started with Temporal Data

In the lessons that follow, you'll learn how to manage, analyze, and map temporal data in ArcGIS for Desktop). You'll use techniques such as time-enabled mapping, analysis using models with an iterator, and analysis using tools with a case field.

You'll learn these techniques through a case study about *Dreissena polymorpha*, commonly known as the zebra mussel. Even though this mollusk is usually about the size of a fingernail,[1] it has earned a well-deserved reputation as a national threat. It's on the list of the world's top 100 invasive species.[2] The United States Geological Survey (USGS) calls it "the most serious nonindigenous biofouling species ever in the freshwater systems of North America."[3] The zebra mussel ultimately led to passage of the National Invasive Species Act in 1996 and has been called "the poster species for invasive law."[4] Most disturbingly, once zebra mussels have become established in a water body, they are impossible to fully eradicate, and no solution has been found to kill them without harming other species.[5]

Although it seems like there's little that can be done, people can help by reporting zebra mussel sightings and taking measures to prevent the mollusks' spread. The first thing people need to do is to learn all they can about zebra mussels—what they are, how to identify them, where they came from, how they spread, and what threats they pose. Then people can use this information themselves and share it with others. Your goal in this project is to find out what you can about the geographic aspects of the zebra mussel issue so that you can then share that important information with others.

Build skills in these areas:

- Creating temporal maps
- Creating cumulative density maps

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[1] http://www.nationalatlas.gov/articles/biology/a_zm.html (accessed October 29, 2015)
[2] http://www.issg.org/database/species/search.asp?st=100ss (accessed October 29, 2015)
[3] http://www.fs.fed.us/invasivespecies/speciesprofiles/documents/zebra_mussel.pdf (accessed October 29, 2015)
[4] http://www.necis.net/intro-to-invasive-species/what-we-know/introducing-the-infamous-invaders/zebra-mussel/ (accessed October 29, 2015)
[5] http://www.nwf.org/Wildlife/Threats-to-Wildlife/Invasive-Species/Invasive-Mussels.aspx (accessed October 29, 2015)

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- Analyzing the geographic distribution of temporal data

What you need:

- ArcGIS for Desktop
- Estimated time: 2 hours, 30 minutes

Title	Description	Time
Lesson 1: Explore the issue and ask spatial questions	Review information about the invasion of the zebra mussels.	10 minutes
Lesson 2: Map the zebra mussel sightings and learn more about the distribution	Explore a map of zebra mussel distribution in the United States and Canada to learn where the mollusks are.	20 minutes
Lesson 3: Map the zebra mussel sightings over time	Create a temporal map of zebra mussels to learn where they first came from.	20 minutes
Lesson 4: Map the zebra mussel density over time	Use a model to create a map with cumulative density rasters of sightings to learn how many zebra mussels there are and whether there are more zebra mussels in some areas than others.	40 minutes
Lesson 5: Analyze how zebra mussels have spread over time	Use the Directional Distribution and Mean Center statistical analysis tools and create a temporal map of the results to learn how the zebra mussels are spreading.	30 minutes
Lesson 6: Review the spatial questions and evaluate the results	Review the results of your analyses and determine whether you have answered the spatial questions adequately.	10 minutes
Lesson 7: Add a timeline to the map (optional)	Create a timeline as a set of geographic features and symbolize it.	20 minutes
Lesson 8: Add ellipses to the timeline (optional)	Edit the timeline to show miniature versions of the ellipses on the map.	15 minutes

Related Esri Training resources:

- Exploring Spatial Patterns in Your Data Using ArcGIS provides an additional explanation of analysis using the Mean Center and Directional Distribution tools: training.esri.com/gateway/index.cfm?fa=catalog.webCourseDetail&courseid=2052

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- Introduction to Surface Modeling Using ArcGIS includes an analysis with the Kernel Density tool: training.esri.com/gateway/index.cfm?fa=catalog.webCourseDetail&courseid=2053

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Lesson 1: Explore the issue and ask spatial questions

In this lesson:

- Explore the issue.
- Ask spatial questions.

Step 1: Explore the issue

Zebra mussels are native to the Black, Caspian, and Azov Seas in southeastern Europe and have steadily spread throughout much of Europe. They first appeared in North America in 1988 in Lake St. Clair, a small lake connecting Lake Huron and Lake Erie, and they were thought to have been transported in the freshwater ballast of a transatlantic ship. There are now estimated to be up to 10 trillion zebra mussels in the Great Lakes alone. [6]

Photo courtesy of US Geological Survey.
(http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/zebra_gallery.aspx)

Like clams, oysters, and scallops, zebra mussels are small bivalve mollusks. They get their name from the striped pattern on their shell. They are usually smaller than a dime but can grow to

[6] http://www.nwf.org/Wildlife/Threats-to-Wildlife/Invasive-Species/Invasive-Mussels.aspx (accessed October 29, 2015)

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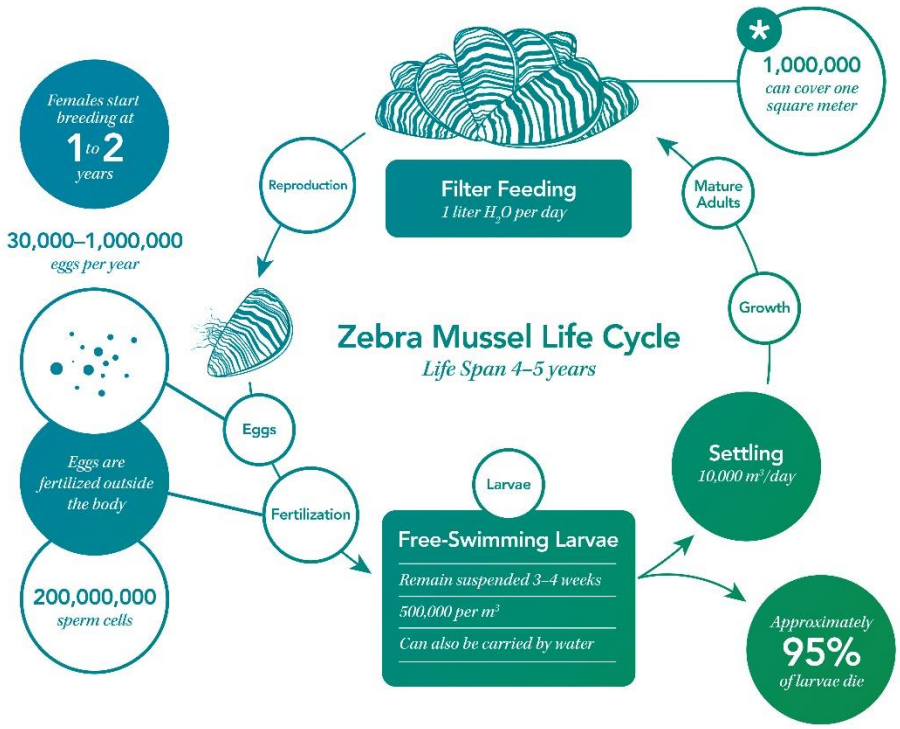
two inches long. They live for four to five years, and females can start breeding at two years of age, bearing between 30,000 and 1 million eggs a year, about 2 percent of which reach adulthood.



Zebra mussels are the only breed of freshwater mollusk that can firmly attach themselves to solid objects.[7] Zebra mussels will latch onto any hard surface—boats, pilings, water intake valves, even other aquatic species and plants—and can easily reattach themselves when dislodged. A million of them can cover one square meter.

Zebra mussels are extremely adaptable and can adjust to a wide range of conditions. They can also spread in a variety of ways. Young zebra mussels can swim and are easily carried by currents, so waters downstream from an infected area have a high probability of becoming infected. Attached to transported boats, adult zebra mussels have hitched rides to places not connected by waterways. Very small juveniles (1–3 mm) look like black pepper and can be easily overlooked, and they may also attach themselves to transported objects, including

[7] http://www.lakegeorgeassociation.org/what-we-do/invasive-species/Zebra-Mussels.asp (accessed October 29, 2015)

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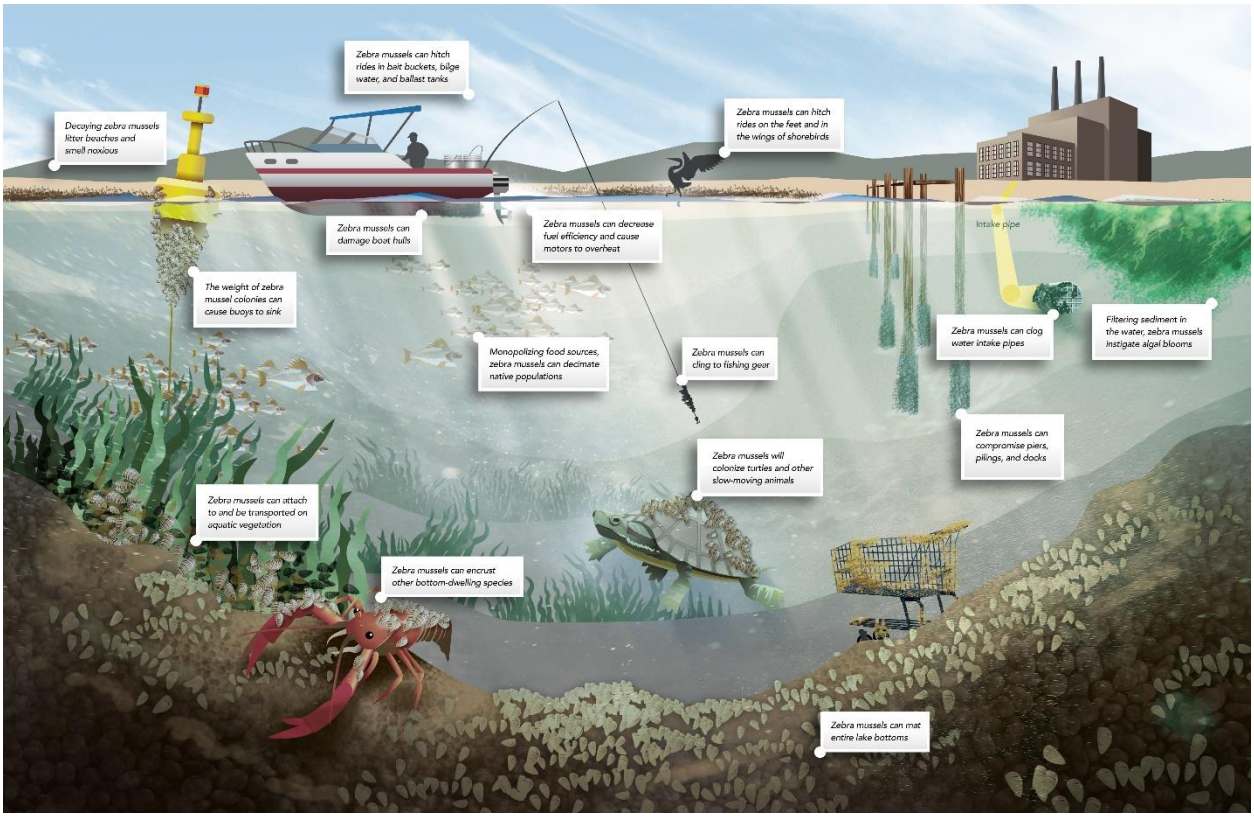
aquatic plants or crustaceans and even fishing rods. Migrating waterfowl can transport larval or young zebra mussels in their feathers or on their feet. Larval mussels can also be transferred in water through ballast exchange, bilge pumps, or bait buckets.



Environmental impacts

Although zebra mussels have a positive impact on some other species, environmental impacts are overwhelmingly negative. While many fish, birds, and other animals eat young and adult mussels, this is not enough to keep the mussels' populations under control. In addition, anything that feeds heavily on zebra mussels will build up high levels of contaminants in its body.[8] Zebra mussels have driven out entire native species (such as other mussels) from lakes.[9] Zebra mussels have devastated native populations of alewives, salmon, whitefish, and other mussels by stripping the food web of phytoplankton. They can colonize other aquatic species, such as mussels and clams, to such an extent that the hosts cannot move or feed.[10] Zebra

[8] http://www.in.gov/dnr/files/ZEBRA-MUSSEL.pdf (accessed October 29, 2015)
[9] http://www.noaa.gov/features/earthobs_0508/zebra.html (accessed October 29, 2015)
[10] http://www.nationalatlas.gov/articles/biology/a_zm.html (accessed October 29, 2015)

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mussels have also attached themselves to slow-moving species, such as turtles and crayfish.[11] Filter feeding and excretion activity by invasive mussels can stimulate nutrient releases in the water column, causing algal blooms.[12] These algal blooms have caused botulism outbreaks, killing thousands of fish and aquatic birds and, of course, impacting human recreation. Migratory birds have even changed their flight patterns in response to zebra mussel availability to prey on them.[13]

Recreational impacts

Dead and dying mussels degrade beaches and nearshore swimming areas. Beaches and nearshore areas become littered with sharp-edged shells, and the fumes from the decaying mussels are foul. Zebra mussels can also cause boating and navigation hazards.[14] Boats can be impacted by increased drag caused by zebra mussel colonization on the hull. Juvenile zebra mussels can get into engine cooling systems, causing overheating and other damage.[15] Zebra mussels can also impact navigation by damaging the wood, steel, and concrete of piers, docks, and other structures. The mussels' added weight has also sunk buoys and other navigational markers.[16]

Commercial impacts

Zebra mussels have caused damage and increased operating expenses worth hundreds of millions of dollars for facilities with conduits to fouled waters. The colonization of zebra mussels can cause equipment to become unusable, valves and other components to become obstructed, and intake screens to reduce water flow. Fishery populations have also been affected.[17] Colonized areas can become corroded or damaged.

Eradication

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[11] http://www.nationalatlas.gov/articles/biology/a_zm.html (accessed October 29, 2015)
[12] http://www.sciencedaily.com/releases/2014/02/140212112747.htm (accessed October 29, 2015)
[13] http://www.nationalatlas.gov/articles/biology/a_zm.html (accessed October 29, 2015)
[14] http://www.nationalatlas.gov/articles/biology/a_zm.html (accessed October 29, 2015)
[15] http://www.nationalatlas.gov/articles/biology/a_zm.html (accessed October 29, 2015)
[16] http://www.bioone.org/doi/abs/10.3394/0380-1330-34.4.770 (accessed October 29, 2015)
[17] http://www.necis.net/intro-to-invasive-species/what-we-know/introducing-the-infamous-invaders/zebra-mussel/ (accessed October 29, 2015)

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Once zebra mussels become established in a body of water, they are impossible to eradicate with current technology.[18] Chemical treatments, mechanical controls, and filters have been tried. Chemicals that kill zebra mussels also kill other species. Mechanical scrapers have been tested, and equipment has been developed to pre-oxidize water at intake valves. Physical barriers and coatings have been used to prevent mussels from attaching to surfaces. Approaches involving hot water, air, and even sound have also been investigated. To this point, no ideal solution currently exists to remove and control zebra mussels.

Knowing all this, you can now begin to formulate questions related to the geographic aspects of the zebra mussel issue.

Step 2: Ask spatial questions

The spatial questions you'll answer are the following:

1. Where are the zebra mussels?
2. Where did the zebra mussels come from?
3. Are there more zebra mussels in some areas than in others?
4. Are the zebra mussels spreading?

Each of these questions has a spatial component. One way to test this is to ask whether the questions can only be answered by taking location into account. If the answer is yes, they're spatial.

To answer these questions, you'll use a variety of approaches, including visual analysis of maps and statistical analysis of spatiotemporal data.

In the next lesson, you'll begin by answering the question, where are the zebra mussels?

[18] http://www.nationalatlas.gov/articles/biology/a_zm.html (accessed October 29, 2015)

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Lesson 2: Map the zebra mussel sightings and learn more about the distribution

In this lesson:

- Map the zebra mussel sightings.
- Learn more about the distribution using additional layers.

In the last lesson, you learned about the zebra mussel problem and identified four spatial questions that will help you learn more about the issue. In this lesson, you'll first explore a map to learn about the distribution of mussels in the United States and Canada. You'll explore the attribute data associated with the data on the map. You'll also use additional map layers to better understand the geographic distributions.

Step 1: Map the zebra mussel sightings

For this project, you'll use ArcGIS for Desktop to map and analyze the data. You'll also work with a map that has been started for you.

1. Open ArcMap.

   Tip: Learn more about downloading the free trial version of ArcGIS for Desktop (http://www.esri.com/arcgis/trial).

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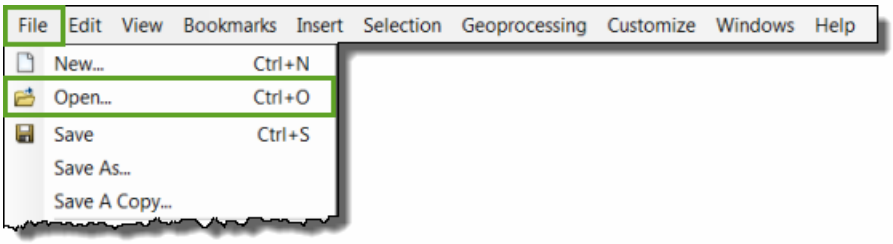
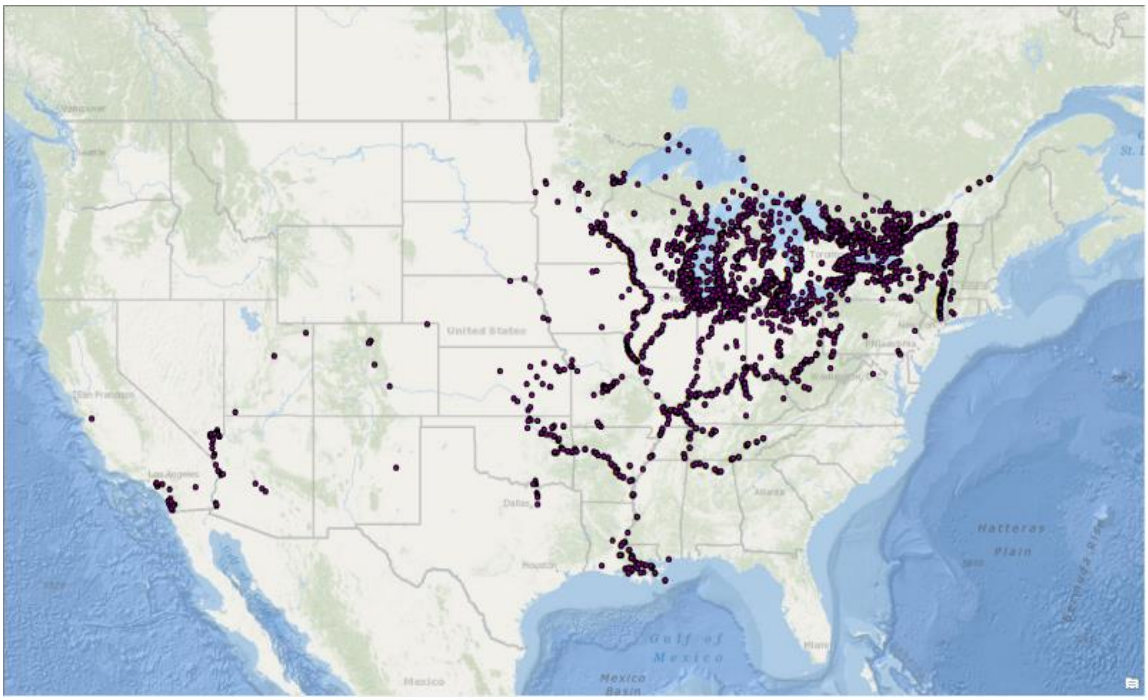
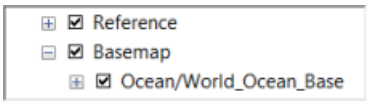
2. On the main menu, click File > Open.



3. Browse to the C:\student\Zebra_Mussels directory. Click Zebra_Mussels.mxd and click Open to open the map document.



On this map, the Mussel Sightings layer shows the locations where zebra mussels have been sighted. This layer is displayed over the Esri World Ocean Basemap and its Reference layer.



Note: The Esri World Ocean Basemap is a layer that's being displayed from ArcGIS Online. If there were no Internet connection, this layer would not be displayed.

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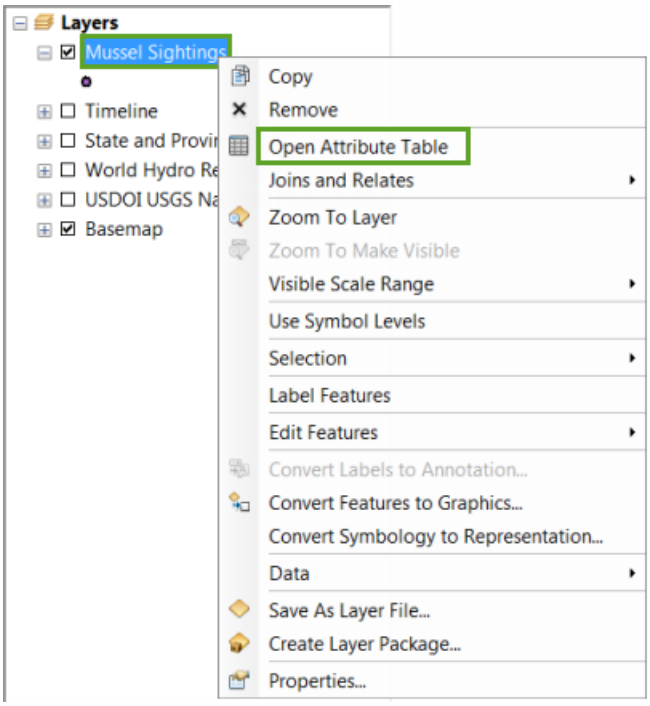
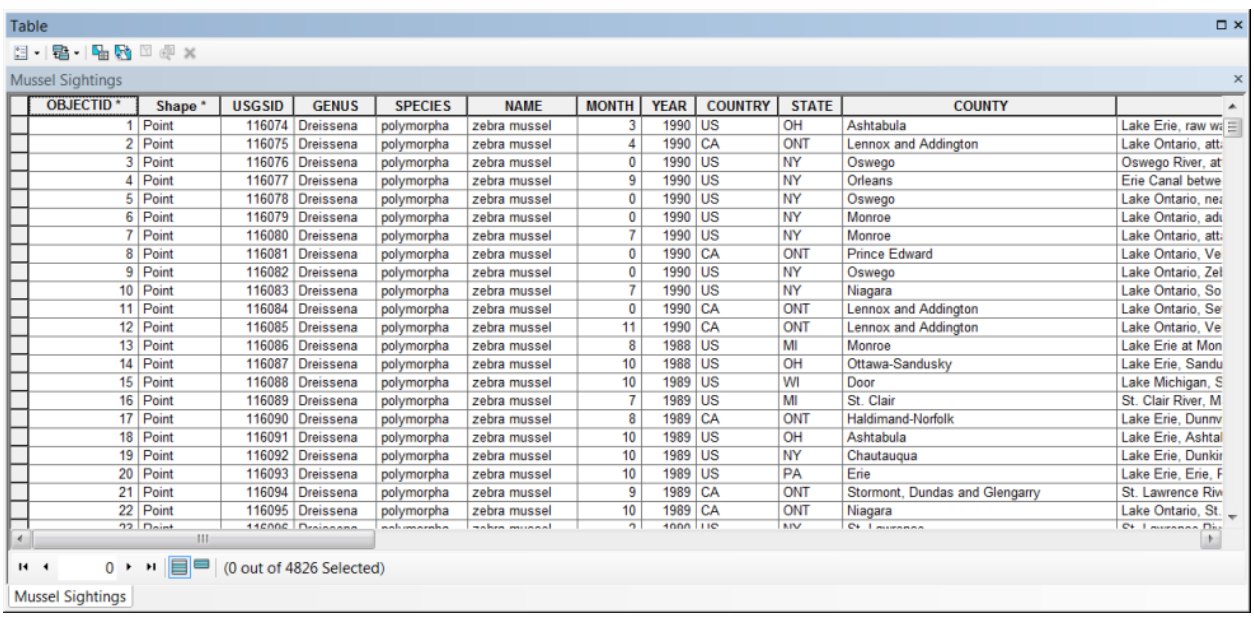
4. Right-click the Mussel Sightings layer and click Open Attribute Table.



5. Scroll down to see when the sightings were recorded and where.



OBJECTID *	Shape *	USGSID	GENUS	SPECIES	NAME	MONTH	YEAR	COUNTRY	STATE	COUNTY	
1	Point	116074	Dreissena	polymorpha	zebra mussel	3	1990	US	OH	Ashtabula	Lake Erie, raw wa
2	Point	116075	Dreissena	polymorpha	zebra mussel	4	1990	CA	ONT	Lennox and Addington	Lake Ontario, att
3	Point	116076	Dreissena	polymorpha	zebra mussel	0	1990	US	NY	Oswego	Oswego River, at
4	Point	116077	Dreissena	polymorpha	zebra mussel	9	1990	US	NY	Orleans	Erie Canal betwe
5	Point	116078	Dreissena	polymorpha	zebra mussel	0	1990	US	NY	Oswego	Lake Ontario, nea
6	Point	116079	Dreissena	polymorpha	zebra mussel	0	1990	US	NY	Monroe	Lake Ontario, adj
7	Point	116080	Dreissena	polymorpha	zebra mussel	7	1990	US	NY	Monroe	Lake Ontario, att
8	Point	116081	Dreissena	polymorpha	zebra mussel	0	1990	CA	ONT	Prince Edward	Lake Ontario, Ve
9	Point	116082	Dreissena	polymorpha	zebra mussel	0	1990	US	NY	Oswego	Lake Ontario, Zel
10	Point	116083	Dreissena	polymorpha	zebra mussel	7	1990	US	NY	Niagara	Lake Ontario, So
11	Point	116084	Dreissena	polymorpha	zebra mussel	0	1990	CA	ONT	Lennox and Addington	Lake Ontario, Se
12	Point	116085	Dreissena	polymorpha	zebra mussel	11	1990	CA	ONT	Lennox and Addington	Lake Ontario, Ve
13	Point	116086	Dreissena	polymorpha	zebra mussel	8	1988	US	MI	Monroe	Lake Erie at Mon
14	Point	116087	Dreissena	polymorpha	zebra mussel	10	1988	US	OH	Ottawa-Sandusky	Lake Erie, Sandu
15	Point	116088	Dreissena	polymorpha	zebra mussel	10	1989	US	WI	Door	Lake Michigan, S
16	Point	116089	Dreissena	polymorpha	zebra mussel	7	1989	US	MI	St. Clair	St. Clair River, M
17	Point	116090	Dreissena	polymorpha	zebra mussel	8	1989	CA	ONT	Haldimand-Norfolk	Lake Erie, Dunnv
18	Point	116091	Dreissena	polymorpha	zebra mussel	10	1989	US	OH	Ashtabula	Lake Erie, Ashtal
19	Point	116092	Dreissena	polymorpha	zebra mussel	10	1989	US	NY	Chautauqua	Lake Erie, Dunki
20	Point	116093	Dreissena	polymorpha	zebra mussel	10	1989	US	PA	Erie	Lake Erie, Erie, F
21	Point	116094	Dreissena	polymorpha	zebra mussel	9	1989	CA	ONT	Stormont, Dundas and Glengarry	St. Lawrence Riv
22	Point	116095	Dreissena	polymorpha	zebra mussel	10	1989	CA	ONT	Niagara	Lake Ontario, St.

Note: The mussel sightings data was collected by the USGS and downloaded from the *National Atlas* website (http://www.nationalatlas.gov/mld/zmusslx.html, accessed October 29, 2015).

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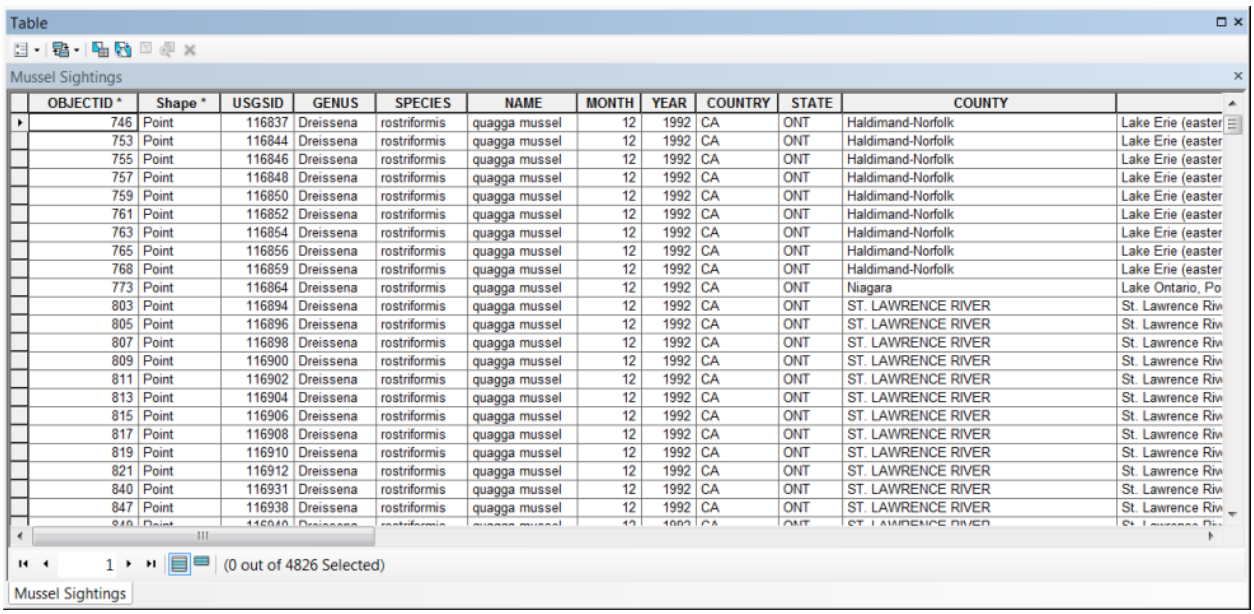
This data is associated with the point features on the map. Note that there are columns, or fields, for many attributes, including the month and year mussels were first recorded and the county in which they were reported.

6. Right-click the NAME column and click Sort Ascending.



OBJECTID *	Shape *	USGSID	GENUS	SPECIES	NAME	MONTH	YEAR	COUNTRY	STATE	COUNTY	
746	Point	116837	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
753	Point	116844	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
755	Point	116846	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
757	Point	116848	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
759	Point	116850	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
761	Point	116852	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
763	Point	116854	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
765	Point	116856	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
768	Point	116859	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Haldimand-Norfolk	Lake Erie (easter
773	Point	116864	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	Niagara	Lake Ontario, Po
803	Point	116894	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
805	Point	116896	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
807	Point	116898	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
809	Point	116900	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
811	Point	116902	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
813	Point	116904	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
815	Point	116906	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
817	Point	116908	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
819	Point	116910	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
821	Point	116912	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
840	Point	116931	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv
847	Point	116938	Dreissena	rostriformis	quagga mussel	12	1992	CA	ONT	ST. LAWRENCE RIVER	St. Lawrence Riv

Note that this dataset also contains sightings for another type of mussel—the quagga mussel.

You only want to include the zebra mussels in this study, so you'll use a definition query to restrict the set so that it excludes the 463 quagga mussel sightings.

7. Click the Close button in the upper right corner to close the attribute table.

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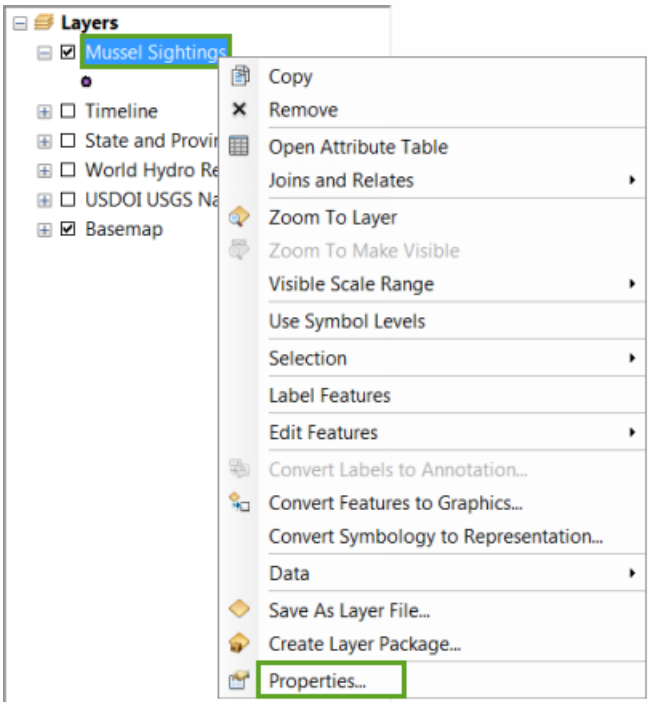
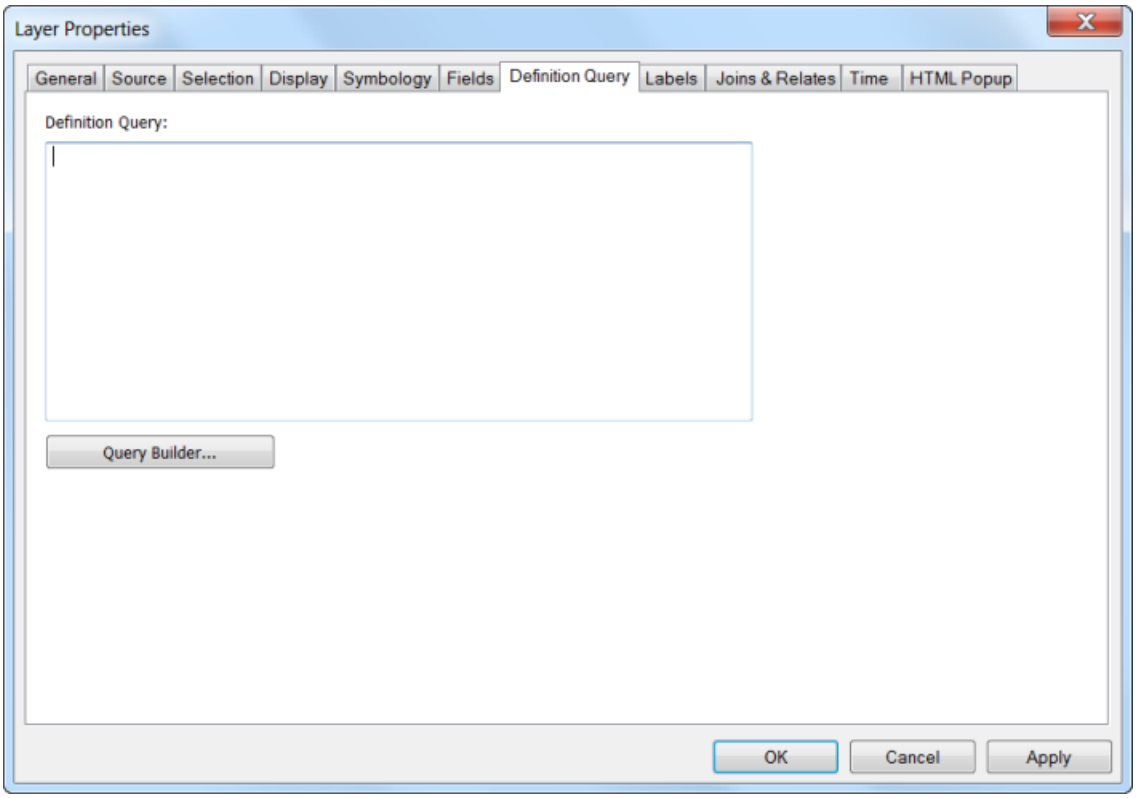
8. Right-click the layer and click Properties.



9. Click the Definition Query tab.



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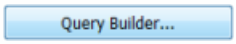
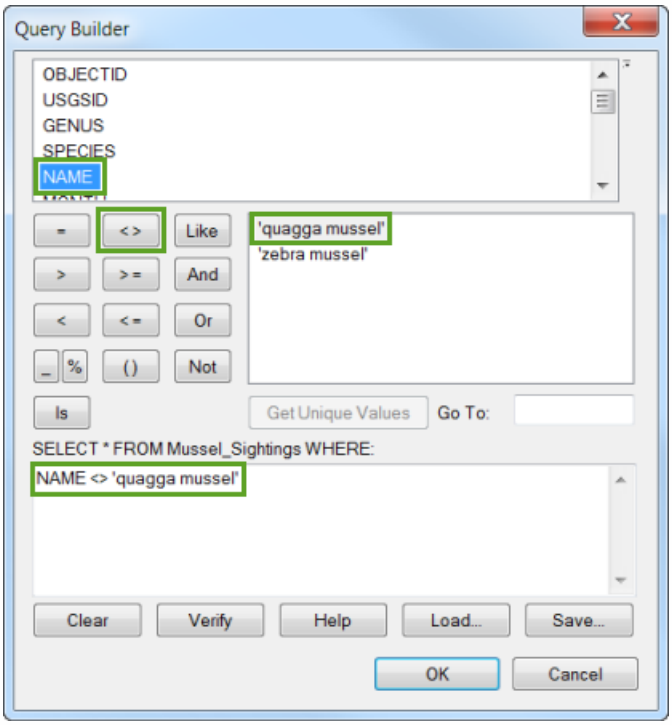
10. Click the Query Builder button.



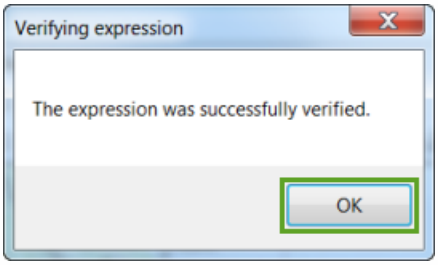
11. On the Query Builder dialog box, click the NAME field, then click <> (not equal to). Click Get Unique Values and click quagga mussel.

    The expression should appear as shown below.



12. Click Verify to make sure there are no errors in the expression.

13. Click OK on the Verifying expression dialog box.



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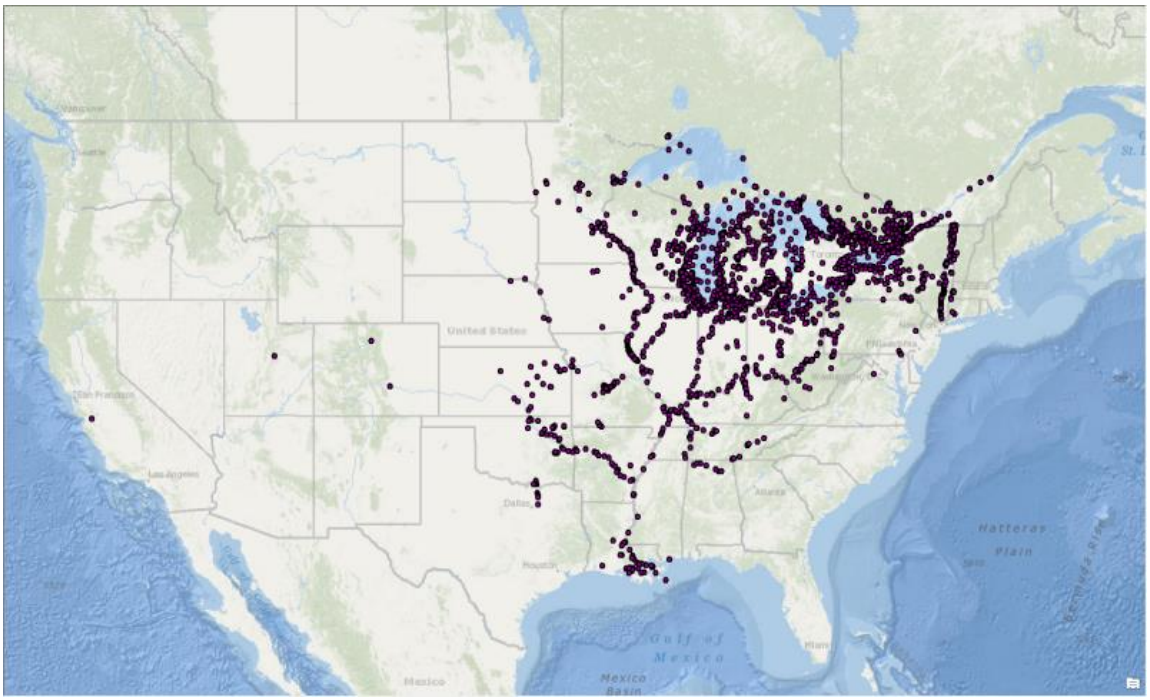
14. Click OK to close the Query Builder dialog box.

15. Click OK to close the Layer Properties dialog box.



The map will update to show only zebra mussels. For example, the sightings in Arizona and Nevada are no longer displayed, since those were for quagga mussels.

Note that there are many overlapping point locations for the sightings. In this dataset, the sightings are precisely located, and some are even coincident. In a later lesson, you'll learn how to display the density of this data.

Although there's limited information on this map, you can use it to answer the first spatial question—where are the zebra mussels?

Interpret: The sightings are concentrated in the Great Lakes area, but zebra mussels have also been found throughout the Midwest from Appalachia to Colorado. Sightings have also been recorded in the Southwest, though there are fewer of them.

Zebra mussels also appear to follow waterways—you'll confirm this by viewing a new layer on the map.

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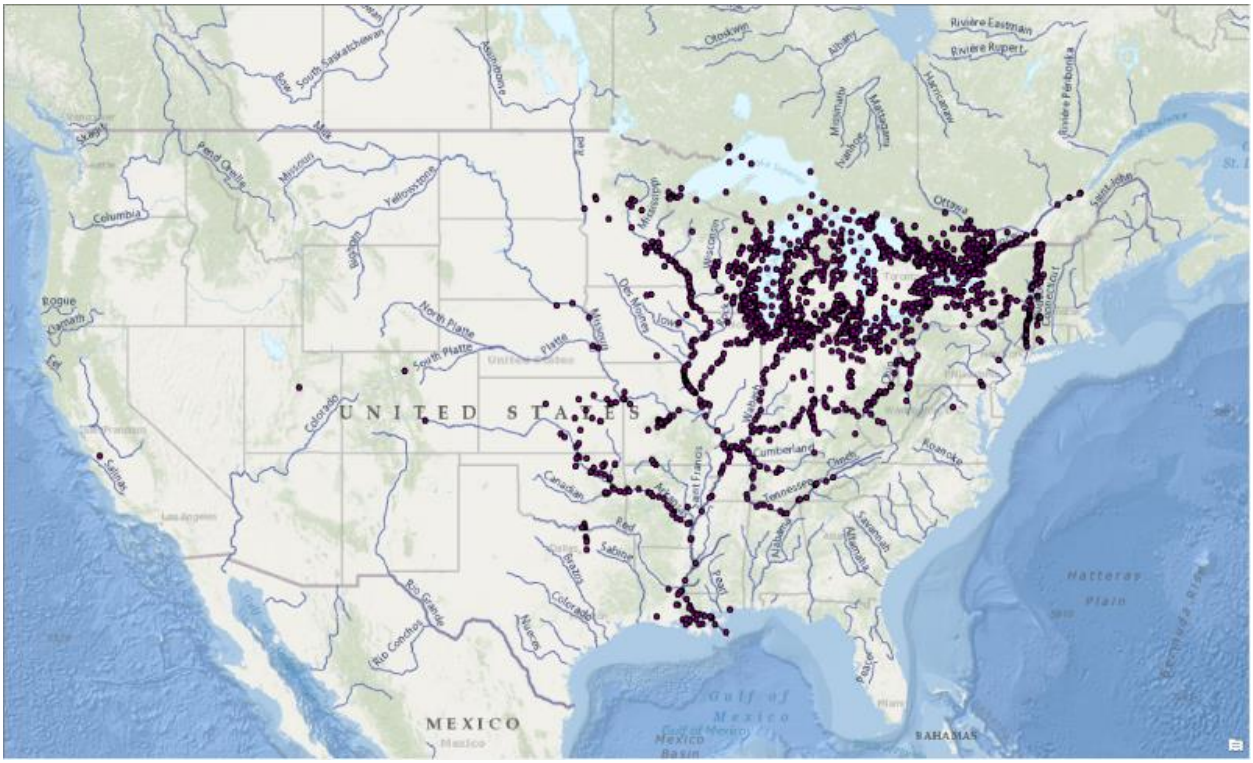
Step 2: Map the zebra mussel sightings

For this project, you'll use ArcGIS for Desktop to map and analyze the data. You'll also work with a map that has been started for you.

1. In the table of contents, click the box to the left of the World Hydro Reference Overlay layer to turn it on.

   Tip: You can turn layer viewing on and off by checking the check box to the left of the layer name. A check will appear when viewing is on.



   Note: Like the Esri World Topographic Basemap, the World Hydro Reference Overlay layer is from ArcGIS Online.

2. Use the pan and zoom buttons on the Tools toolbar to explore the map and learn about where zebra mussels have been sighted.

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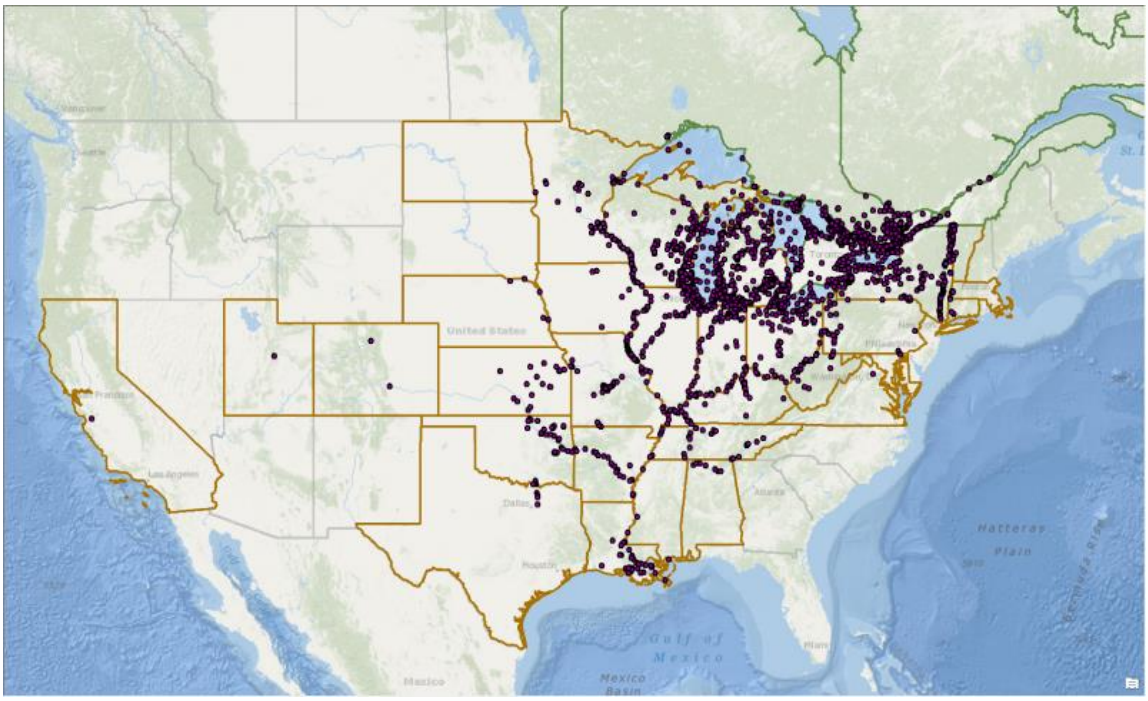
Interpret: You'll learn that they have been reported in 9 of the 10 longest rivers in the conterminous United States—the Missouri, Mississippi, Saint Lawrence, Arkansas, Atchafalaya, Ohio, and Red Rivers east of the Continental Divide, and the Colorado River in the West. Only the Rio Grande has escaped invasion to this point.

Zebra mussels have also invaded some smaller rivers, such as the Wabash in Indiana and the Cumberland in Tennessee, and lakes, like the Finger Lakes in New York, that are connected to these larger river systems.

3. In the table of contents, turn off the Hydro Reference Overlay layer and turn on the State and Province Sightings layer.



Note: The State and Province Sightings data is from Natural Earth (http://www.naturalearthdata.com/).

The State and Province Sightings layer shows the US states and Canadian provinces that have reported zebra mussel sightings.

Interpret: On this map, you can see that there have been sightings in most US states and

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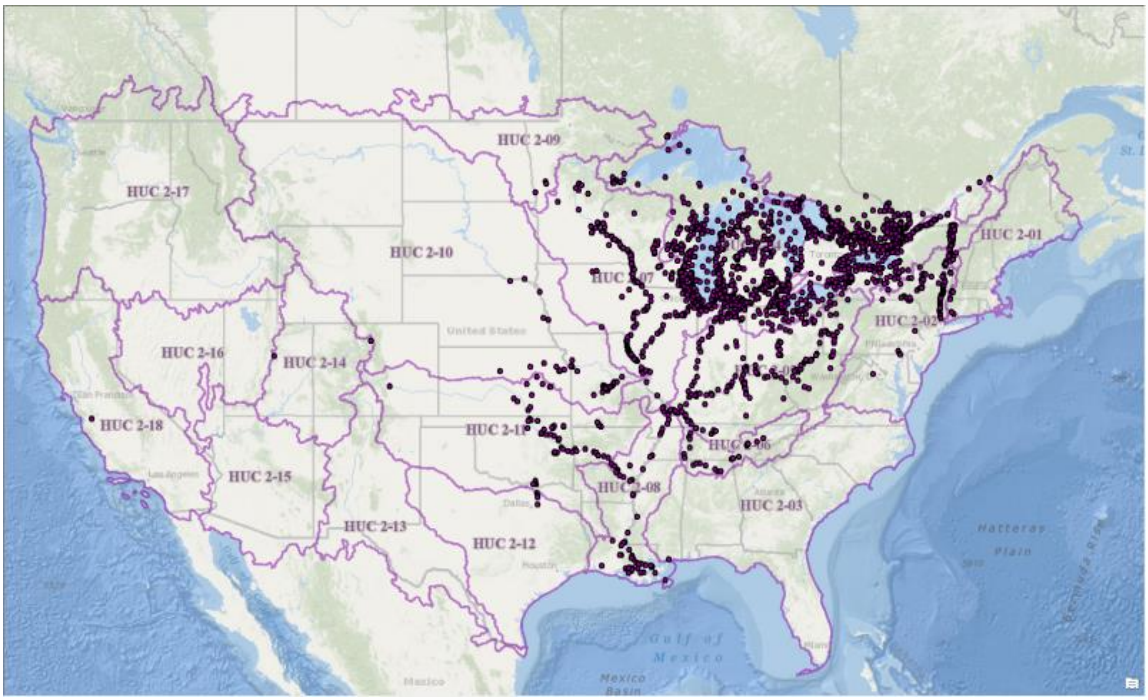
in two Canadian provinces. There have not yet been any sightings in the Northwest (Washington, Oregon, Idaho, Montana, Wyoming, and South Dakota), nor have zebra mussels been sighted in the Southeast (North Carolina, South Carolina, Georgia, and Florida). A few other states along the Eastern Seaboard have also escaped invasion (Maine, New Hampshire, Rhode Island, New Jersey, and Delaware).

4. Turn off the State and Province Sightings layer and turn on the United States Department of the Interior (USDOI) USGS National Hydrography Dataset (NHD) layer.



The NHD layer shows the United States classified into 18 major regions based on hydrology.[19] The regions contain either the drainage area of a major river, such as the Missouri River, or the drainage areas of a set of rivers, such as the Texas-Gulf region, which is made up of the drainages for a number of rivers that empty into the Gulf of Mexico.

Interpret: On this map, you can see that 14 of the 18 major hydrologic regions have been invaded by zebra mussels—only the Rio Grande (HUC 2-12), Lower Colorado (HUC 2-15), Great Basin (HUC 2-16), and Pacific Northwest (HUC 2-17) regions remain uninfected.

[19] http://water.usgs.gov/GIS/huc.html (accessed October 29, 2015)

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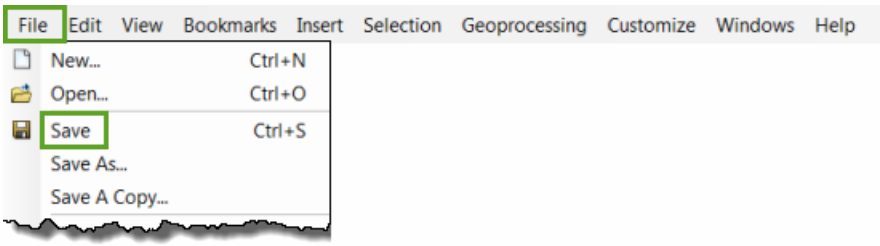
5. Turn off the NHD layer.

6. On the main menu, click File > Save to save the map.



Now that you know where the zebra mussels are, you'll learn more about where they first came from, which is the topic of the next lesson.

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Lesson 3: Map the zebra mussel sightings over time

In this lesson:

- Set the time properties on the layer.
- Use the Time Slider window to display the layer over time.
- Display the data cumulatively.
- Change the symbology of the layer.
- Create the Zebra Mussel Sightings layer.

In the last lesson, you looked at a map of all zebra mussel sightings. Looking at maps of the sightings year by year will help you learn where they were first sighted. Then you can answer the question, where did the zebra mussels come from?

In this lesson, you'll start by setting the time properties on the Mussel Sightings layer. Then you'll use the Time Slider window to display the layer over time. You'll also modify some time property options and the symbology to highlight aspects of the display that will allow you to better understand the change over time. Finally, you'll create a new feature class that contains only the zebra mussel sightings, which you will use in the remaining lessons.

There are two steps to displaying temporal data with ArcGIS:

1. Set the time properties on the layer.
2. Display the layer using the Time Slider window.

Step 1: Set the time properties on the layer

In this step, you'll set the time properties for the layer. To do this, you need to know the format of the temporal attributes in your data and how the features that vary over time are represented geographically. In the last lesson, you learned that the zebra mussel sightings are

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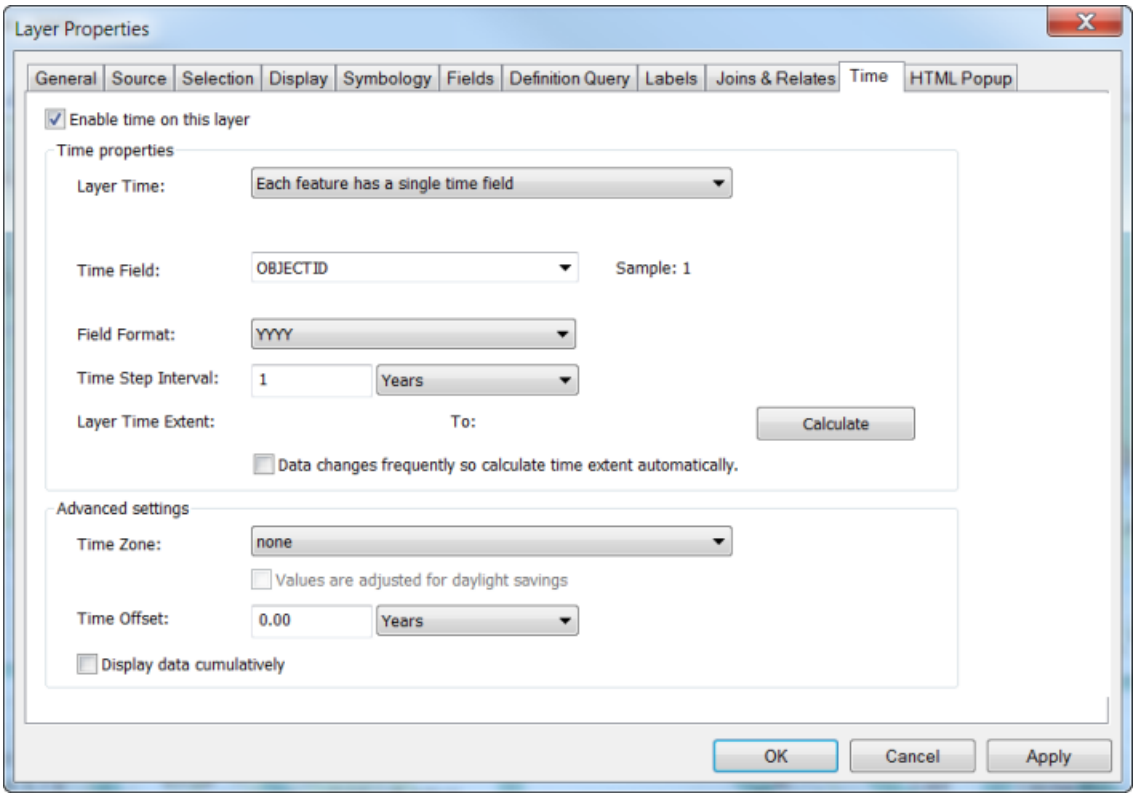
represented as point features and that there's an attribute called YEAR to indicate when each sighting occurred. You'll use that information to set the time properties on the layer.

1. Open the layer properties for the Mussel Sightings layer.

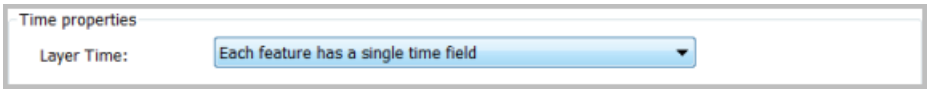
2. Click the Time tab.

3. Check the Enable time on this layer check box.

The other settings on the dialog box are now enabled.



4. For Layer Time, keep the default set to Each feature has a single time field.



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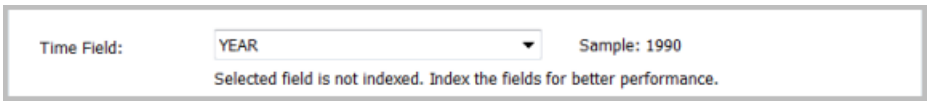
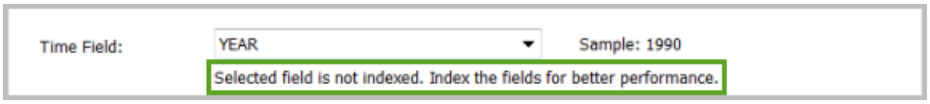
5. Set Time Field to YEAR.



Tip: For Time Field, you can use any attribute that's sortable, either numerically or alphabetically. You might use an attribute that's not a time or date if you wanted to show the change in a nontemporal attribute, for example, the magnitude of earthquakes or depth of wells.

You can see that there's a message reminding you that the selected field is not indexed and that you should index the field for better display performance.



When a layer has many features or features with complex geometry, such as lines or polygons with many vertices, the display may slow down significantly. One way to improve display performance is to index the time fields. The layers you're working with won't have display issues, so you don't need to index the time fields.

6. Click Calculate to determine the time extent of the layer.

The first and last time steps will be updated automatically.

7. Since the data in this layer was collected by year, set Time Step Interval to 1.00 and keep the default unit setting of Years.

Note: For your data, you do not need to use the additional options to calculate the time extent automatically, set a time zone, or use a time offset.

8. Click OK.

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9. Save the map.

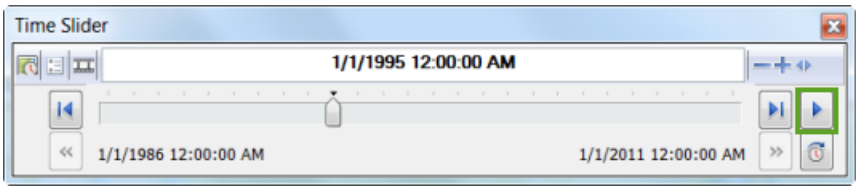
Step 2: Use the Time Slider window to view the layer over time

Once the time properties for the layer are set, you can display the layer using the Time Slider window. This window provides controls and additional options that allow you to display temporal data in ArcMap, ArcScene, and ArcGlobe.

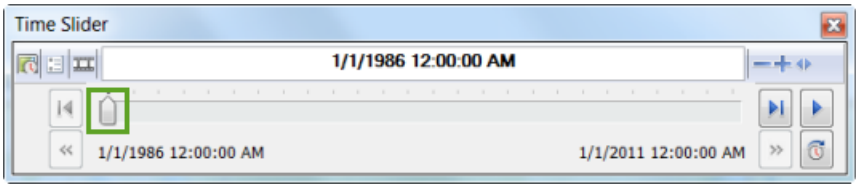
1. Open the Time Slider window by clicking the Open Time Slider window button on the Tools toolbar.

Tip: This button is not enabled if you don't have any time-enabled datasets in your ArcMap, ArcScene, or ArcGlobe document.

2. Click the Play button to display the layer over time.



3. Move the Time Slider control to set the display to the first time period.



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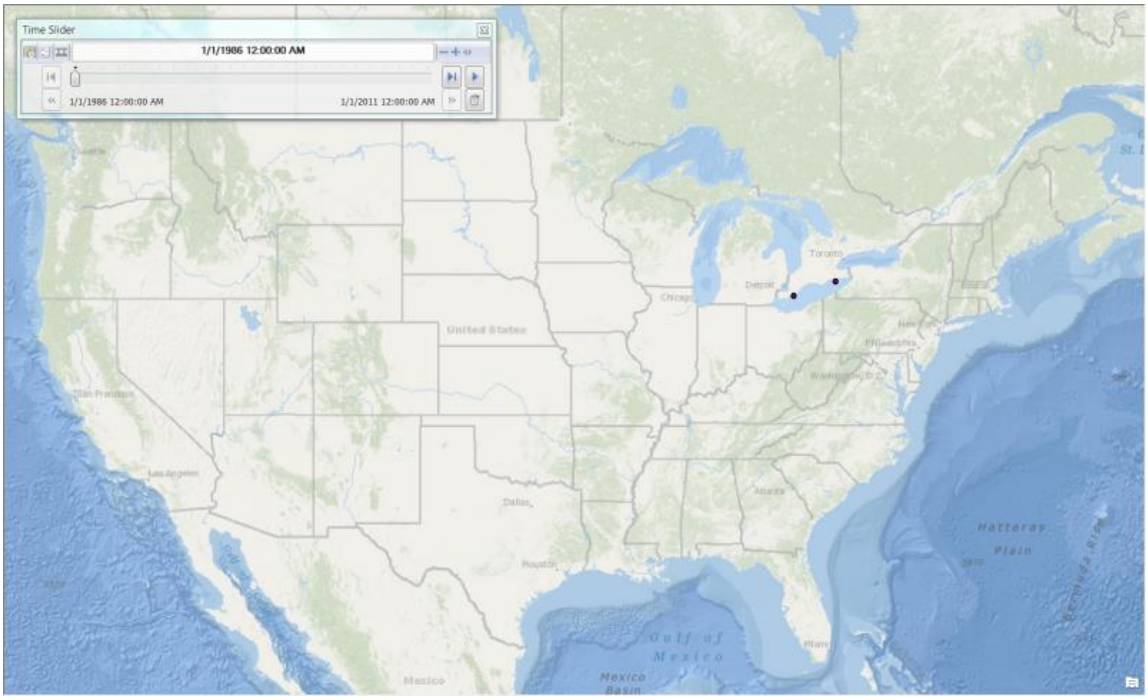

Interpret: This map helps you answer the question, where did the zebra mussels come from? You can see that they were first sighted in 1986 in Lake Erie—one sighting was in the east end of the lake, and the other was in the west. But wait—recall how you read in Lesson 1 that others have reported that zebra mussels were discovered in North America in 1988 in Lake St. Clair. Your map suggests that those accounts are wrong and that zebra mussels were actually sighted two years earlier in a different lake altogether!

And your map is right! That's because scientists at the USGS updated their data based on an authoritative report that described these earlier sightings.[20] The report also confirmed that zebra mussels are hypothesized to have been introduced to North America in the ballast water of a ship that had traveled from Europe to the Great Lakes.

There's more you can learn from these maps, but the data will be easier to interpret if you display it cumulatively so that you can see not just the current time step but also all previous time steps.

[20] http://www.bioone.org/doi/abs/10.3394/0380-1330-34.4.770 (accessed October 29, 2015)

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Step 3: Display the data cumulatively

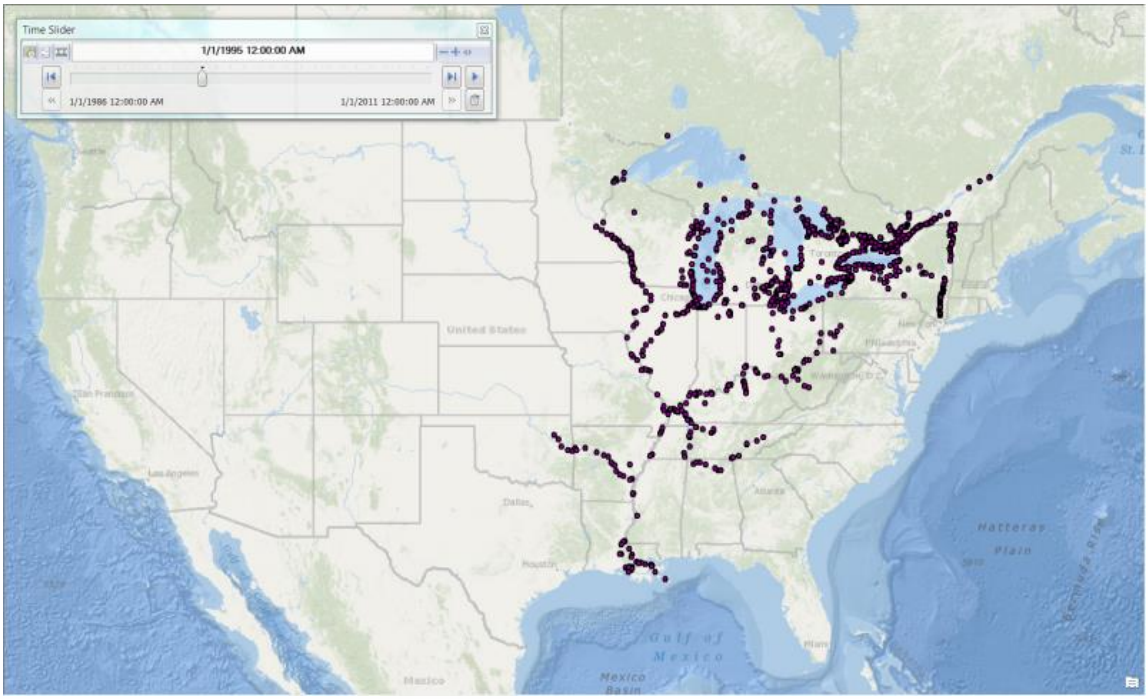
In this step, you'll enable the option to display the zebra mussel data. You'll also change the symbology of the layer so that you can distinguish maps from among the time steps.

1. Open the layer properties for the Mussel Sightings layer.

2. On the Time tab, check the Display data cumulatively check box at the bottom.

3. Click OK.

4. Use the Time Slider window to display the layer over time.



On this map, it's easier to see how the distribution has changed over time, but it's

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difficult to distinguish individual time steps. You can fix that by changing the symbology of the layer.

5. Save the map.

Step 4: Change the symbology of the layer

You'll use a method called *Match to symbols in a style*, which will assign prespecified symbols to the point features based on an attribute—in this case, the year. The symbology you set for this layer will also be used for others later in this project.

1. To see the style that contains the symbols, click Customize > Style Manager on the main menu.

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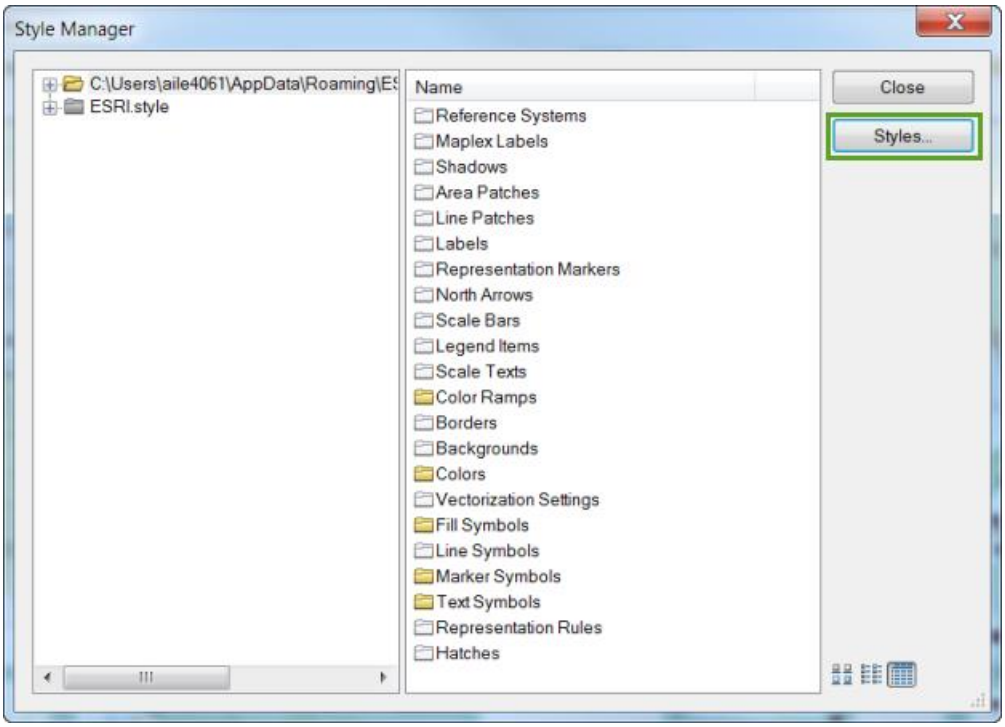
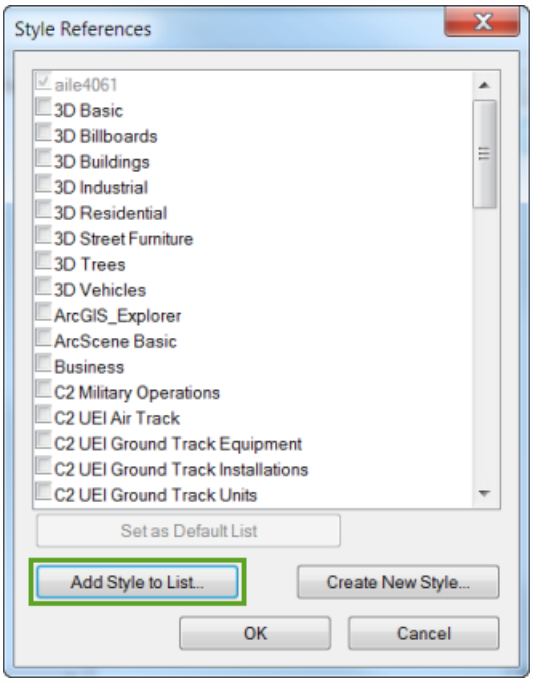
2. On the Style Manager dialog box, click Styles.



3. On the Style References dialog box, click Add Style to List.



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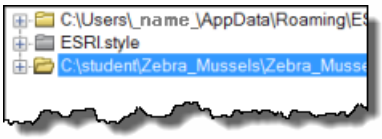
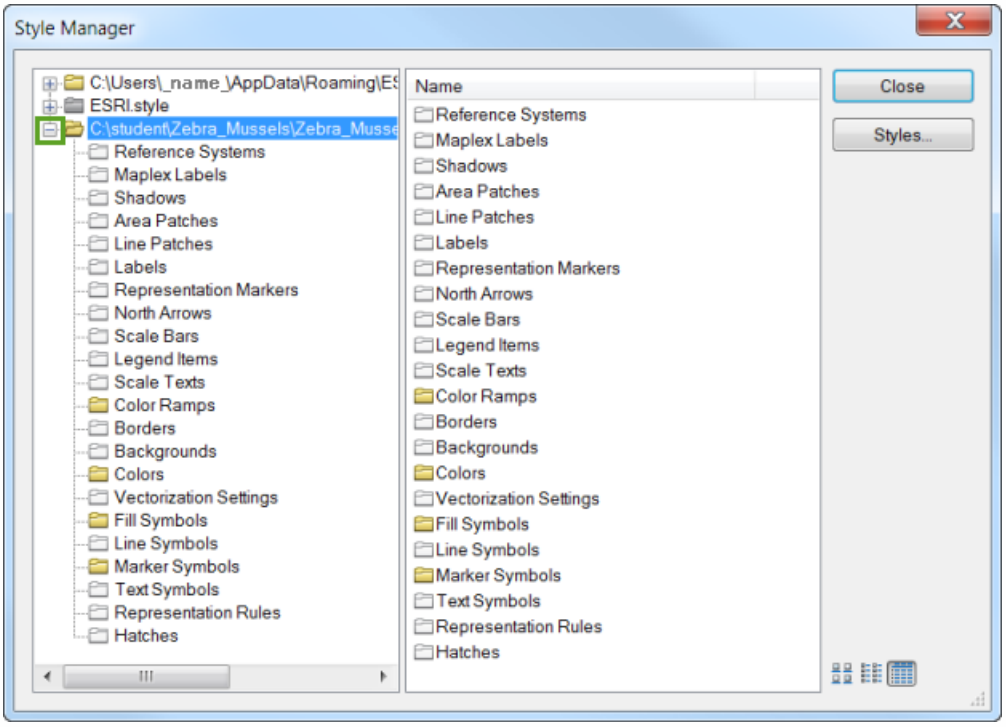
4. Browse to the C:\student\Zebra_Mussels directory and select the Zebra_Mussels.sty file.



The style will be displayed in the left pane of Style Manager.

Note: The file extension for an ArcGIS style file is .sty.

5. Click the box with the plus sign to the left of the Zebra Mussels folder to expand its view.



Note that there are symbols for some types (Color Ramps, Colors, and so forth), as indicated by yellow folders, but not for others, which are shown with white folders.

6. Click the Marker Symbols folder to see the symbols.

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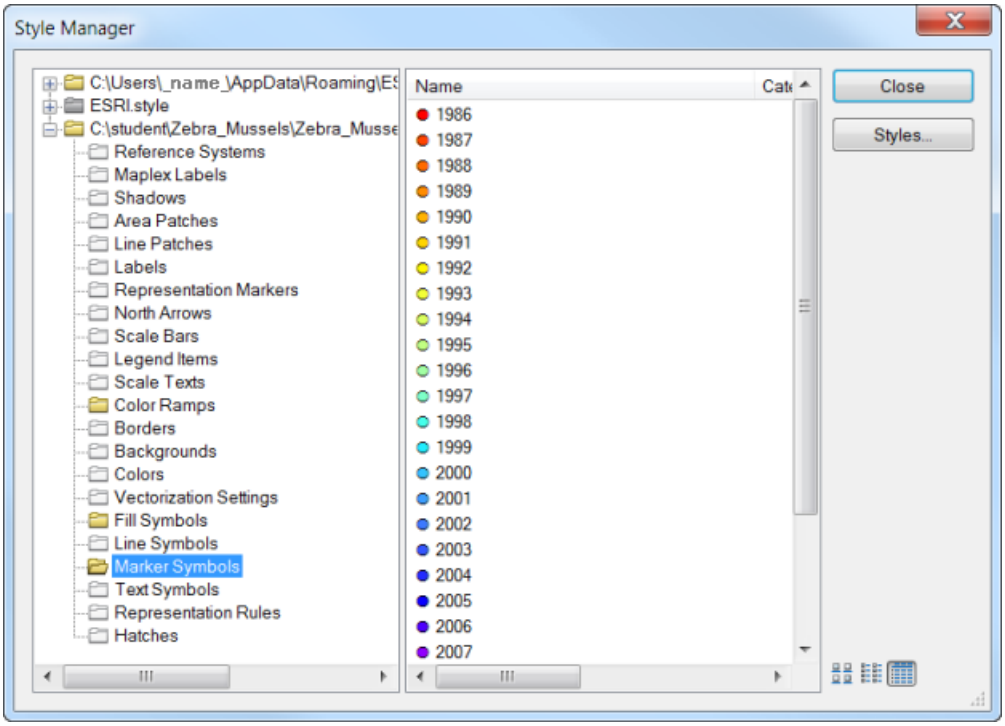

Note that the symbols' names are the same as the year values for the zebra mussel sightings.

7. Close the dialog box.

   To use the Match to symbols in a style option, there must be a text attribute in the layer with values that exactly match the names of the symbols, so you'll need to check if there's such a field.

8. Open the layer properties for the Mussel Sightings layer.

9. On the Fields tab, click the YEAR field.

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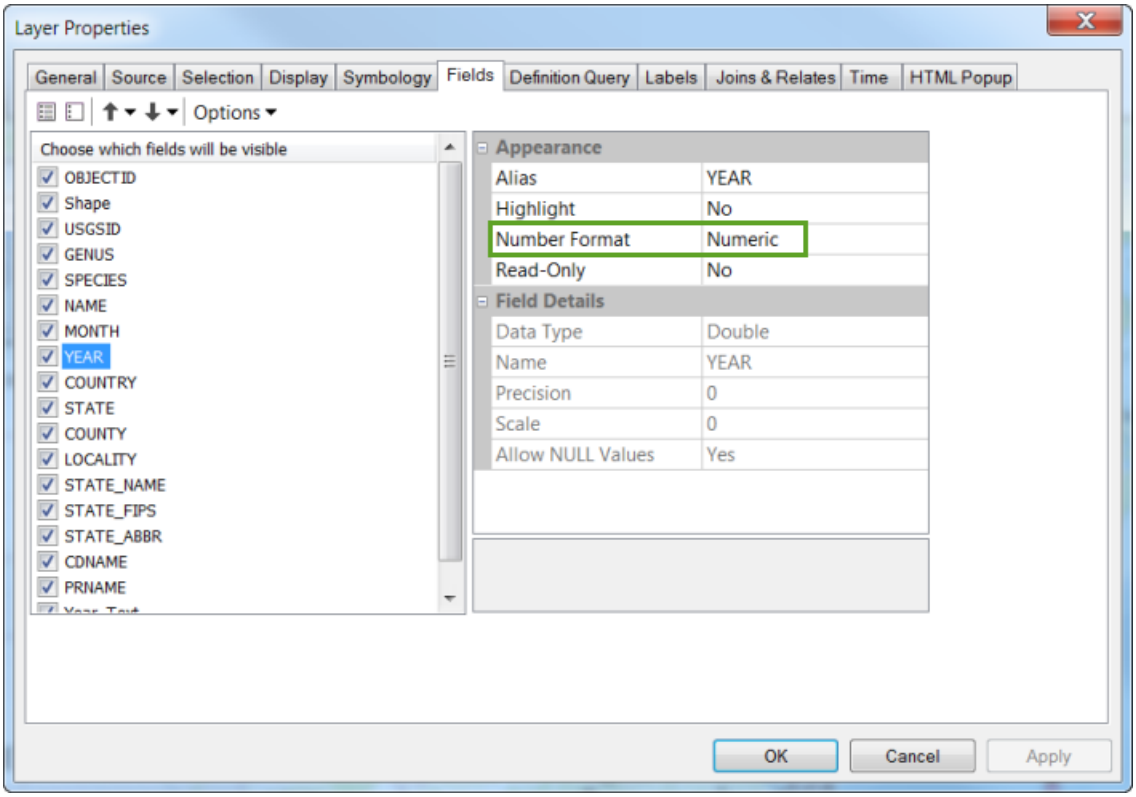
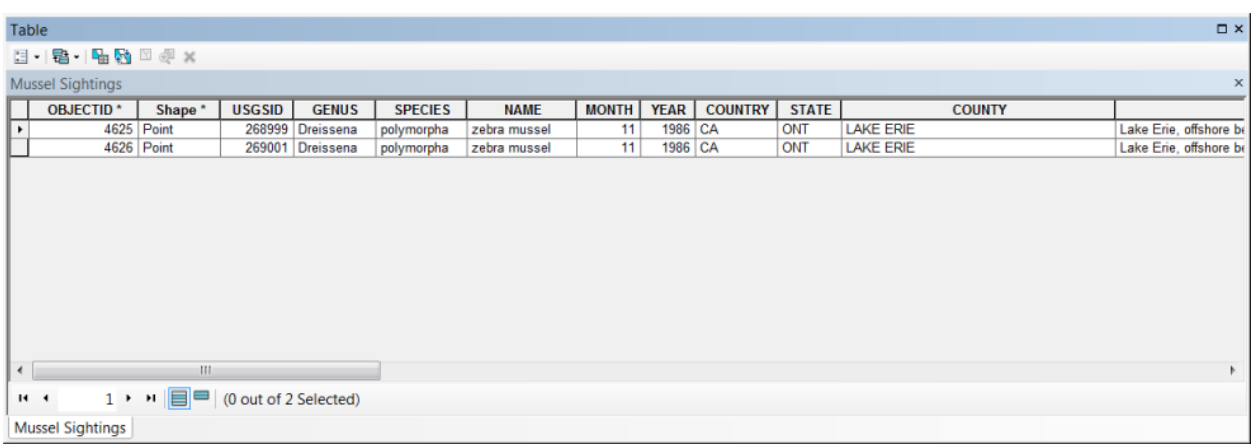


Note that this is a numeric field type. Recall that this data is from the USGS, so the field types are already set in the data. You cannot change a field type, but you can create a new field of the type you want and calculate the values to be equal to those in another field.

10. Close the Layer Properties dialog box.

11. Open the attribute table for the Mussel Sightings layer.



OBJECTID *	Shape *	USGSID	GENUS	SPECIES	NAME	MONTH	YEAR	COUNTRY	STATE	COUNTY	
4625	Point	268999	Dreissena	polymorpha	zebra mussel	11	1986	CA	ONT	LAKE ERIE	Lake Erie, offshore b
4626	Point	269001	Dreissena	polymorpha	zebra mussel	11	1986	CA	ONT	LAKE ERIE	Lake Erie, offshore b

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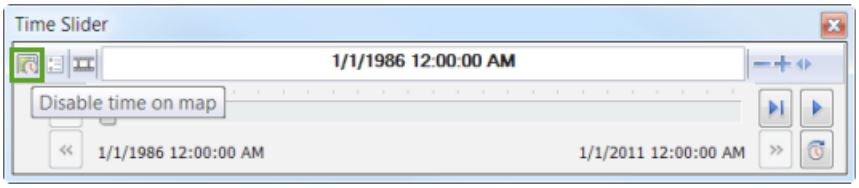
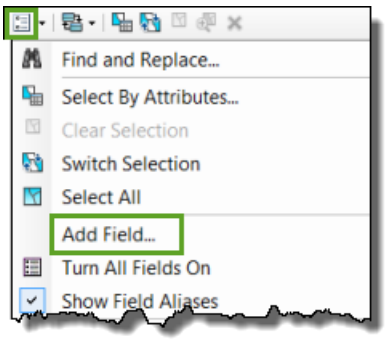
Note that not all the records are shown. This is because time is still enabled on the map, so the only records you see in the table are those for the current time step. If you calculate the values in a field while time is enabled, only the current time step's records will be calculated. So, you need to disable time on the map.

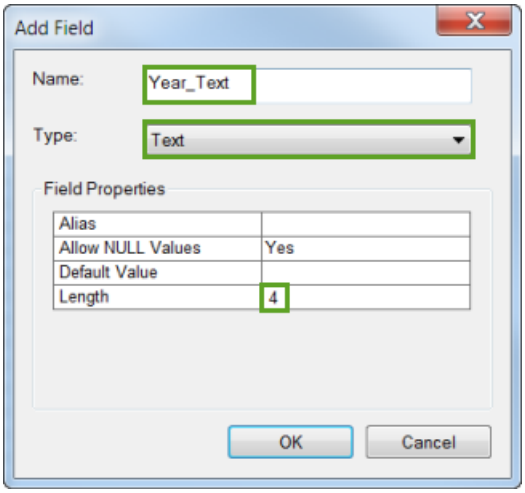
12. In the Time Slider window, click the first button in the upper left corner to disable time on the map.



13. On the attribute table toolbar, click the Table Options button and click Add Field.



14. Type "**Year_Text**" as the name, change Type to Text, and set Length to 4.



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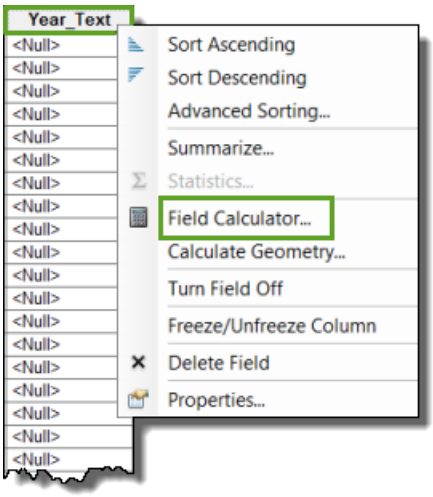
15. Click OK.

16. Scroll to the right to see the added field.

17. Right-click the Year_Text field name and click Field Calculator.



18. In the Fields list, double-click YEAR.

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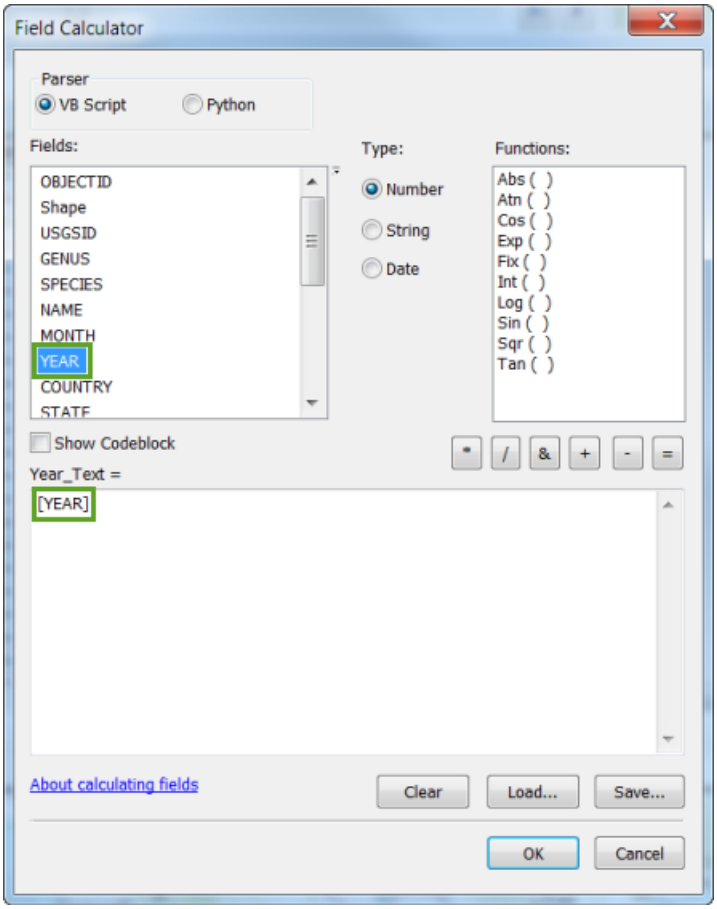
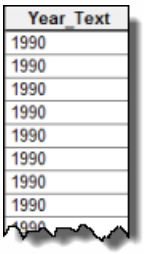


It will appear in the expression area. This expression will calculate Year_Text to equal YEAR.

19. Click OK and check that the values have been updated.



Year_Text
1990
1990
1990
1990
1990
1990
1990
1990

20. Close the attribute table.

21. Open the layer properties.

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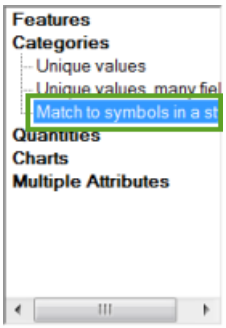
22. On the Symbology tab, click Categories > Match to symbols in a style.



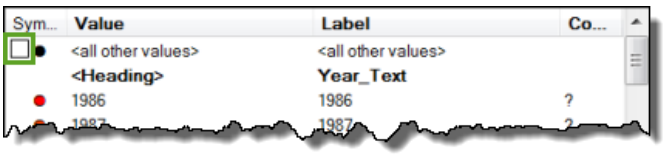
23. Set Value Field to Year_Text.

24. Click the Browse button to browse to and select the Zebra_Mussels style.

25. Click Match Symbols.

    The symbols will be changed to those in the style.

26. Click the check box next to <all other values> to turn off the display for these features.



Note: Although there are zero features with other values, which is indicated by the count to the right of the label, unchecking this option will also turn off this symbol display in the table of contents.

27. Click OK.

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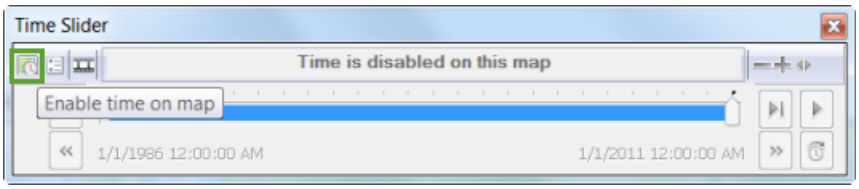
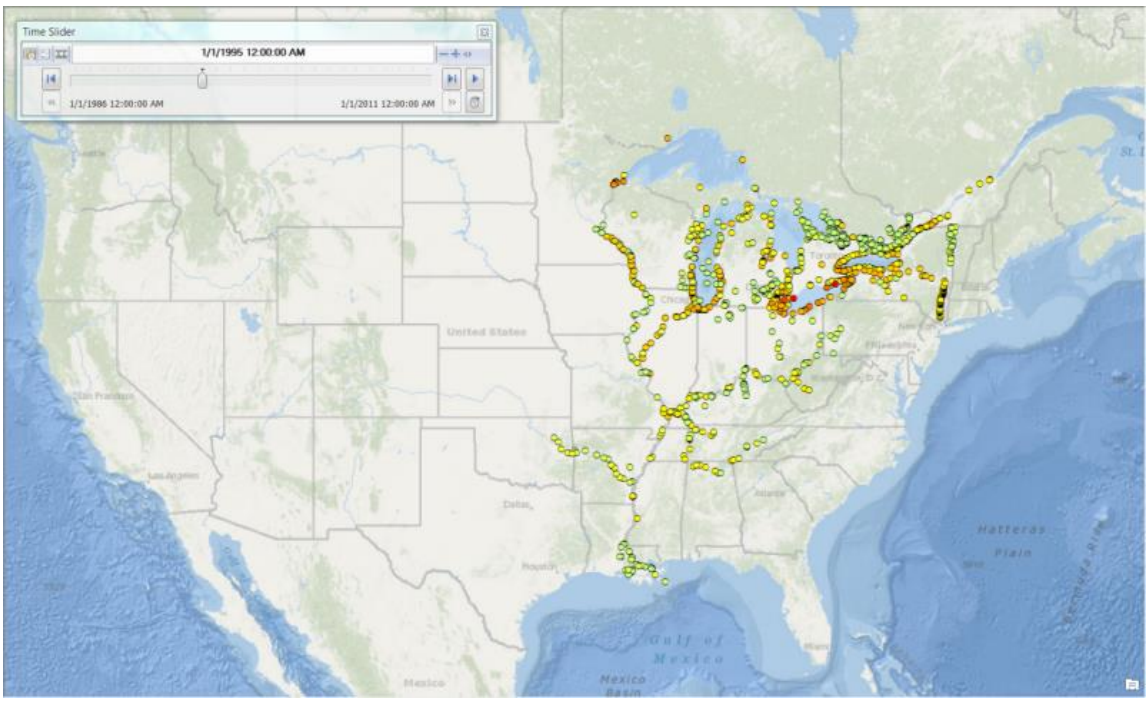
28. Click the box with the minus sign next to the Mussel Sightings layer to collapse its view in the table of contents.

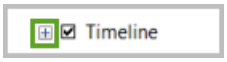
29. Open the Time Slider window and click the first button in the upper left corner to enable time on the map.





On this map, it's easier to keep track of the change over time. To help you see this even better, you'll turn on a timeline that was created for this map. The timeline will show the entire time extent and a clear indication of the current time step. It will also serve as a legend for the map.

30. Click the box with the plus sign next to the Timeline group layer to expand its view.



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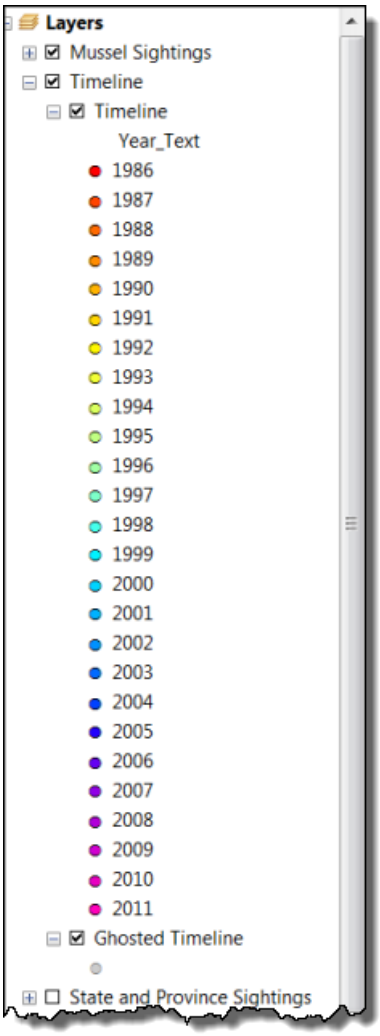

There are two layers. The bottom one has gray symbols, and the top one has the same symbols as the Mussel Sightings layer.

31. Collapse the view for the Timeline group layer.

32. Turn on the Timeline group layer.

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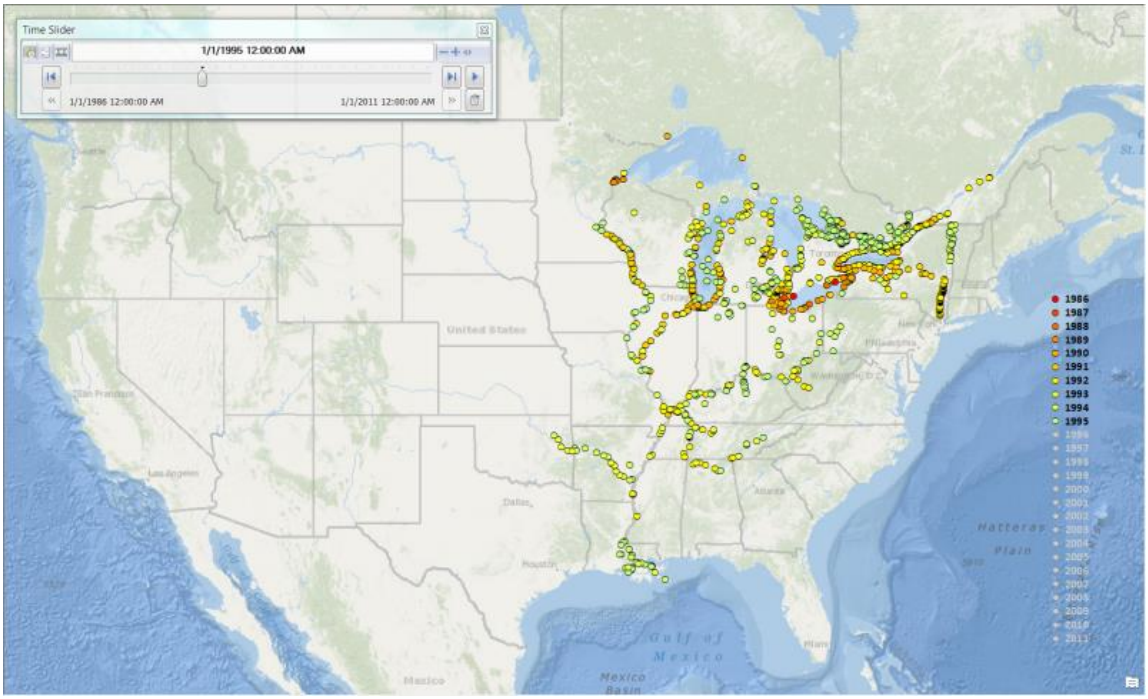
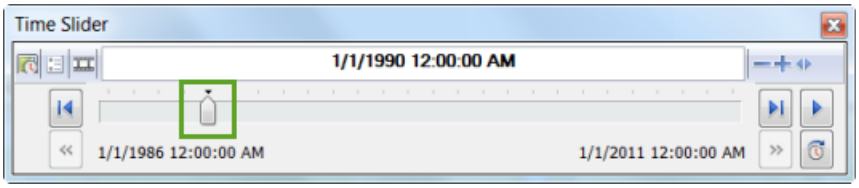


Although you can use the information in the Time Slider window to track the progression of time, the timeline allows you to do this more efficiently because it's part of the map display, and the features in the timeline are visually associated through their symbology with those on the map. In this way, the timeline also serves as a legend for the map. Additionally, the features in the timeline are displayed over time in a north-to-south order, much like the overall pattern of zebra mussel sightings on the map.

Note: Lesson 7 provides instructions for making this timeline.

33. Move the Time Slider control to 1990.



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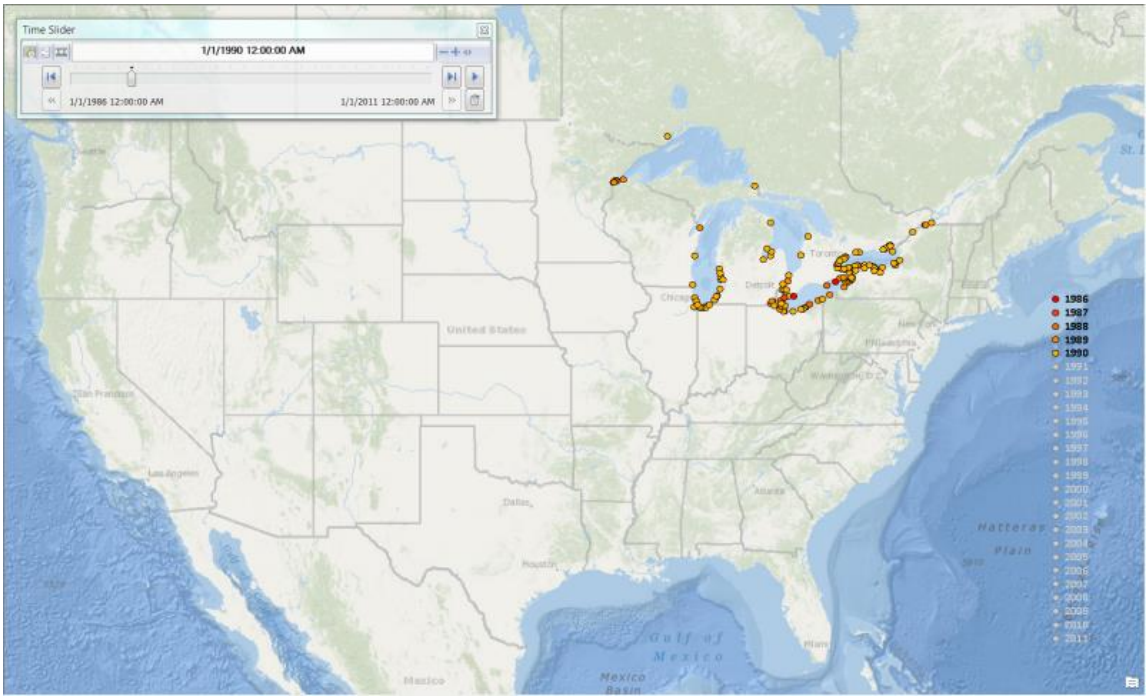
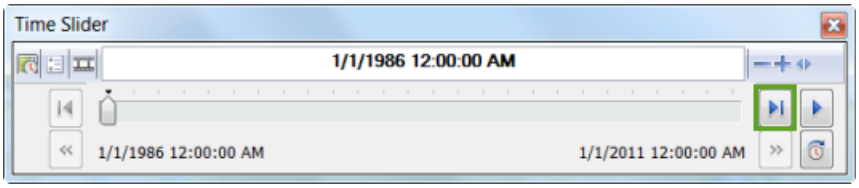


Interpret: By 1990, only four years after being introduced to North America, zebra mussels had been sighted in all the Great Lakes and were moving into the Saint Lawrence River.

34. Click the Next Time Step button to advance one time step to 1991.



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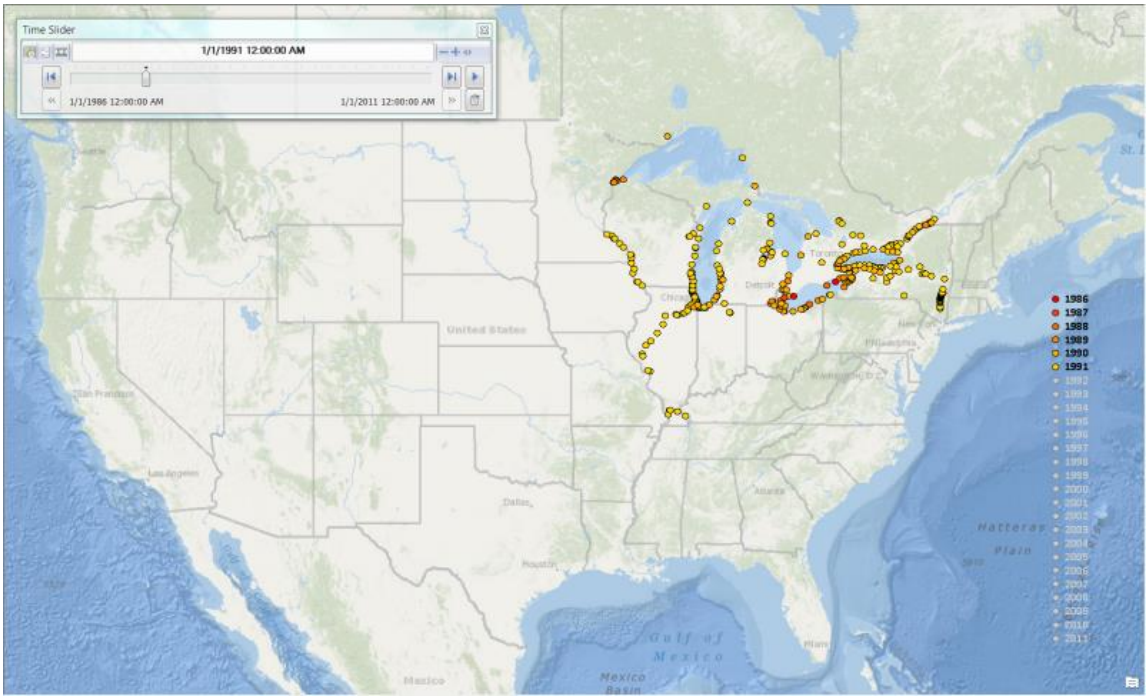
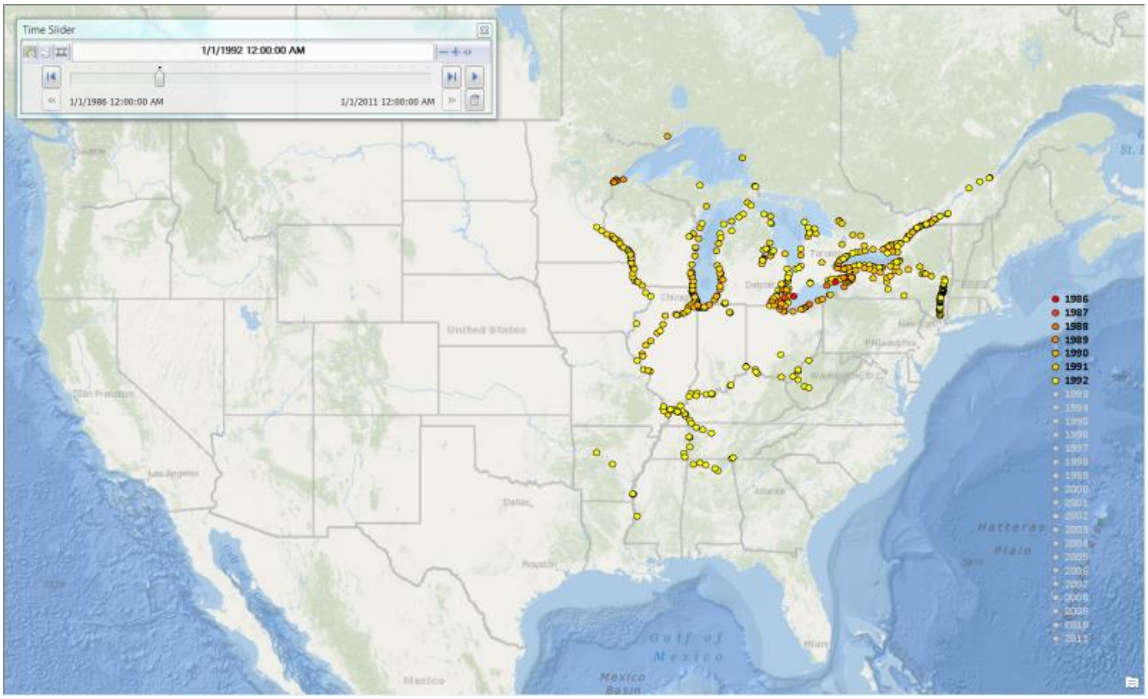


Interpret: By 1991, zebra mussels had escaped the Great Lakes and found their way farther down the Saint Lawrence River and down the Mohawk to the Hudson River in New York. They had also reached the Mississippi River via the Illinois River.

35. Advance to the next time step.



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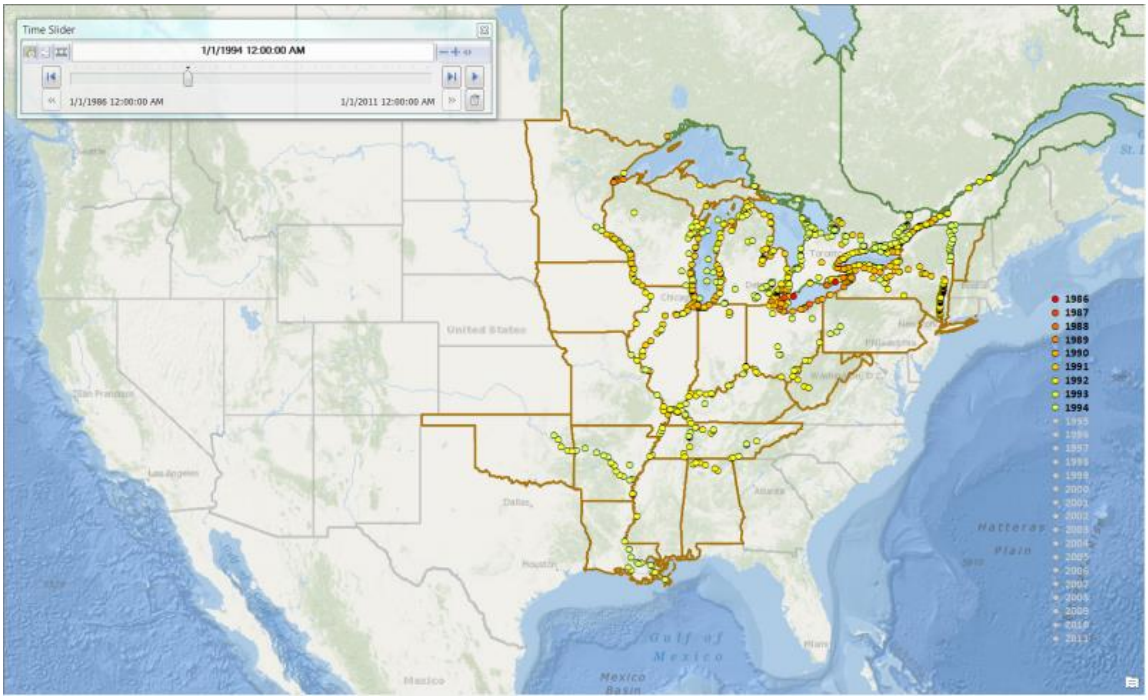
Interpret: By 1992, zebra mussels had made their way to the mouth of the Saint Lawrence River at Quebec. They had also been sighted in the waters of the Arkansas, Cumberland, Ohio, and Tennessee Rivers and were making their way down the Mississippi River to the Gulf of Mexico.

36. Turn on the State and Province Sightings layer.

37. Advance two years to 1994.



Interpret: Only eight years after their introduction to North America in the Great Lakes, zebra mussels had found their way to the sea via the Saint Lawrence, Hudson, and Mississippi Rivers. They were found in the water bodies in or adjacent to 16 US states (Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Mississippi, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Vermont, and West Virginia) and 2 Canadian provinces (Ontario and Quebec).

38. Advance through the other time steps, turning helpful layers on or off to learn more about the invasion of the zebra mussels.

Interpret: You'll learn that in 1999, they were found in the Missouri River between Iowa

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and Nebraska. In 2001, they were reported farther downstream in the Missouri River in the state of Kansas. In 2003, they invaded Virginia as well as water bodies in Nebraska. In 2008, they were in the upper reaches of the Arkansas River in Colorado. That same year, they were sighted on the other side of the Continental Divide, at the headwaters of the Colorado River in Utah; they also found their way to California. In 2009, they invaded Texas and Massachusetts. In 2010, they moved into North Dakota. By 2011, they had been sighted in 30 US states and still only 2 Canadian provinces.

39. Save the map.

You've now answered two of your four spatial questions. Before going any further, you'll do a little data management by creating a new feature class that contains only the zebra mussel sightings, which you'll use in the remaining lessons.

Step 5: Create the Zebra Mussel Sightings layer

There are two reasons to create a new layer containing only the sightings for zebra mussels—both relate to the definition query that you set on the Mussel Sightings layer so that quagga mussel sightings would not be shown:

- Definition queries tend to slow the drawing time when displaying data over time.
- Definition queries cannot be used in any layers from which web map services are created.

Since the mussel sightings data is fairly simple (in other words, there are not many features and the geometry is not complex), you may not notice an improvement in drawing performance. However, you'll be making a map service from this layer in a later exercise, so for that reason alone, you'll want to create this new feature class.

You'll create the feature class by exporting the data for the Mussel Sightings layer. Because this layer has a definition query, only features that meet the query criteria will be exported.

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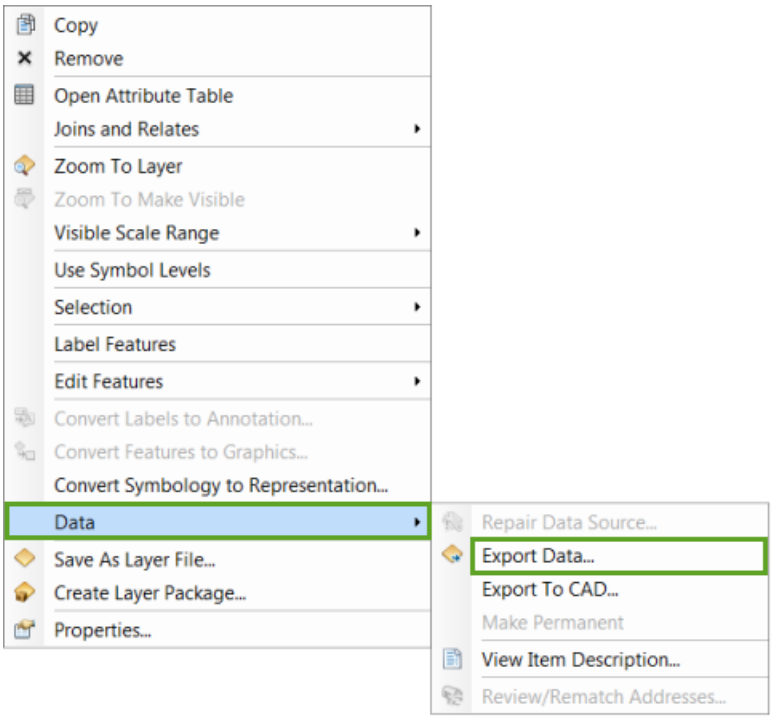
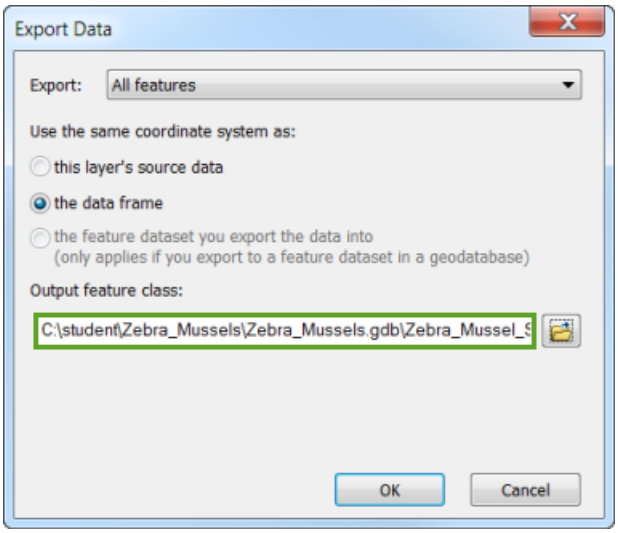
1. Right-click the Mussel Sightings layer in the table of contents and click Data > Export Data.



2. On the Export Data dialog box, keep the default options to export all features using the coordinate system of the data frame, and set the Output feature class to Zebra_Mussel_Sightings in the C:\student\Zebra_Mussels\Zebra_Mussels geodatabase.



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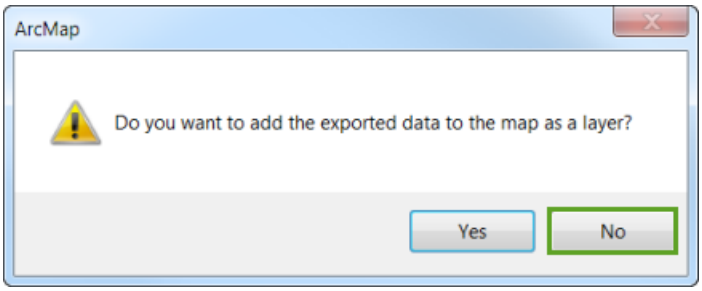
3. Click OK.

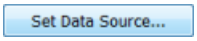
4. Click No so that the exported data is not added to the map as a layer.



You could add the data to ArcMap and redefine the layer properties, but an easier approach is to change the source of the Mussel Sightings layer to the Zebra_Mussel_Sightings feature class. Doing this will prevent your having to reapply the symbology and reset the time properties.

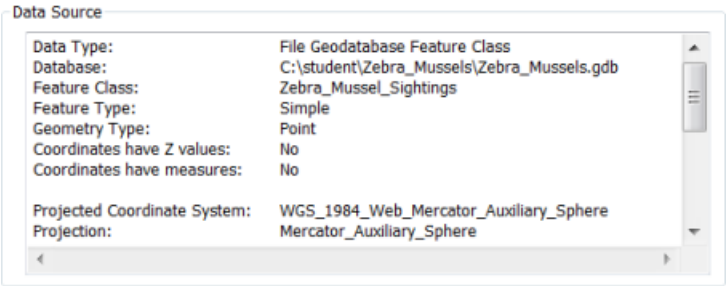
5. Open the layer properties for the Mussel Sightings layer.

6. On the Source tab, click Set Data Source.



7. Browse to the C:\student\Zebra_Mussels\Zebra_Mussels geodatabase and click the Zebra_Mussel_Sightings feature class.

8. Click Add.



The source will be updated.

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9. On the General tab, change the layer name to **Zebra Mussel Sightings**.

10. On the Definition Query tab, press the Backspace key on your keyboard to erase the query.

11. Click OK.

    This layer will look the same, but it can now be used to create a map service.

In the next lesson, you'll answer the questions, how many zebra mussels are there, and are there more zebra mussels in some areas than in others?

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Lesson 4: Map the zebra mussel density over time

In this lesson:

- Create the mosaic dataset.
- Add the model to ArcToolbox.
- Run the model.
- Calculate statistics for the mosaic dataset.
- Change the symbology of the layers.
- Add the time field to the Footprint layer.
- Display the cumulative density rasters over time.

As you saw in the last lesson, one of the challenges with mapping the data for the zebra mussel sightings is that many of the symbols overlap. Instead of trying to determine the number of zebra mussels by mapping the points, you can make a density map to show where the points are concentrated.

Density maps are generated and displayed as a continuous surface in which there's a smooth gradation from areas of higher concentrations to areas of lower concentrations. The density surface is generated in ArcMap as a raster layer. For each cell in the raster layer, you can find the density of the features, such as the number of sightings per square mile.

One way to calculate density would be to use the sightings for a single year. Another way would be to use the sightings for a year and all previous years. You'll use the second option to generate cumulative density maps.

In this lesson, you'll use a model that has been created to generate these density maps. The model will produce 26 rasters, one for each year and using the sightings in that year and all previous years. To display these rasters over time, you'll add them to a mosaic dataset, because you can enable time on a mosaic dataset just as you did for the Mussel Sightings layer in Lesson 3.

The steps you'll follow in this lesson represent standard workflows for including temporal analysis in a model using iterators and mosaic datasets to display raster data over time. These

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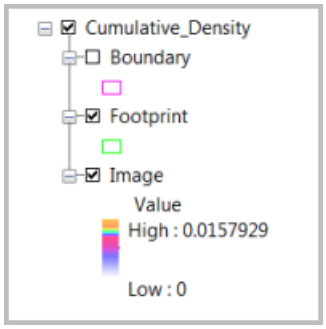
workflows require some data management, such as creating the mosaic dataset, calculating statistics, adding fields, and calculating field values. Although this means that it takes longer for you to actually see the maps, you'll know what steps to take in the future to work with temporal models and display raster data over time.

Before you start: Learn about mosaic datasets

A mosaic dataset is created in a geodatabase and then rasters are added to it. When rasters are added to a mosaic dataset, a pointer to the location of the data is stored within the mosaic dataset. The actual raster data is not transferred to or stored within the mosaic dataset.

When a mosaic dataset is added to ArcMap, the layer that appears in the table of contents is shown as a special group layer that always has the same three layers—Boundary, Footprint, and Image—each of which is also displayed on the map.



Each of these layers has its own layer properties:

- The Boundary layer displays the boundary of the entire mosaic dataset. By default, the boundary is the extent of all the raster datasets within the mosaic dataset.
- The Footprint layer displays the footprints for each raster within the mosaic dataset. The attribute table of the Footprint layer displays a list of all the rasters in the mosaic dataset and many of their properties, such as the minimum and maximum pixel sizes, that are used to display the raster in the mosaicked image. You can add a time field to this attribute table to display the rasters in the mosaic dataset over time.
- The Image layer controls the display of the rasters. For this layer, you can modify the display properties, such as the color ramp, stretch, resampling, and mosaic method.

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In this lesson, you'll learn how to work with these layers to show raster data over time.

Because you'll be generating a lot of new data, you'll start by creating a new file geodatabase to store the rasters. In this geodatabase, you'll create the mosaic dataset that a model will add the rasters to. Then you'll add the model to ArcToolbox and use it to generate the cumulative density rasters and add them to the mosaic dataset. You'll display the mosaic dataset over time to see the changes in the density of zebra mussel sightings.

Step 1: Create the mosaic dataset

You'll create the new file geodatabase in the Catalog window.

1. On the Standard toolbar, click the Catalog button to open the Catalog window.

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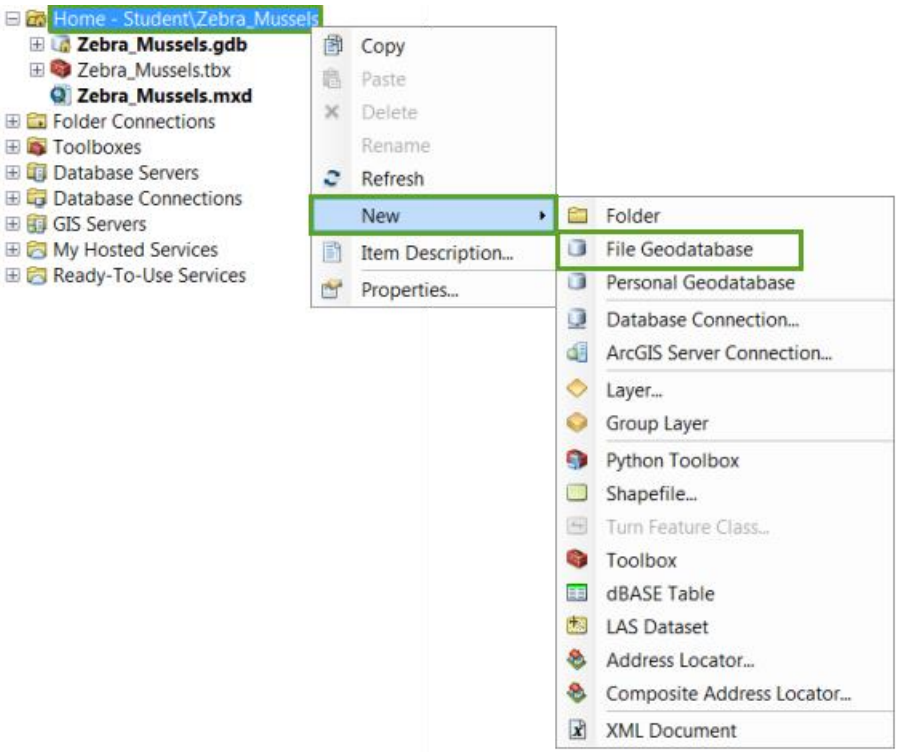
2. Right-click the Zebra_Mussels folder name and click New > File Geodatabase.



3. Rename the geodatabase **Zebra_Mussel_Density** using the same method as renaming a layer.

   Now you'll create the mosaic dataset in this new geodatabase. One thing you need to specify when creating a mosaic dataset is the coordinate system. You'll use the same coordinate system as the feature classes in the Zebra_Mussels geodatabase, so you need to find out what that is.

4. Right-click any feature class in the geodatabase and click Properties.

5. Click the XY Coordinate System tab.

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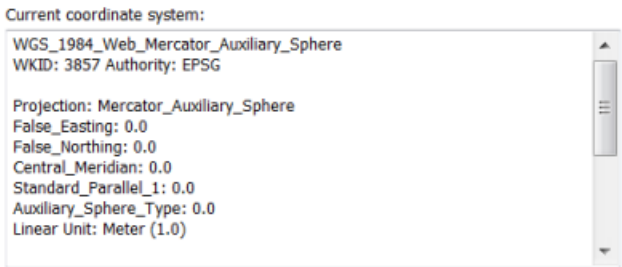
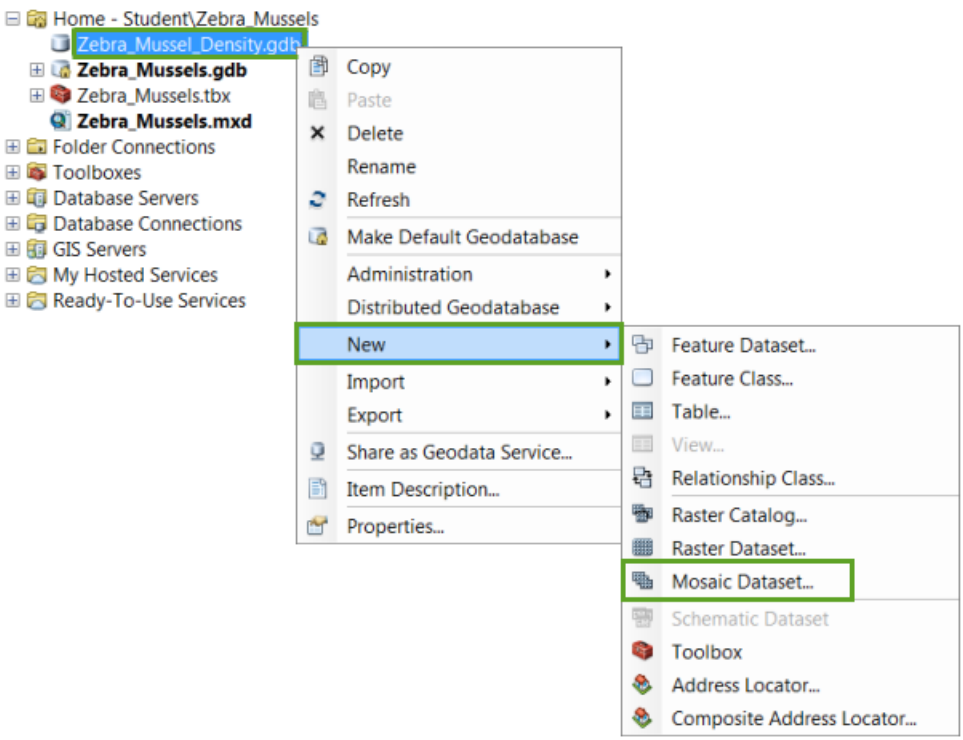


Note that the Current coordinate system is WGS_1984_Web_Mercator_Auxiliary_Sphere.

6. Close the Feature Class Properties dialog box.

7. Right-click the Zebra_Mussel_Density geodatabase and click New > Mosaic Dataset.



8. Make sure the Output Location is the Zebra_Mussel_Density geodatabase and name the mosaic dataset **Cumulative_Density**.

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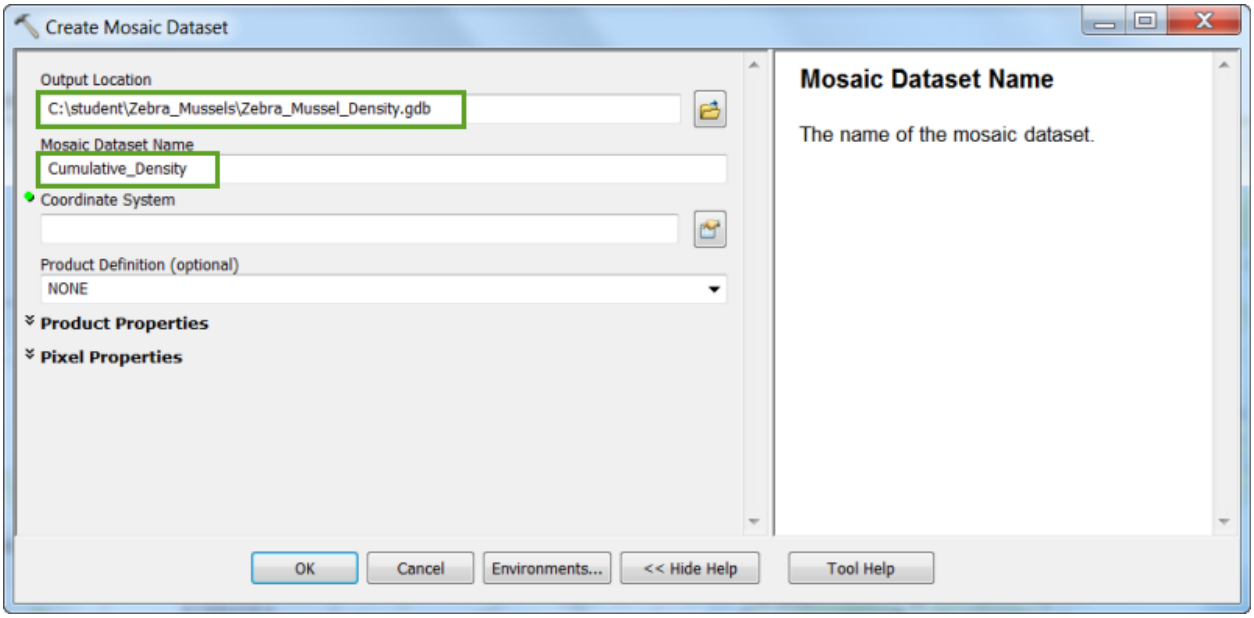

9. Click the browse button for the Coordinate System parameter and select the WGS 1984 Web Mercator (auxiliary sphere) projection, which is in the Projected Coordinate Systems > World folder.

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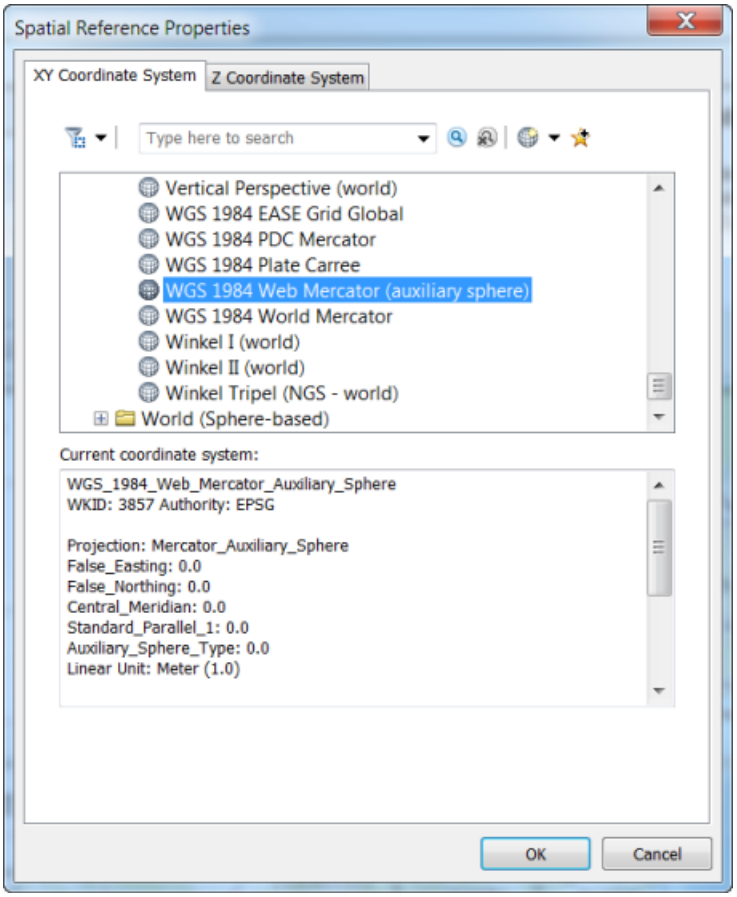
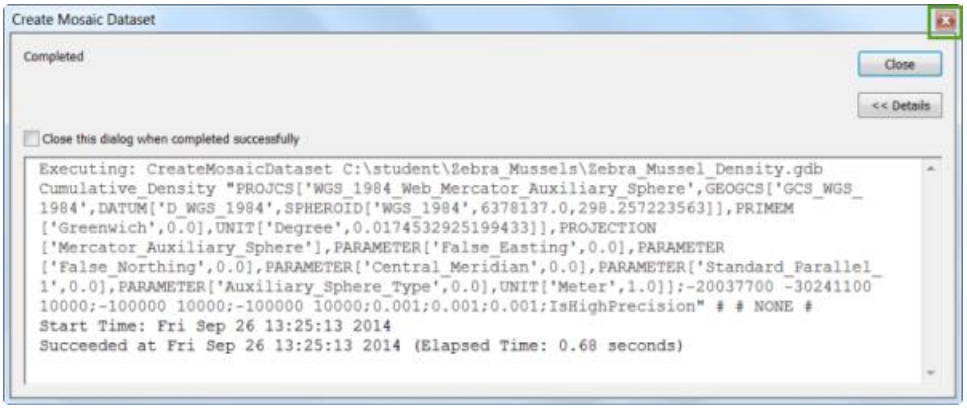


10. Click OK on the Spatial Reference Properties dialog box.

11. Click OK on the Create Mosaic Dataset dialog box to finish creating the mosaic dataset.

12. Click the Close button in the upper right corner of the results dialog box to close it.



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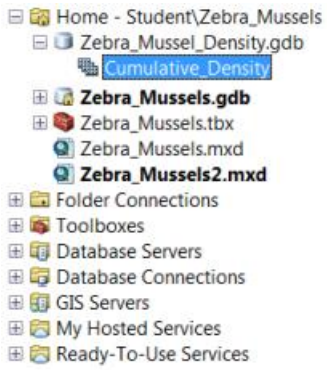
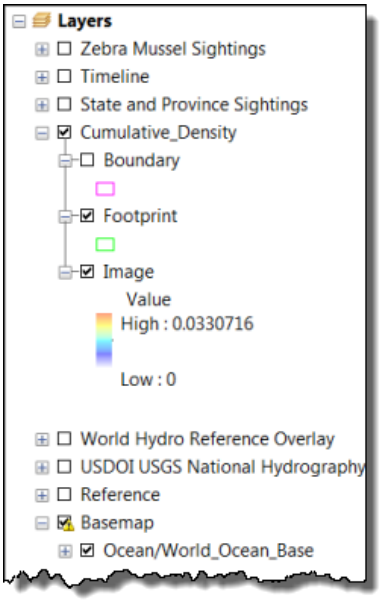
The mosaic dataset will appear in the Catalog window.



The mosaic dataset group layer will appear in the table of contents, but it will not display on the map because no rasters have yet been added to it.



For the rasters to be added to the mosaic dataset when you run the model in the next step, the mosaic dataset cannot be in the ArcMap document, so you need to remove it.

13. Right-click the Cumulative_Density group layer in the table of contents and click Remove.

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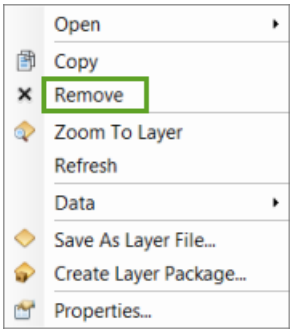

14. Save the map.

Now you can use the model to generate the rasters and add them to the mosaic dataset.

Step 2: Add the model to ArcToolbox

In this step, you'll add the model to ArcToolbox.

1. On the Standard toolbar, click the ArcToolbox button to open the ArcToolbox window.

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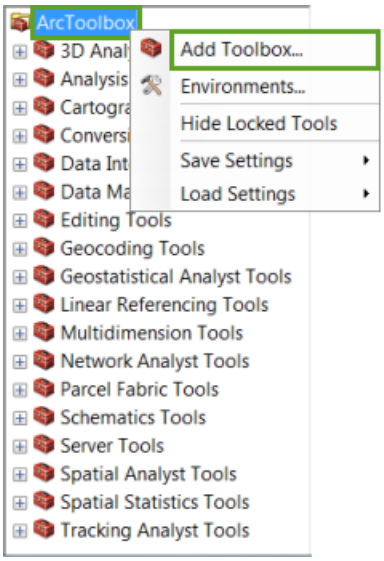
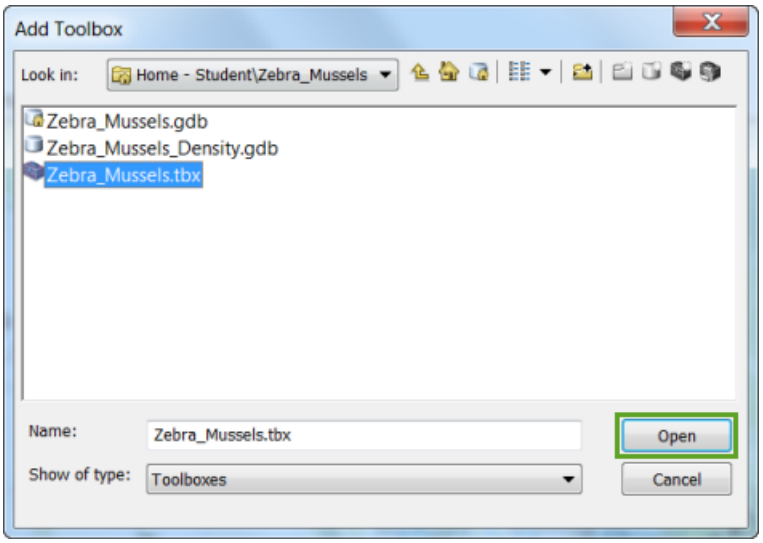
2. Right-click ArcToolbox and click Add Toolbox.



3. Browse to the C:\student\Zebra_Mussels directory, click the Zebra Mussels toolbox, and then click Open to select it.



The Zebra Mussels toolbox will appear at the bottom of the ArcToolbox window.

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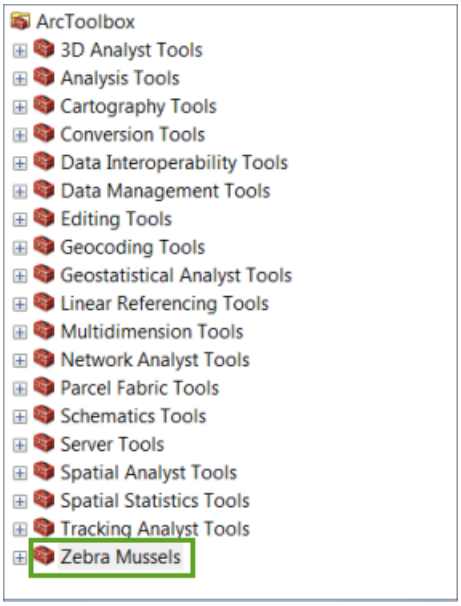

Tip: Toolboxes appear alphabetically when they are added.

4. Expand the view for the Zebra Mussels toolbox to see the Cumulative Density model.

5. Save the map.

Step 3: Run the model

In this step, you'll run the model and calculate statistics for the mosaic dataset. Before running the model, you'll enable the ArcGIS Spatial Analyst extension because the model uses the Kernel Density tool, which is in the Spatial Analyst toolbox.

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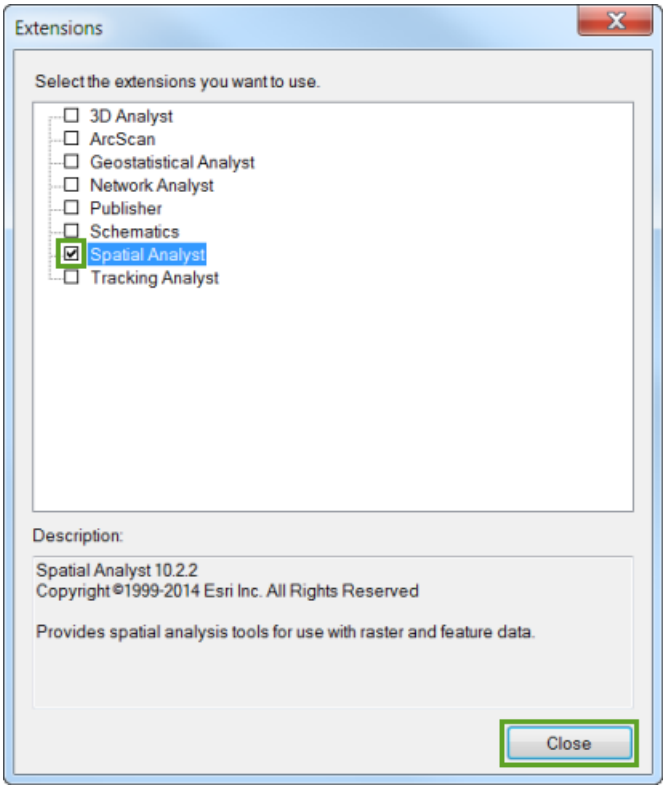
1. On the main menu, click Customize > Extensions.

2. On the Extensions dialog box, check the Spatial Analyst check box and click Close.



3. In ArcToolbox, right-click the Cumulative Density model and click Edit to view it.

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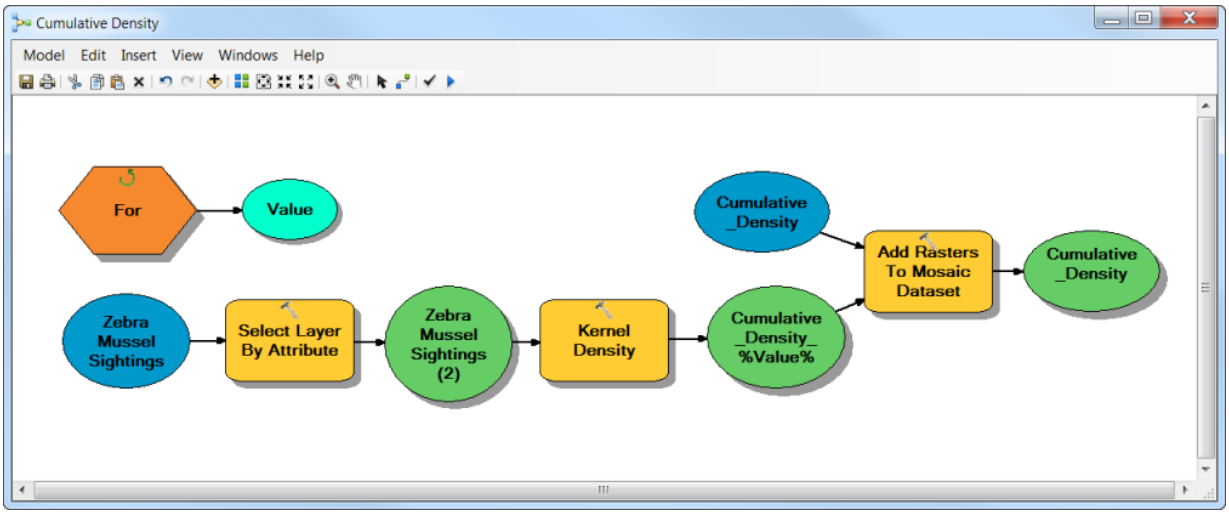
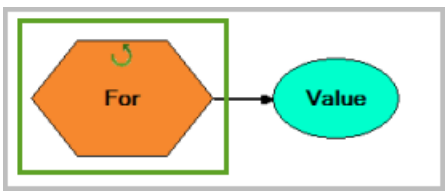
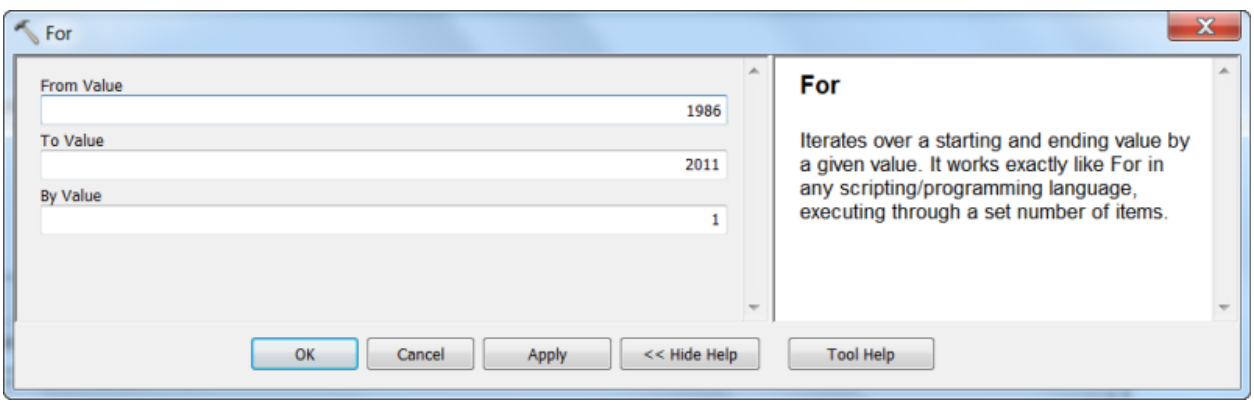


This model selects the points for each year and all previous years and uses them to create a cumulative density raster. The raster is then added to the mosaic dataset.

Note that the model has a For iterator. Iterators are used in models to repeat a process on a set of inputs. In this model, it repeats the process for each year.



4. Double-click the For iterator to see its parameters.



The From Value parameter is set to 1986, the first year in the data. The To Value parameter is set to 2011, the last year. The By Value parameter is set to 1 so that the process is repeated for each year. The value that's being used in the tools is stored in

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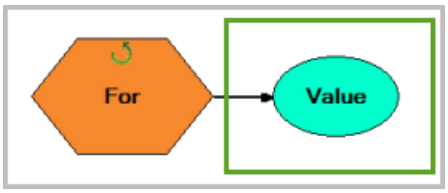
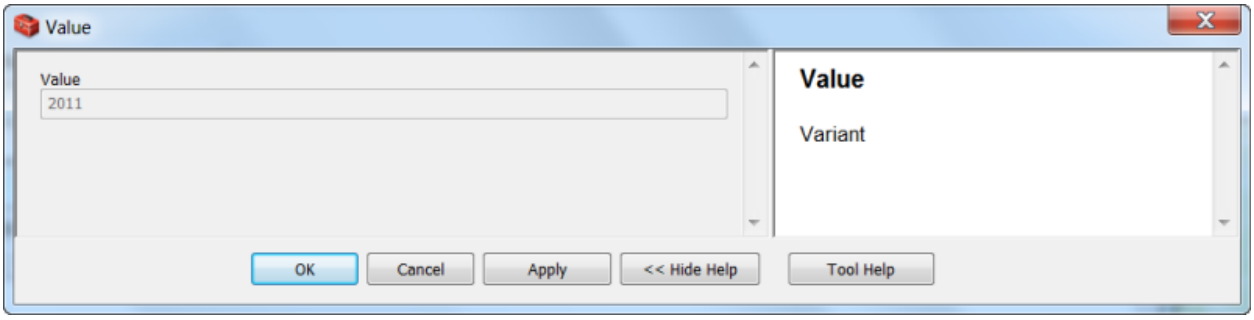
the Value variable, shown in the bright green oval.



5. Close the dialog box.

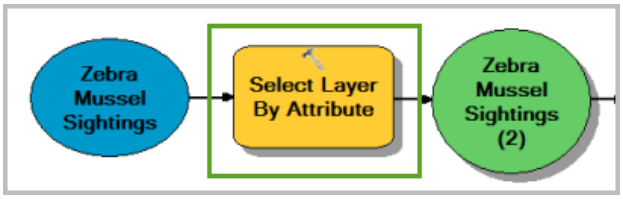
6. Double-click the Value variable.



This variable will update as the model runs. This value is used in the three tools in this model.

7. Close the dialog box.

8. Double-click the Select Layer By Attribute tool.



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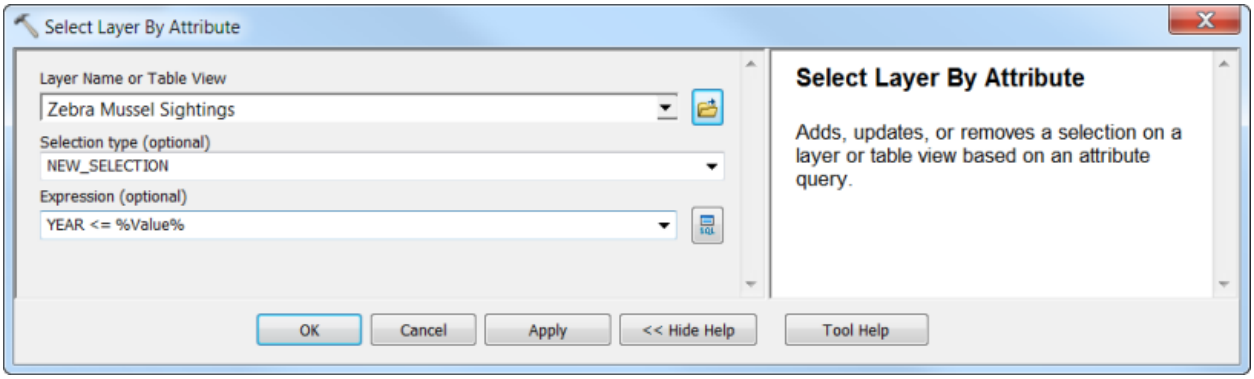
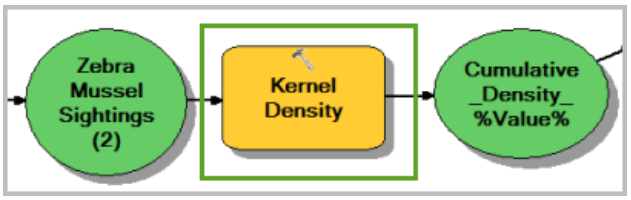


Note that the expression uses the Value variable, indicated by %Value%. When the YEAR attribute is less than or equal to the year in the Value variable, the points in the current year and all previous years will be selected. They are then used as the input for the Kernel Density tool.

Note: If you wanted to create density rasters using the sightings for each single year, you would change the expression to YEAR = %Value%.

9. Close the dialog box.

10. Double-click the Kernel Density tool.



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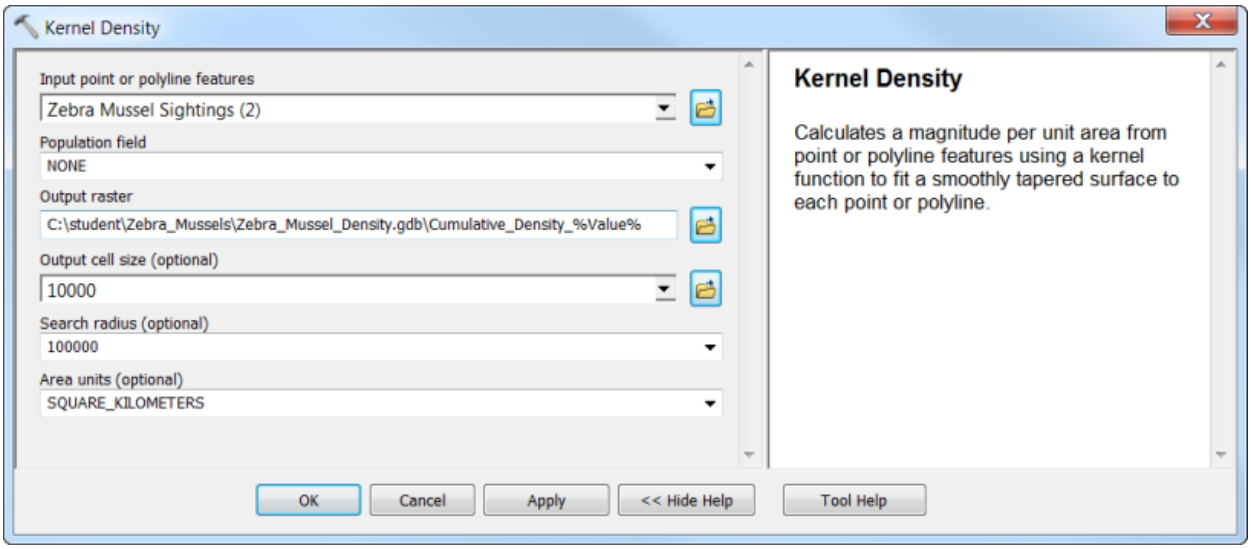
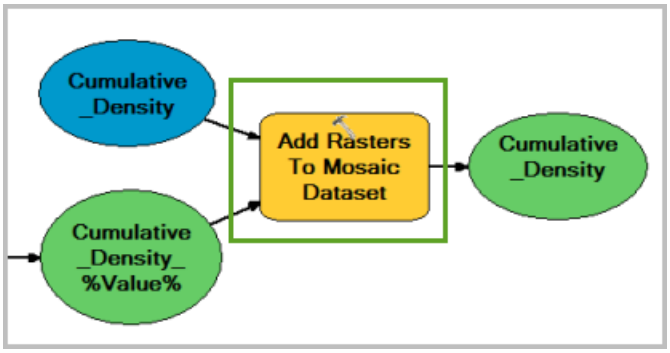


Note that the output raster name will include the year. Also, note that the output density value will be in square kilometers, so values for the cells will be the number of sightings per square kilometer.

11. Close the dialog box.

12. Double-click the Add Rasters To Mosaic Dataset tool.



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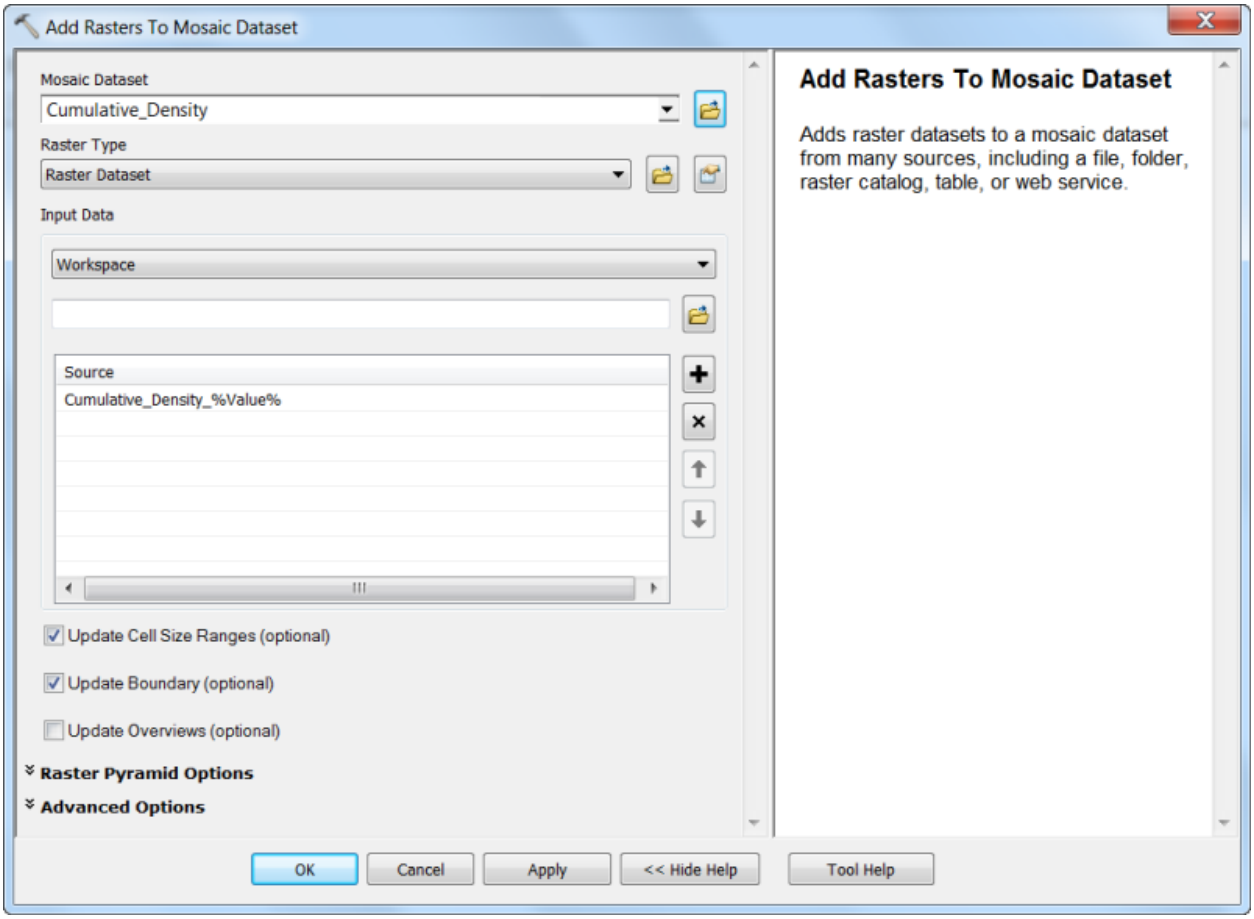

The cumulative density raster for each year will be shown in the Input Data parameter.

13. Close the dialog box.

14. Click the Validate Entire Model button to make sure there are no errors in the model.

15. Click the Run button to run the model.

The progress will be noted on the results dialog box.

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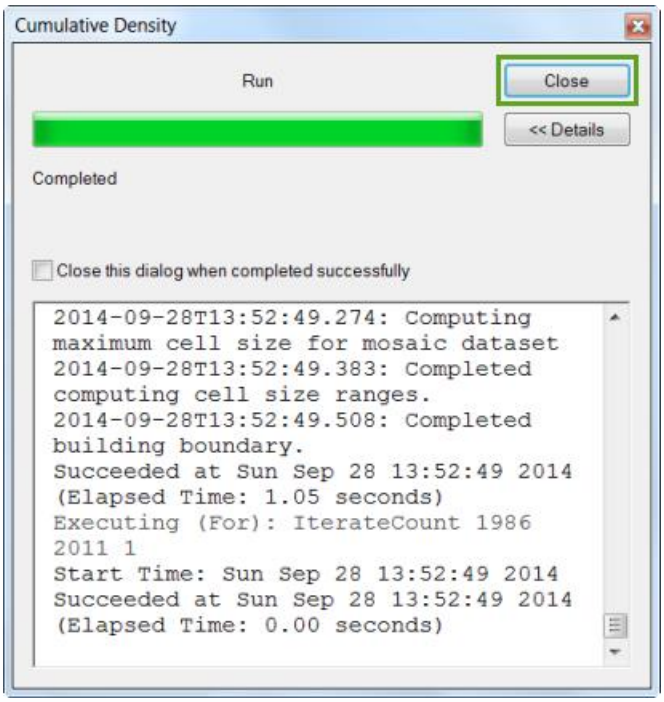
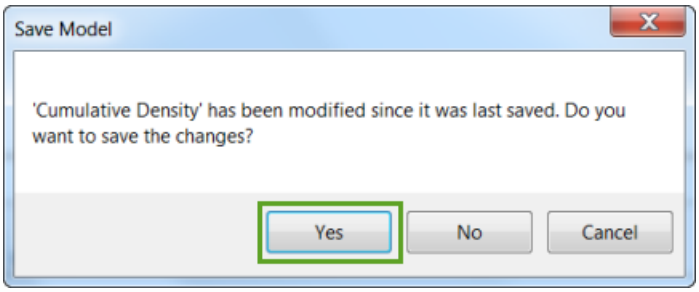
16. Close the results dialog box.



17. When the model has finished running, click the X in the upper right corner to close it.

18. Click Yes when asked if you want to save the changes.



19. Open the Catalog window.

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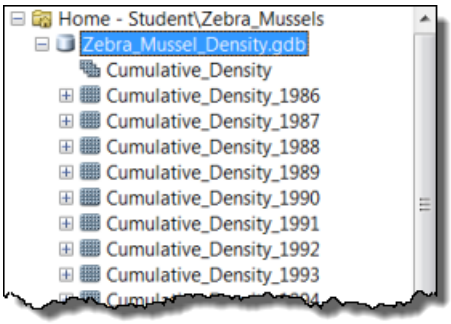

The cumulative density rasters have been created and added to the mosaic dataset. Next, you'll calculate statistics for the mosaic dataset so that you can properly display it.

20. Save the map.

Step 4: Calculate statistics for the mosaic dataset

Statistics are required for your raster and mosaic datasets in order to perform certain tasks, such as applying a contrast stretch or classifying your data. Calculating statistics on the mosaic dataset will allow you to apply a contrast stretch using the Stretched renderer with a color ramp that has been created for you.

1. Right-click the Cumulative_Density mosaic dataset and click Enhance > Calculate Statistics.

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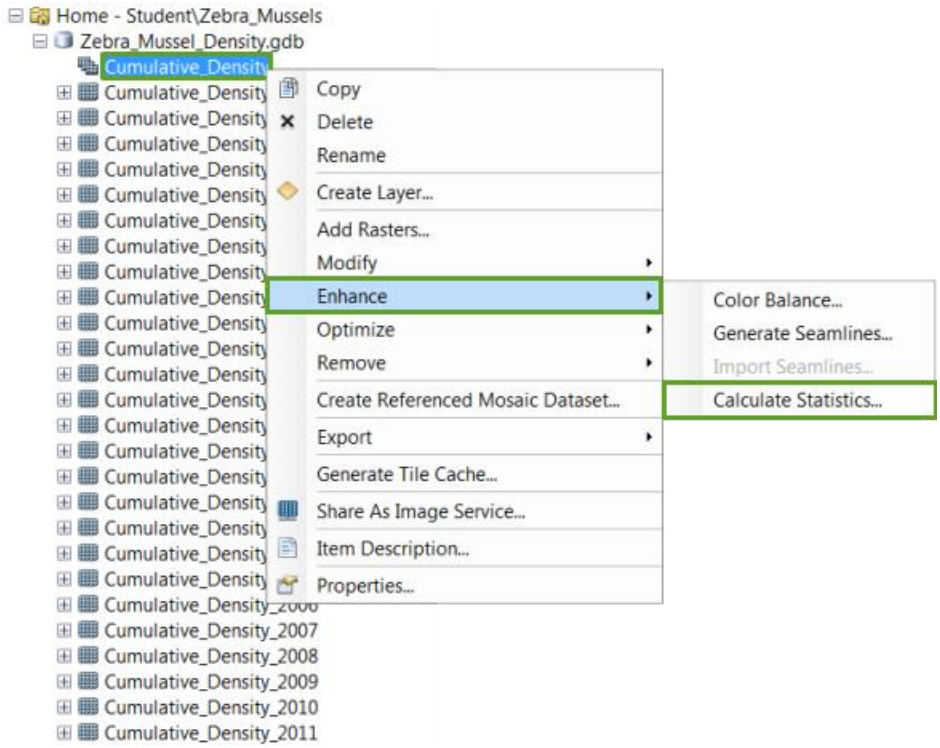

2. Keep the default parameters and click OK to run the tool.

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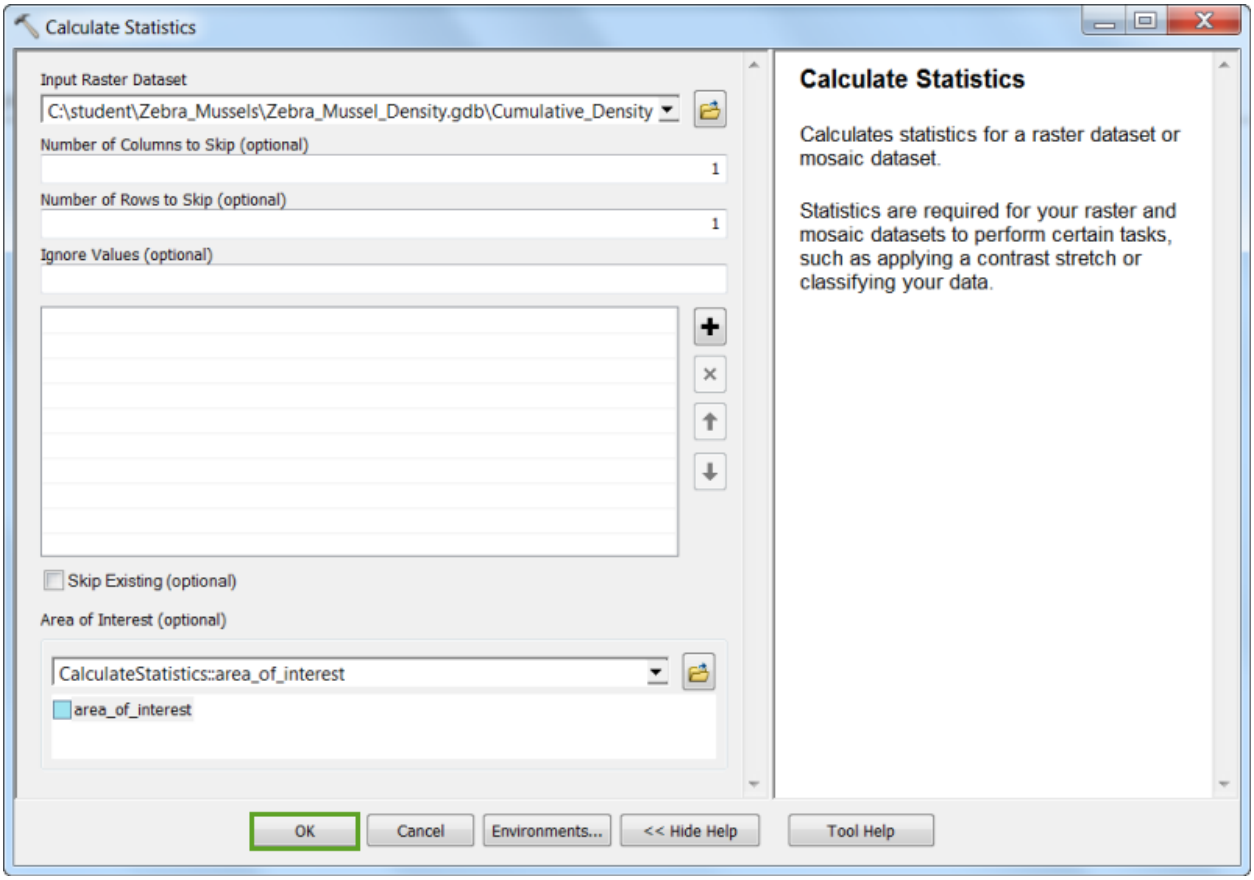

This process will take a minute or so.

3. Close the results dialog box.

4. Click the Cumulative_Density mosaic dataset and drag it into the ArcMap map display.

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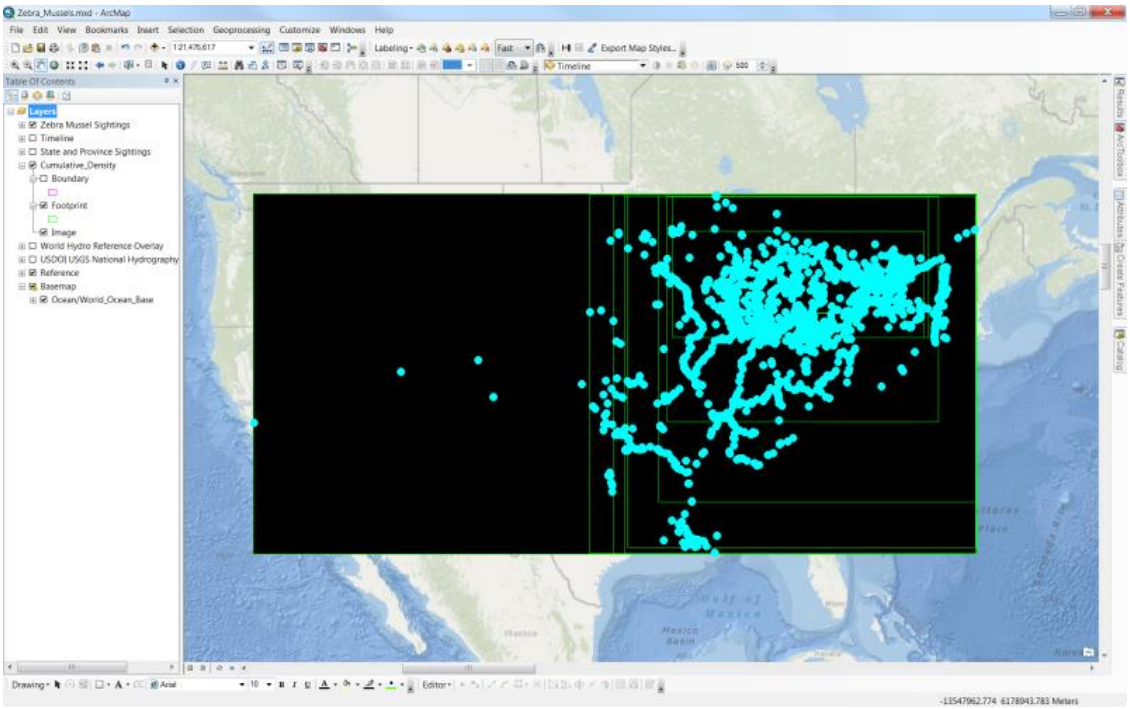
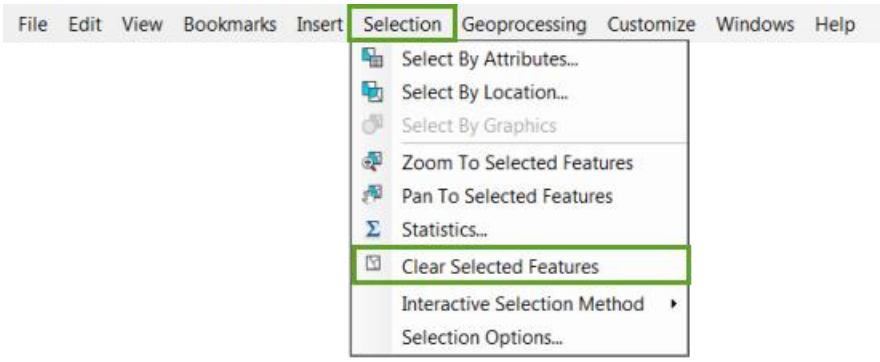


Note that all the points in the Zebra Mussel Sightings layer are currently selected because the last time step included 2011 and all previous years. You'll clear the features so that you can see them better.

5. On the Standard toolbar, click Selection > Clear Selected Features.



The zebra mussel sightings will now be displayed with their symbology over the cumulative density rasters.

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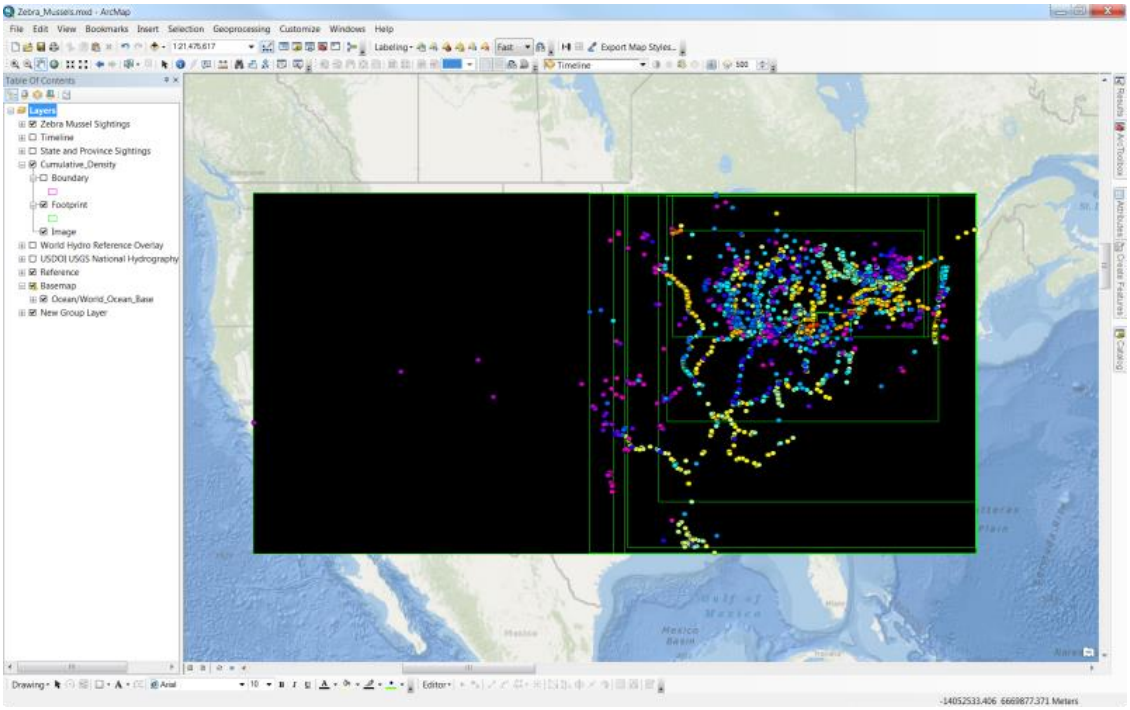

6. Save the map.

The next step is to change the symbology of the layers in the Cumulative_Density group layer.

Step 5: Change the symbology of the layers

In this step, you'll modify the symbology used to display the mosaic dataset.

1. Turn off viewing for the Boundary layer, since you do not need to show the extent of the mosaic dataset.

2. Turn off viewing for the Footprint layer, since you do not need to show the extent of each cumulative density raster.

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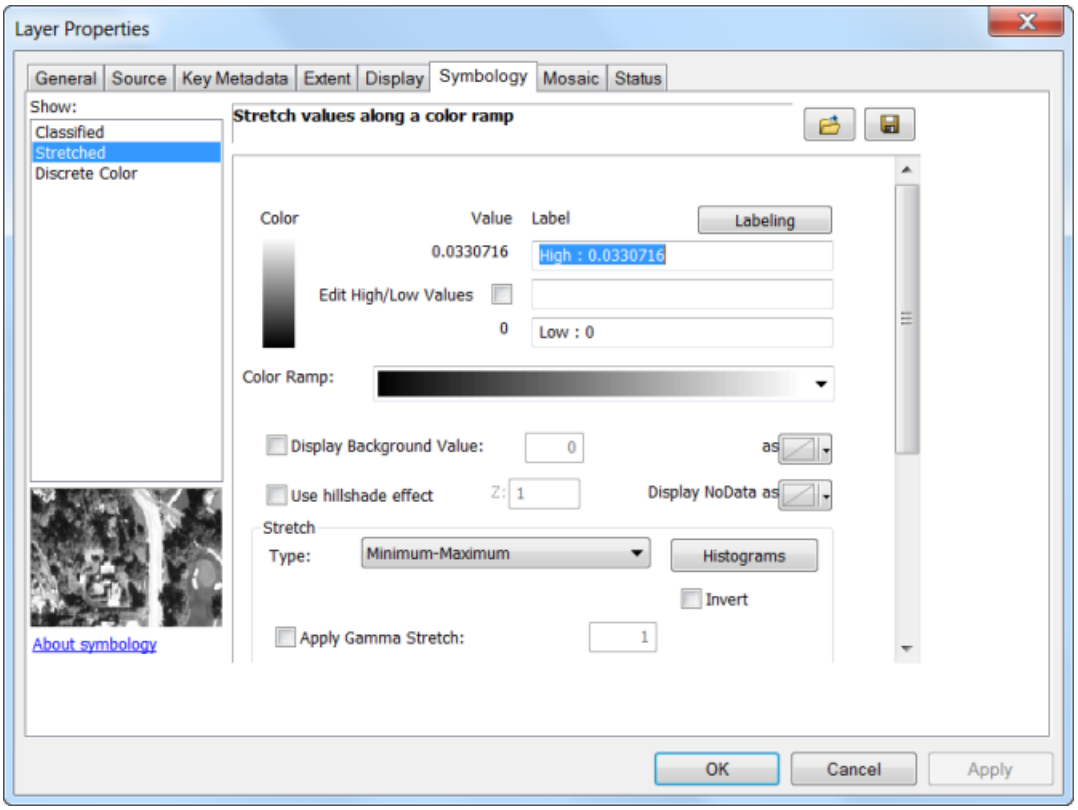
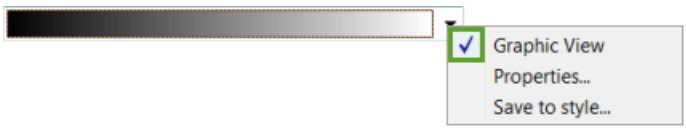
3. Open the layer properties for the Image layer and click the Symbology tab.

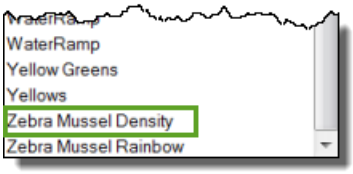


4. Right-click the drop-down arrow next to the color ramp to turn off Graphic View.



When Graphic View is unchecked, the name of the color ramp appears instead.

5. Click the drop-down arrow and scroll to the bottom to select the Zebra Mussel Density color ramp.



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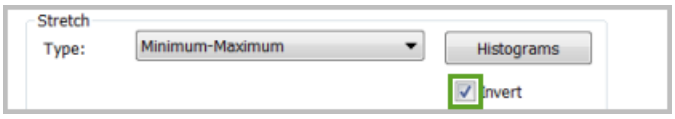
Note: This color ramp is in the Zebra Mussels style that you referenced in Lesson 2.

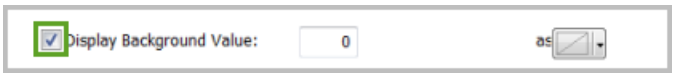
6. Check the Invert check box.



The colors will now range from yellow for high values to white for low values.

A few more modifications to the symbology will improve the appearance of the layer.

7. Check the Display Background Value check box.



By keeping the default number (0) and symbology (No Color), cells with a value of 0 will not be displayed, so cells with no density will not be shown on the map.

8. Change the Stretch Type to Percent Clip and set the max to 1.

This will provide more color variation in the midrange of cell values.

9. Check the Apply Gamma Stretch check box and set the value to 2.5.

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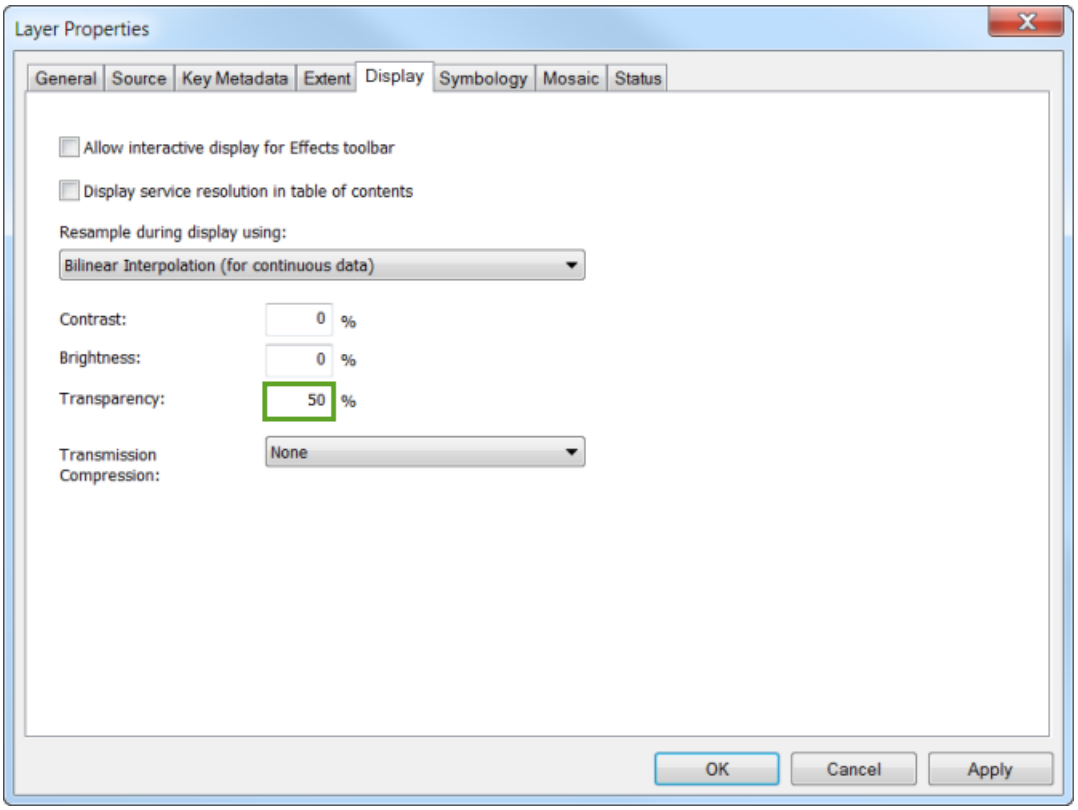
This will increase the contrast in the lighter colors.

10. On the Display tab, set Transparency to 50 percent.



11. Click OK.

12. Turn off all but the Cumulative_Density, Reference, and Basemap layers.

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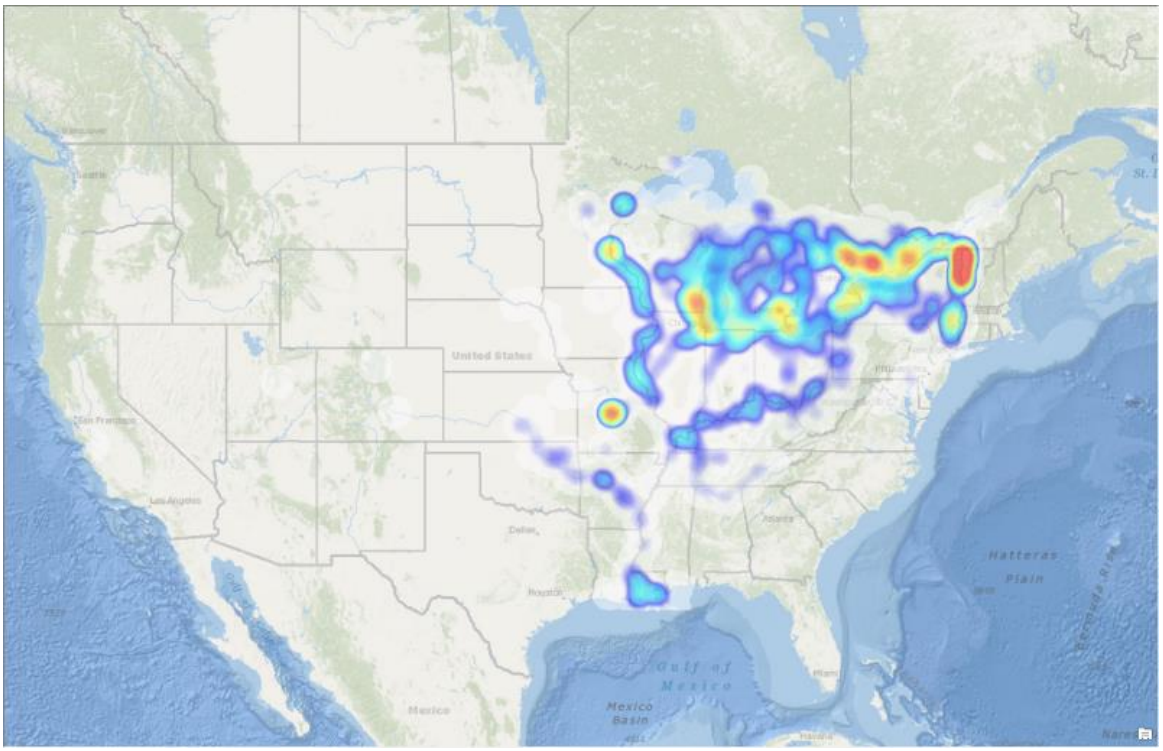

On this map, which shows the density raster for the last time step, you see the cumulative density for all zebra mussel sightings. Areas of higher density are displayed in reds, and areas of lower density are displayed in purples. The lowest values, in white, fade into the background so that you do not focus on them. This map helps you see how dense the zebra mussel sightings are and where there are areas with similar densities.

Interpret: As you can probably guess by now, some of the highest density areas are around the Great Lakes, where zebra mussels first invaded North America's freshwater systems. There are a couple of surprises, though, such as the very high densities in Minneapolis and midstate Missouri, and other high-density areas in Duluth, at the southern tip of Illinois, and at the mouth of the Mississippi River. The density of sightings in these areas was not apparent on the point symbol maps.

Now you'll take a look at the area of highest concentration.

13. On the main menu, click Bookmarks > Lake Champlain.

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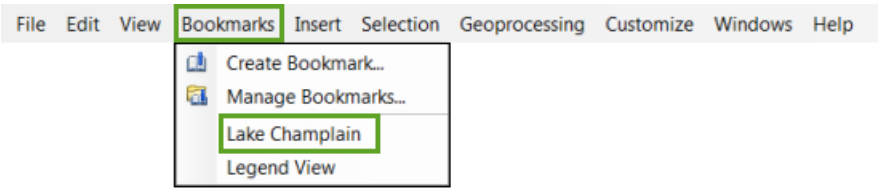
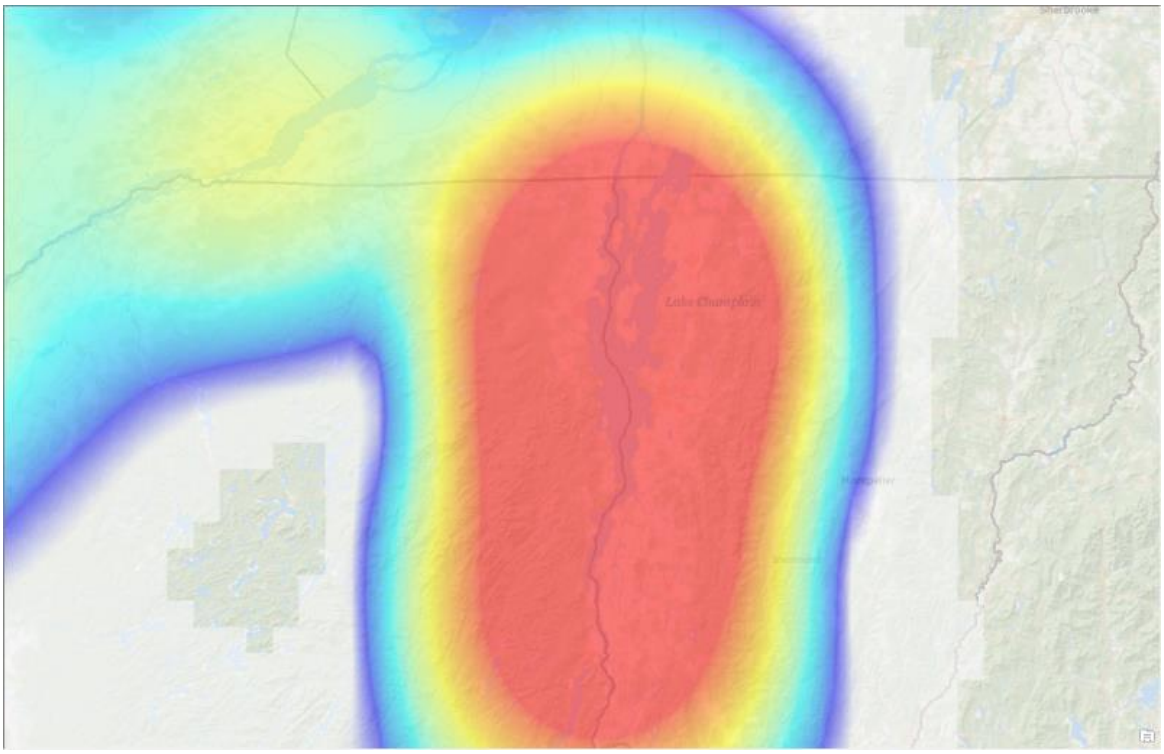


The map will zoom to a predefined bookmark around Lake Champlain between upstate New York and Vermont.



You can find the density values using the Identify tool.

14. On the Tools toolbar, click the Identify button.

15. Click a cell in the center of the lake.

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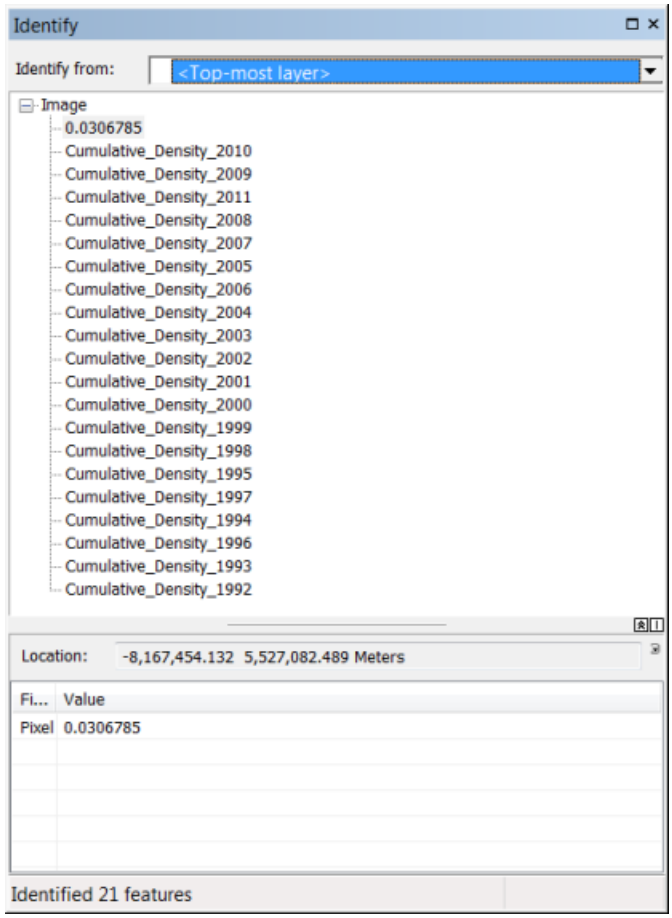

Note that the values in multiple cumulative density rasters are shown. You can click any year to see the value for that year.

In the example above, the cell had a value of .0306 sightings per square kilometer in the topmost layer, which is the cumulative density raster for 2010. This value does not represent an actual count because the density surface graduates smoothly from the highest-concentration areas to the lowest. So, the best way to interpret a density raster is to look at the relative differences rather than the absolute values.

16. Click other cells to see how their values decrease as the distance from the center of the lake increases.

17. On the Tools toolbar, click the Go Back To Previous Extent button to return the view to the previous extent.

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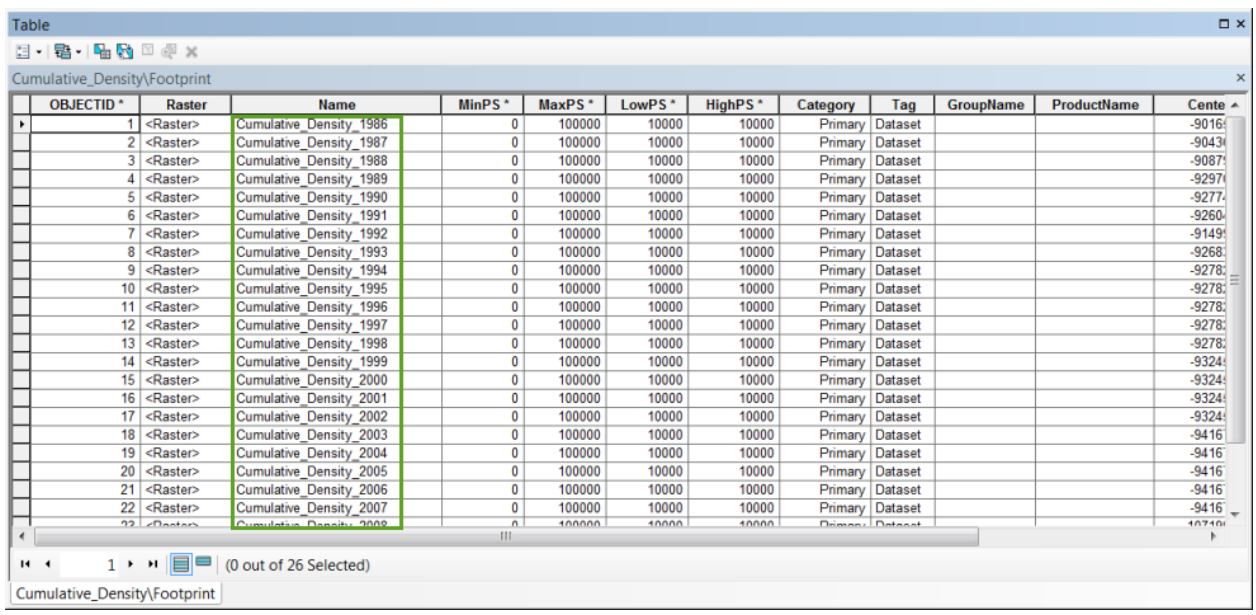
In the next step, you'll prepare the data so that you can display the rasters over time.

18. Save the map.

Step 6: Add the time field to the Footprint layer

In this step, you'll add a field to the attribute table of the Footprint layer. This field will be used as the time field, and it will allow you to display the cumulative density rasters over time.

1. Open the attribute table for the Footprint layer.



OBJECTID *	Raster	Name	MinPS *	MaxPS *	LowPS *	HighPS *	Category	Tag	GroupName	ProductName	Cente
1	<Raster>	Cumulative_Density_1986	0	100000	10000	10000	Primary	Dataset			-9016
2	<Raster>	Cumulative_Density_1987	0	100000	10000	10000	Primary	Dataset			-9043
3	<Raster>	Cumulative_Density_1988	0	100000	10000	10000	Primary	Dataset			-9087
4	<Raster>	Cumulative_Density_1989	0	100000	10000	10000	Primary	Dataset			-9297
5	<Raster>	Cumulative_Density_1990	0	100000	10000	10000	Primary	Dataset			-9277
6	<Raster>	Cumulative_Density_1991	0	100000	10000	10000	Primary	Dataset			-9260
7	<Raster>	Cumulative_Density_1992	0	100000	10000	10000	Primary	Dataset			-9149
8	<Raster>	Cumulative_Density_1993	0	100000	10000	10000	Primary	Dataset			-9268
9	<Raster>	Cumulative_Density_1994	0	100000	10000	10000	Primary	Dataset			-9278
10	<Raster>	Cumulative_Density_1995	0	100000	10000	10000	Primary	Dataset			-9278
11	<Raster>	Cumulative_Density_1996	0	100000	10000	10000	Primary	Dataset			-9278
12	<Raster>	Cumulative_Density_1997	0	100000	10000	10000	Primary	Dataset			-9278
13	<Raster>	Cumulative_Density_1998	0	100000	10000	10000	Primary	Dataset			-9278
14	<Raster>	Cumulative_Density_1999	0	100000	10000	10000	Primary	Dataset			-9324
15	<Raster>	Cumulative_Density_2000	0	100000	10000	10000	Primary	Dataset			-9324
16	<Raster>	Cumulative_Density_2001	0	100000	10000	10000	Primary	Dataset			-9324
17	<Raster>	Cumulative_Density_2002	0	100000	10000	10000	Primary	Dataset			-9324
18	<Raster>	Cumulative_Density_2003	0	100000	10000	10000	Primary	Dataset			-9416
19	<Raster>	Cumulative_Density_2004	0	100000	10000	10000	Primary	Dataset			-9416
20	<Raster>	Cumulative_Density_2005	0	100000	10000	10000	Primary	Dataset			-9416
21	<Raster>	Cumulative_Density_2006	0	100000	10000	10000	Primary	Dataset			-9416
22	<Raster>	Cumulative_Density_2007	0	100000	10000	10000	Primary	Dataset			-9416

Note that the Name field contains information about the year. You'll use this to calculate the values in a new time field.

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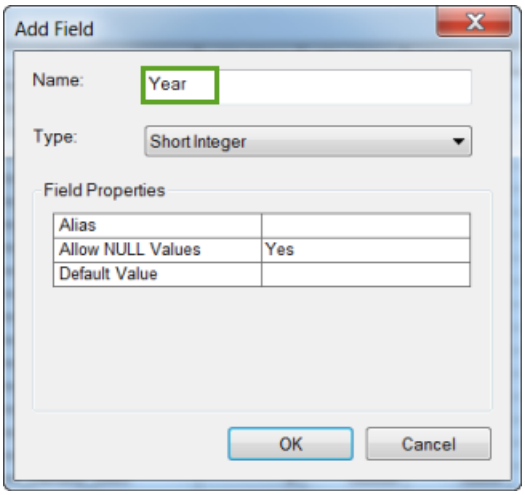
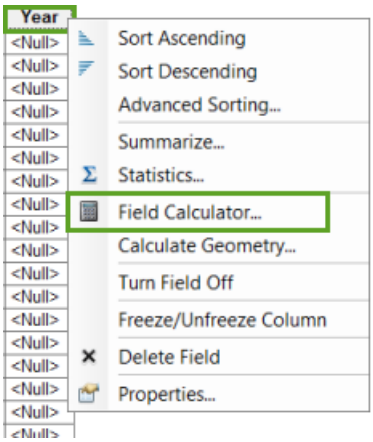
2. Add a field by naming it **Year** with the Type default of Short Integer.



3. Scroll to the right to right-click the Year field and click Field Calculator.



4. Enter the expression shown below and click OK.

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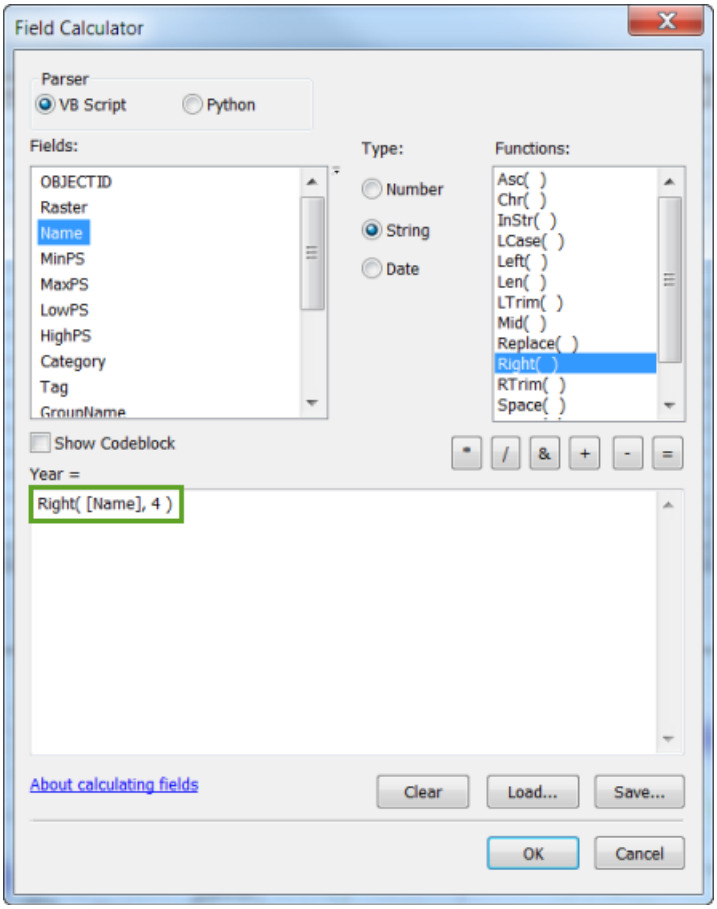
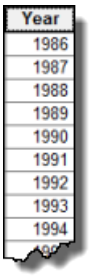


This expression calculates the values for the time field to be the last four characters in the Name field.

Tip: You can change the Type to String and select the Right function to build the expression interactively.

5. Click OK.



The Year values will be updated, starting with 1986 for the first record.

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6. Close the attribute table.

7. Save the map.

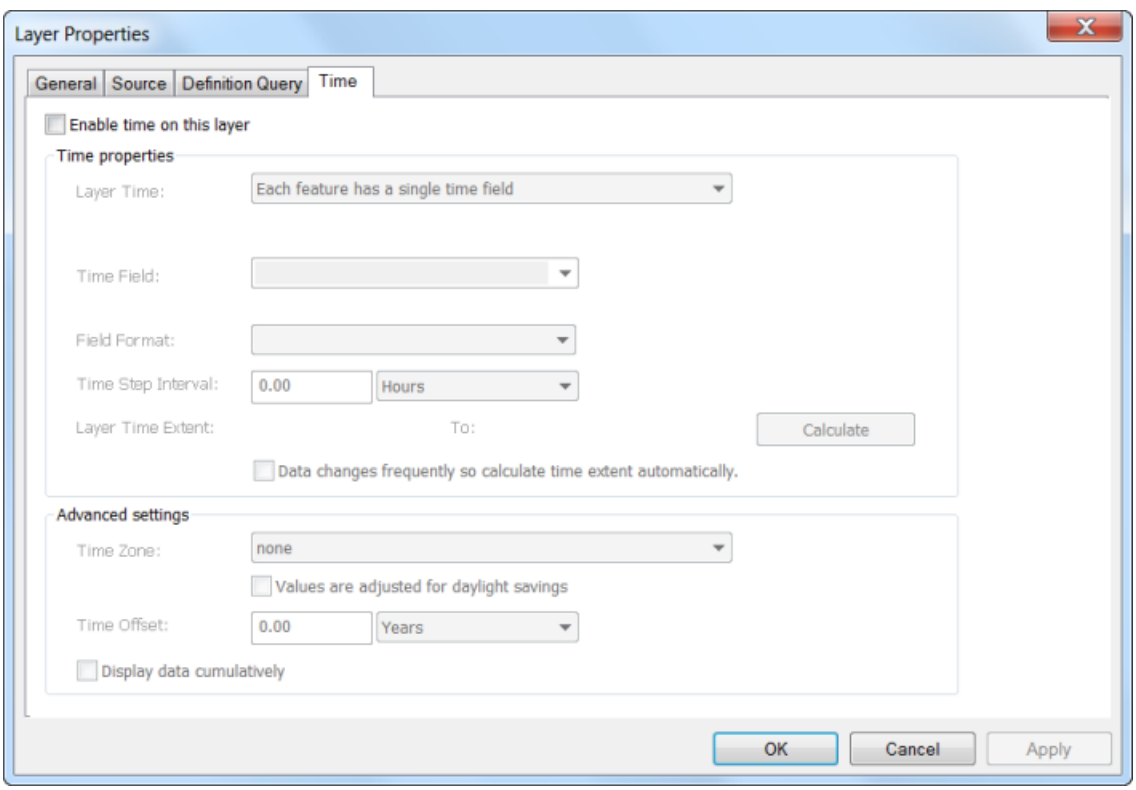
The last step is to display the rasters over time.

Step 7: Display the cumulative density rasters over time

In this step, you'll set the time properties on the Cumulative_Density group layer and then use the Time Slider window to display the rasters over time.

1. Open the layer properties for the Cumulative_Density group layer.

2. Click the Time tab.



Note that the tabs on the Layer Properties dialog box are different from the layers

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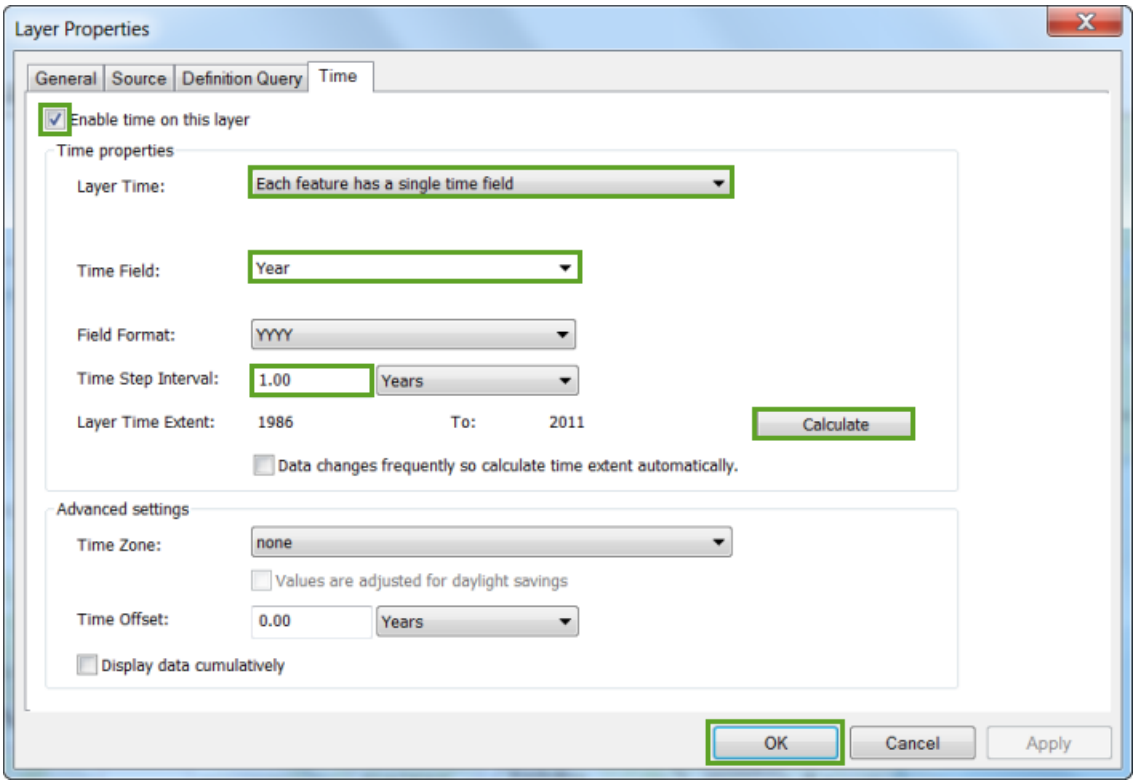
you've been working with so far. That's because this layer is a mosaic dataset. However, there's still a Time tab.

3. Set the time properties as shown below and click OK.



4. Move the Time Slider control to 1990.

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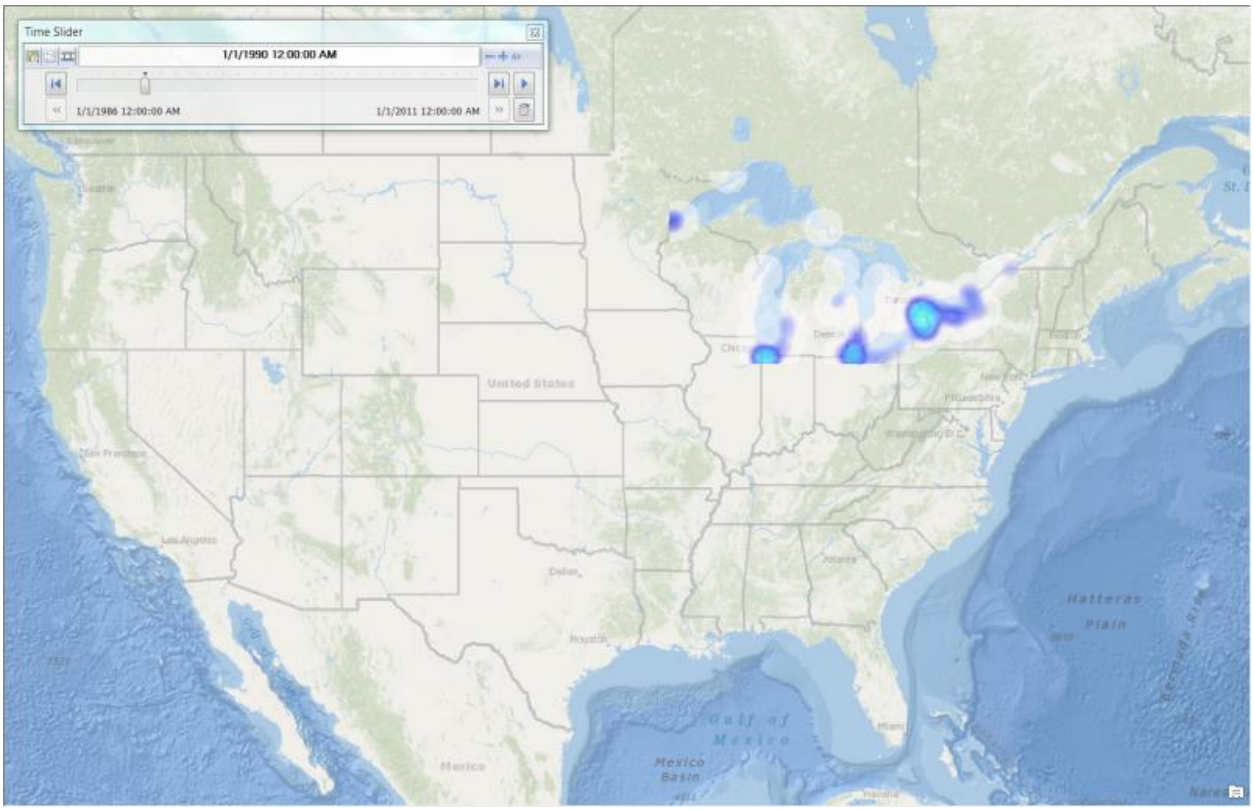

Interpret: By 1990, there was a high concentration of zebra mussel sightings in the west end of Lake Erie, but even more zebra mussels were sighted in the east end of the lake and the west end of Lake Ontario. There were also concentrated sightings in lower Lake Michigan.

5. Advance the Time Slider control to 1991.

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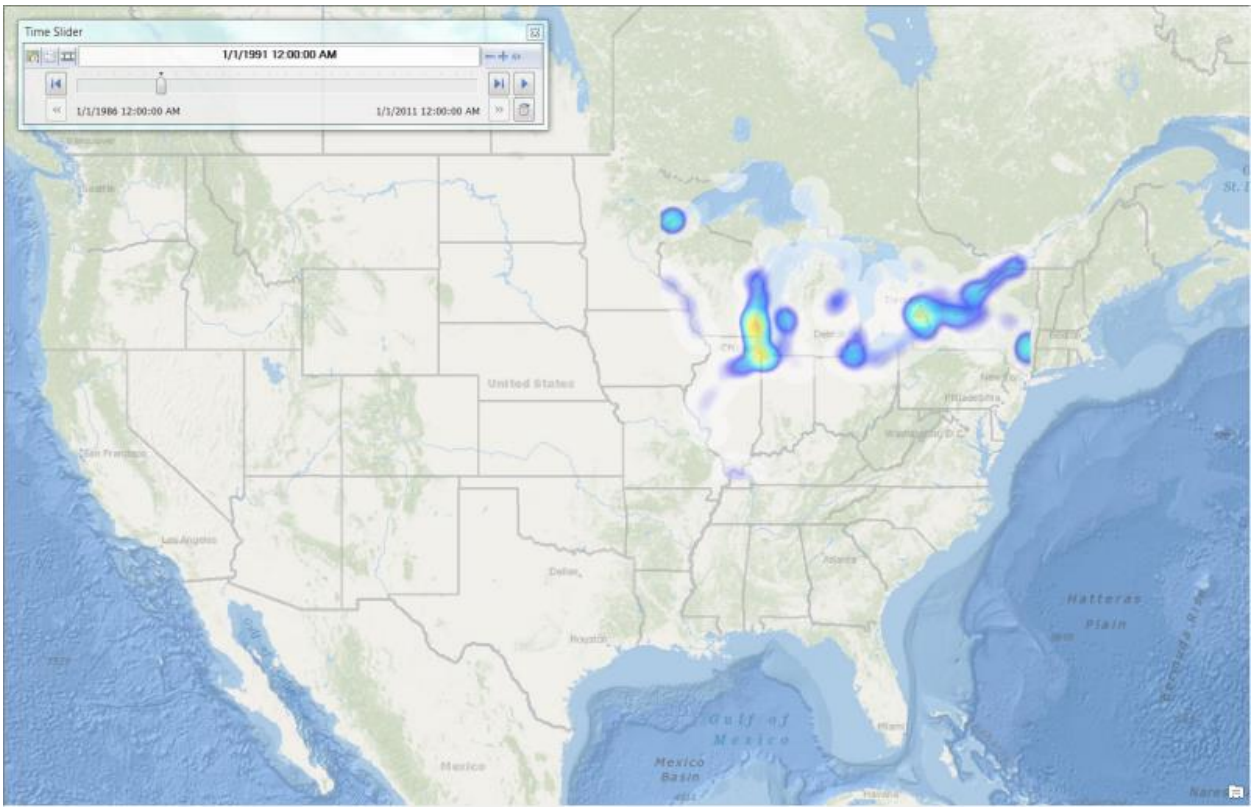

Note that the extent of the density rasters is no larger than the maximum extent of all the input point features, so for some years, like 1991, the edge effects will be apparent.

Interpret: A year later, the concentration of sightings in Lake Michigan was moving north. There was also a concentration of sightings in Lake Superior near Duluth and in the Hudson River of New York.

6. Advance to the next time step.

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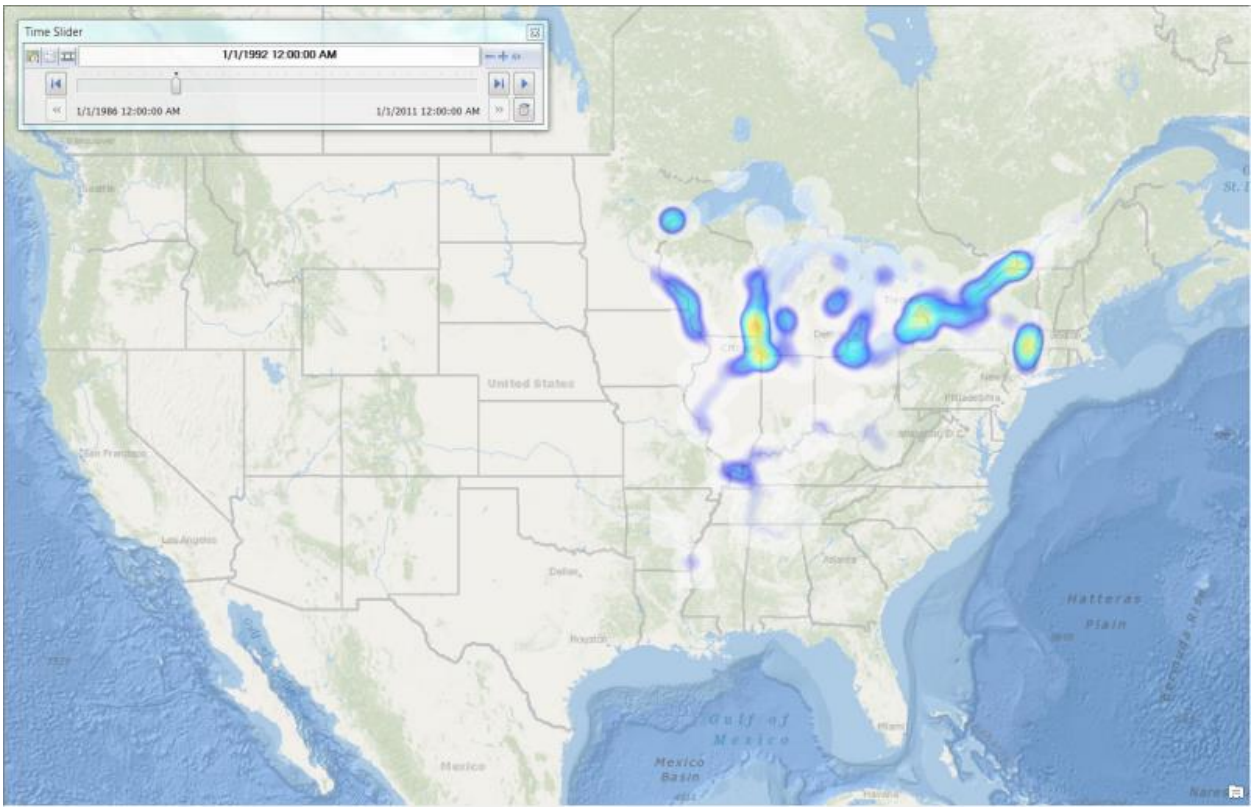

Interpret: By 1992, the concentration of zebra mussel sightings in Lake Ontario spread down the Saint Lawrence River to its mouth. On this map, you're starting to see evidence of their spread along waterways in the linear pattern of some of the concentrations. Note the connected concentrations from Lake Erie to Lake Ontario to the mouth of the Saint Lawrence River in Montreal. Also, note the linear concentration along the Mississippi River in southeast Minnesota.

7. Advance to 1995.

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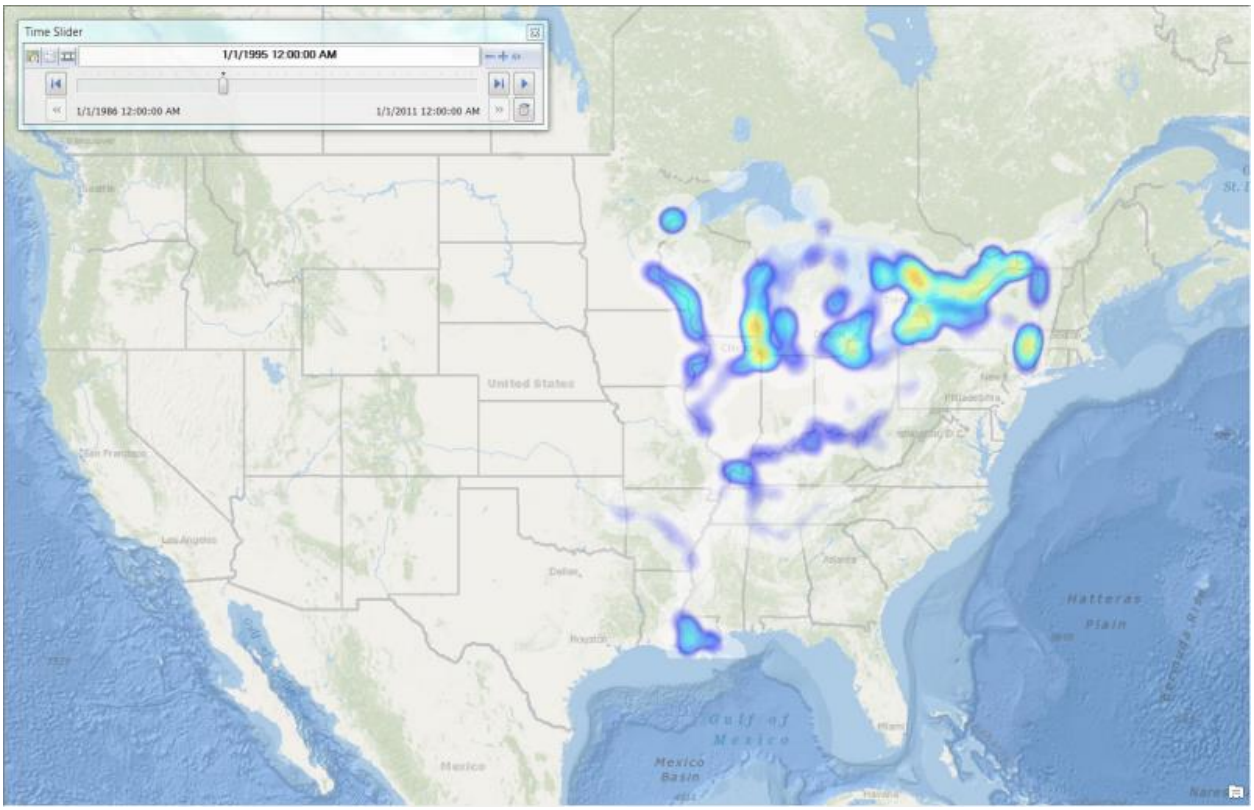

Interpret: By 1995, zebra mussel sightings were also concentrated further downstream in the Mississippi River at the southern tip of Illinois and in the river's delta at the Gulf of Mexico. Lower concentrations are also evident in other rivers, including the Hudson, Ohio, Tennessee, Arkansas, and Illinois, giving the impression that these river systems provided opportunities for zebra mussels to spread downstream.

8. Advance through the other time steps, zooming in or out to learn more about the density of zebra mussel sightings.

   Interpret: You'll learn that by 1996, the highest concentrations were found in Lake Champlain, a pattern that was repeated in all remaining time periods. In 2007, a separate concentration was found in the Lake of the Ozarks in Missouri. Recall that zebra mussels can be transported to new waters on recreational boats, fishing gear, and other objects. Perhaps this is how zebra mussels first got into the waterways of the Ozarks.

9. Save the map.

In this lesson, you answered the question, are there more zebra mussels in some areas than in

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others? You also saw patterns suggesting that they spread within lakes and along rivers. In the next lesson, you'll use spatial statistics to confirm your suspicion that the zebra mussels are spreading.

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Lesson 5: Analyze how zebra mussels have spread over time

In this lesson:

- Analyze the directional trends.
- Change the symbology of the ellipses.
- Analyze the central tendency.
- Change the symbology of the points.
- Display the ellipses and points over time.
- Create a ghosted copy of the ellipses.

You learned in the last lesson that you can get a sense of the spread in the distribution of zebra mussel sightings when you visually analyze maps of the change over time; however, spatial statistics tools give you statistical evidence to confirm your impressions. With these tools, you can summarize the spatial pattern of the zebra mussel sightings in terms of directional trends and central tendency.

To determine whether there's a directional trend in the distribution for each year, you'll use the Directional Deviation tool to create features called *standard deviation ellipses*. The ellipses allow you to see whether the distribution of features is elongated and has a particular orientation. Comparing the size, shape, overlap of ellipses, or changes in ellipses from year to year may indicate how the zebra mussels are spreading.

To analyze the central tendency, you'll use the Mean Center tool to create point features representing the center of concentration. This is useful for tracking changes in the distribution from year to year. If the mean center shifts, this is an indication of the spread in a certain direction and over a certain distance.

In this lesson, you'll analyze the directional trends and central tendency of the zebra mussel sightings for each year, using the spatial statistics tools described above. You'll change the symbology of the ellipses and points that are the output of the tools. Then you'll map the analysis results over time to confirm whether the zebra mussels are spreading.

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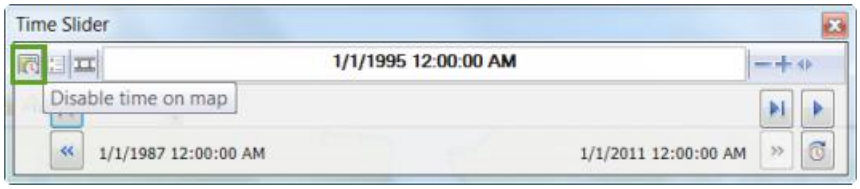
Step 1: Analyze the directional trends

In this step, you'll use the Directional Distribution tool to create the standard deviational ellipses.

In the last lesson, you used an iterator in a model to analyze the data for each time period. The tools you'll use in this lesson have a parameter, called the *case field*, that will group sightings for each year so that an ellipse is created for each time period. For the tool to work properly using the case field, you first need to disable time on the layer.

1. Turn off the Cumulative_Density group layer and collapse its view.

2. Open the Time Slider window and click the first button in the upper left corner to disable time on the map.



   Tip: You could also disable time on the Zebra Mussel Sightings layer.

3. Close the Time Slider window.

4. Open the ArcToolbox window and expand the Spatial Statistics Tools toolbox.

5. In the Measuring Geographic Distributions toolset, double-click the Directional Distribution tool.

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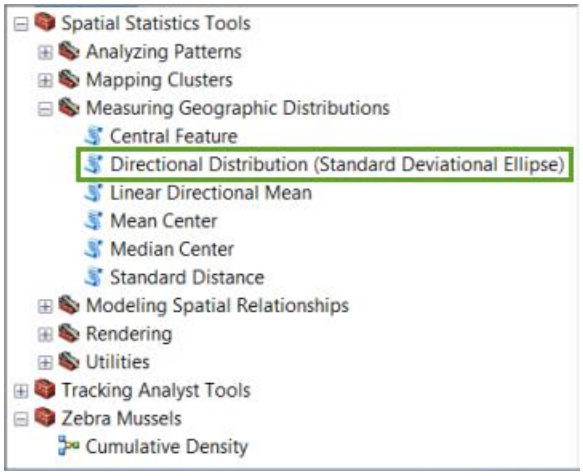
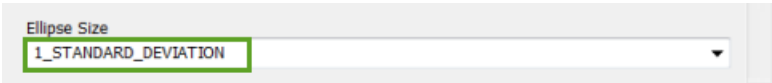


6. On the Directional Distribution dialog box, set the Input Feature Class to Zebra Mussel Sightings.

7. Set the Output Ellipse Feature Class to Standard_Deviational_Ellipses in the C:\student\Zebra_Mussels\Zebra_Mussels geodatabase.

8. Keep the default Ellipse Size setting of 1_STANDARD_DEVIATION.



Note: When the underlying spatial pattern of features is concentrated in the center with fewer features toward the periphery (a spatial normal distribution), setting the ellipse size to 1_STANDARD_DEVIATION results in an ellipse that contains approximately 68 percent of the features. Two standard deviations will contain approximately 95 percent of the features, and three standard deviations will contain approximately 99 percent of the features.

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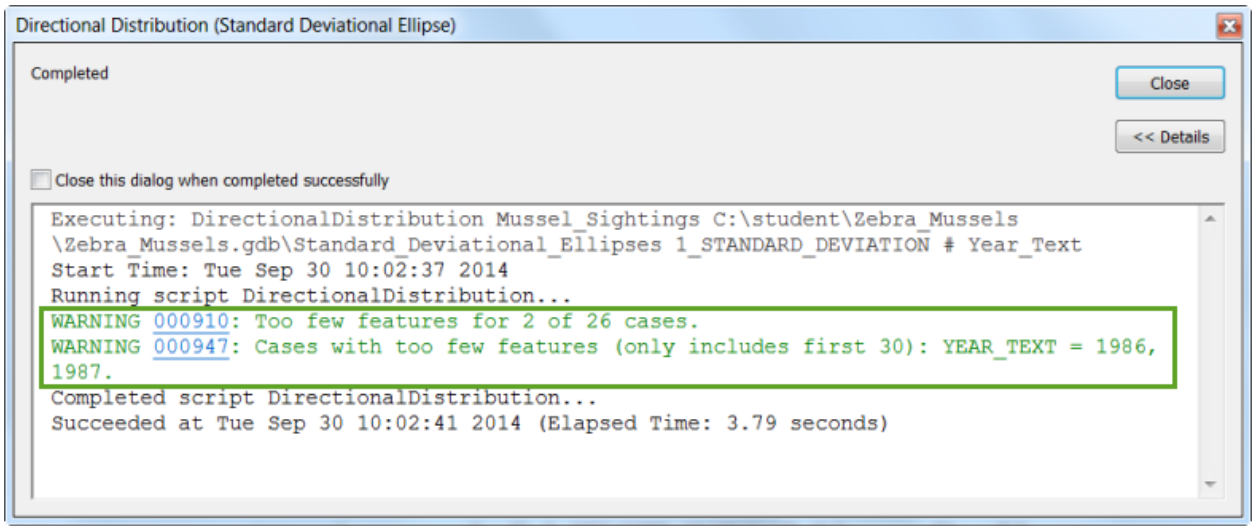
You'll use one standard deviation to create ellipses around the most centralized sightings to see how the core areas of concentration have spread over time.

9. Set the Case Field to Year_Text.

Note that the case field can be of an integer, date, or string type. You created the Year_Text field so that you could use the option Match to symbols in a style, as presented in Lesson 3. Using the Year_Text field in this tool will create a separate ellipse for each year.

Tip: The case field you specify will be added to the attribute table of the output ellipse feature class.

10. Click OK to run the tool.



See the results dialog box and note that the years 1986 and 1987 have too few features to create an ellipse; however, ellipses were created for the other years.

11. Close the results dialog box.

The ellipses have been added to the table of contents and the map display.

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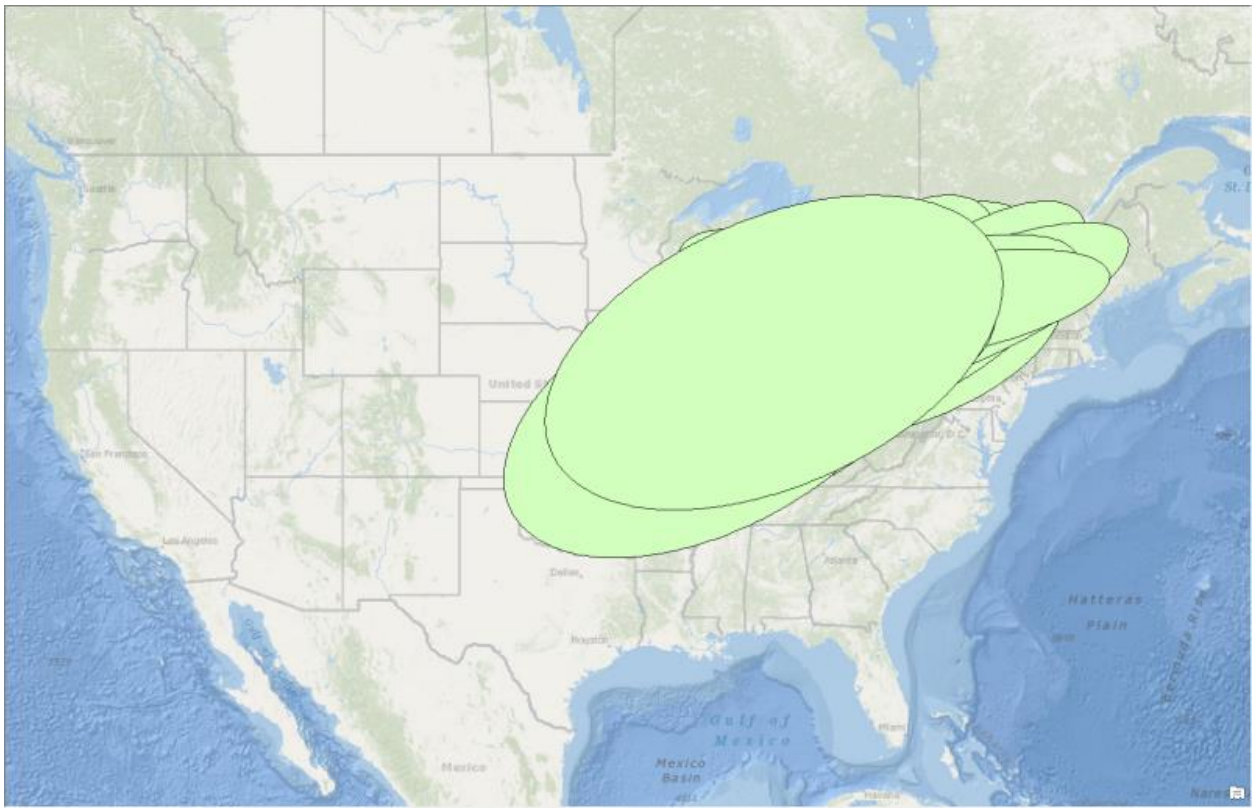
12. Turn off all but the Standard_Deviational_Ellipses and the Basemap layers.



This map is largely uninformative because the ellipses for the latest time periods obscure those for earlier time periods. You'll change the symbology to improve the display.

13. Save the map.

Step 2: Change the symbology of the ellipses

You'll symbolize the ellipses using an outline that's the same color as the points for the Zebra Mussel Sightings layer. You'll do this by using the option Match symbols in a style. But first, you need to create a field that contains the same names as the symbols.

1. To see the symbols you'll be using, open Style Manager and view the Fill Symbols in the Zebra Mussels style.

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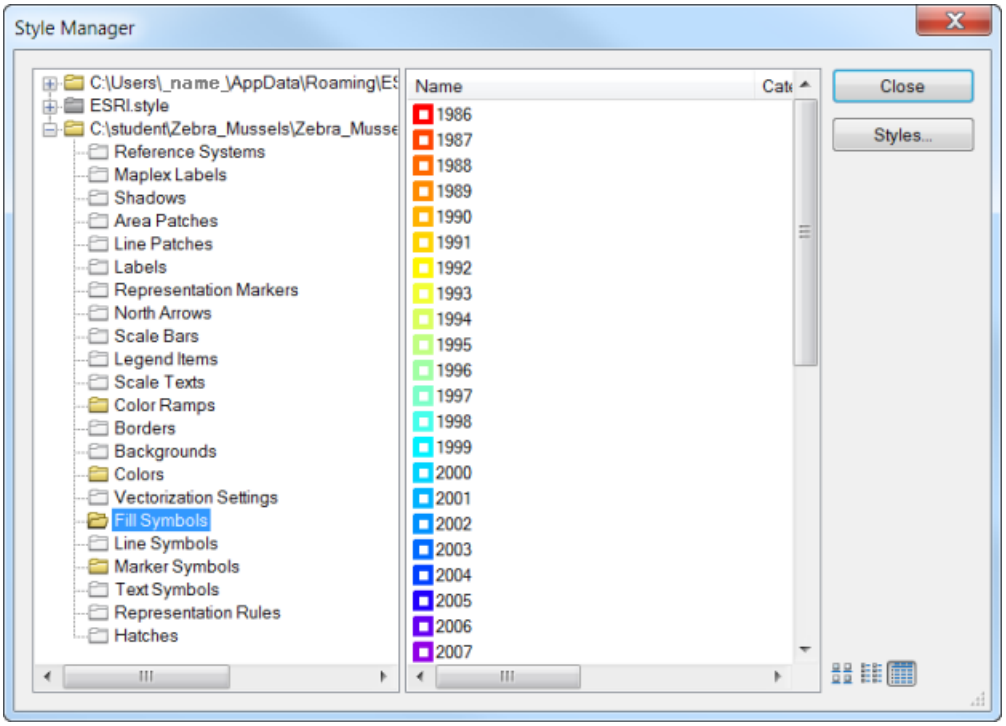

The names of these symbols are the same as the year. Because you used Year_Text as the case field when you created the Standard_Deviational_Ellipses layer, that field will be added to the attribute table of the ellipses. You'll use that field to match to the symbols in the style.

2. Close Style Manager.

3. Open the layer properties for the Standard_Deviational_Ellipses layer.

4. On the Symbology tab, match the symbols by setting the Value Field to Year_Text.

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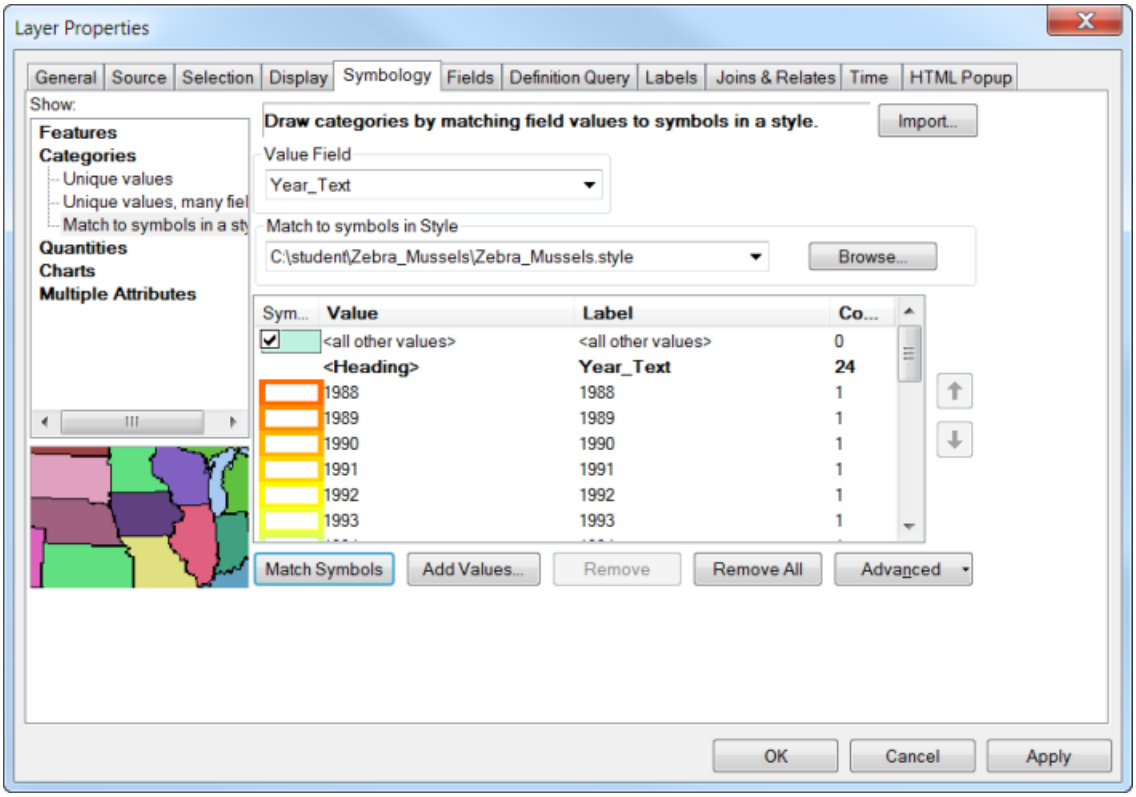

Note: The instructions for matching to symbols in a style were presented in Lesson 3.

5. Check the check box next to <all other values> to turn off the display for these features.

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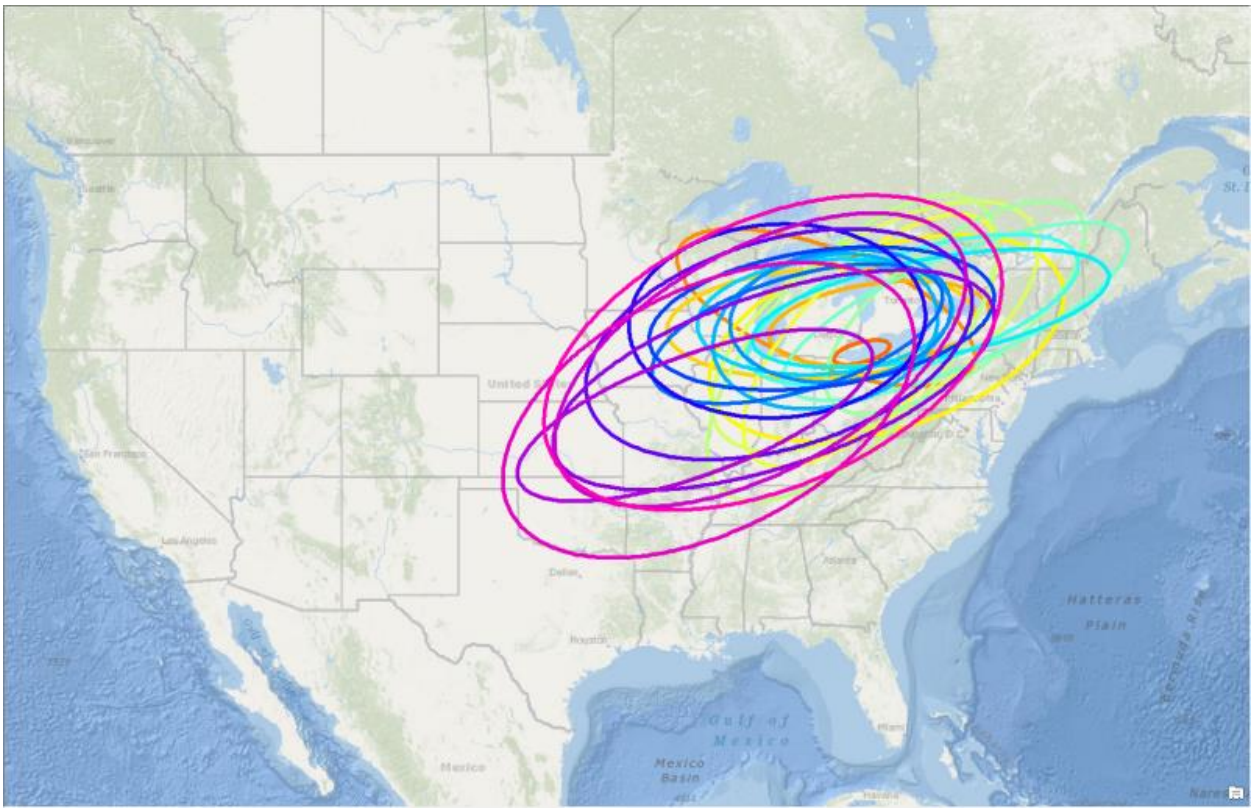
6. Click OK to see the map.



On this map, you can distinguish the ellipses for each of the years, though they will be easier to compare when you display them over time. You'll do that in step 5 of this lesson. The most important things to note about the ellipses are their shape, size, and center.

The shape indicates whether there's a directional trend. The more elongated the oval, the stronger the trend. The ovals on this map indicate that there's a directional trend, primarily toward the northeast and southwest.

The size of the ellipse indicates the extent of the distribution and encompasses the percentage of features specified by the Ellipse Size parameter in the Direction Distribution tool. On this map, the ellipses encompass 68 percent of the sightings for each year. Ellipses for the earlier time periods are smaller; for later time periods, larger ellipses were generated.

The center of the ellipse is the geographic center (or the center of concentration) for the set of features specified—68 percent of the sightings for each year on this map. You can

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infer this from the shape of the ellipse, but to see the sightings more clearly on the map, you can also create these points. In the next step, you'll create the mean center points so that they can be displayed along with the ellipses when you examine the change over time.

7. Save the map.

Step 3: Analyze the central tendency

For this step, you'll use the Mean Center tool, which will analyze the central tendency in the zebra mussel sightings for each year. The result will be point features that represent the geographic center of concentration. The point features will also coincide with the center of the ellipses.

1. In the Measuring Geographic Distributions toolset, open the Mean Center tool.

2. Set the Input Feature Class to Zebra Mussel Sightings.

3. Set the Output Feature Class to Mean_Center_Points in the C:\student\Zebra_Mussels\Zebra_Mussels geodatabase.

4. Set the Case Field to Year_Text.

5. Click OK.

6. Close the results dialog box.

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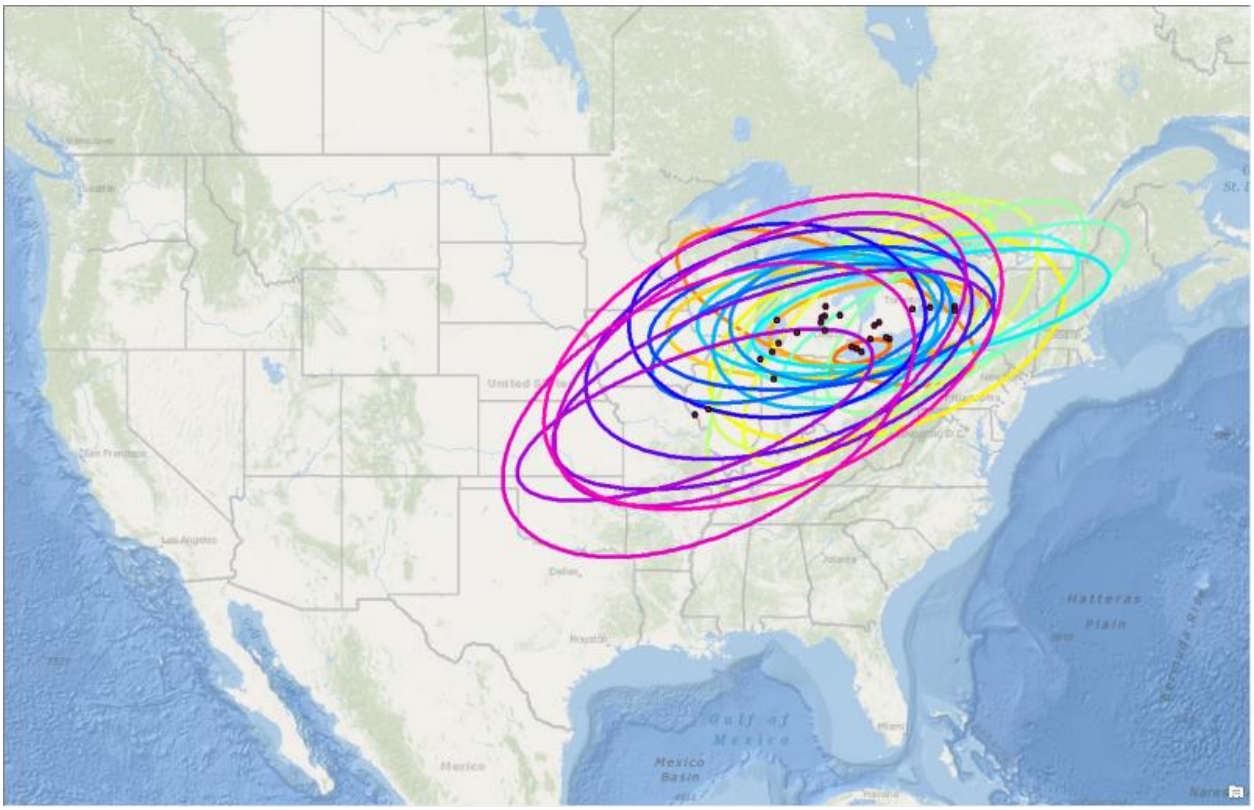

The mean center points will be added to the map.

On this map, you can see that most of the points are located in or near the Great Lakes, indicating that throughout time, the center of concentration has continued to be near the location where the mussels were first introduced.

Because it's difficult to tell which points are associated with which years, you'll symbolize the points so that they are the same as the Zebra Mussel Sightings layer.

7. Save the map.

Step 4: Change the symbology of the points

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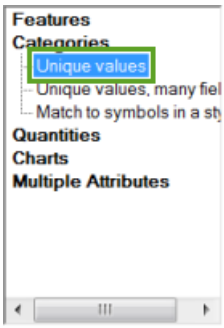
You'll display the mean center points using symbology that is similar to the Zebra Mussel Sightings layer, but the mean center points will be larger and distinguishable by a dot in the center of the symbol.

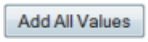
1. Open the layer properties for the Mean_Center_Points layer.

2. On the Symbology tab, click Categories > Unique values.



3. Set the Value Field to Year_Text.

4. Click Add All Values.



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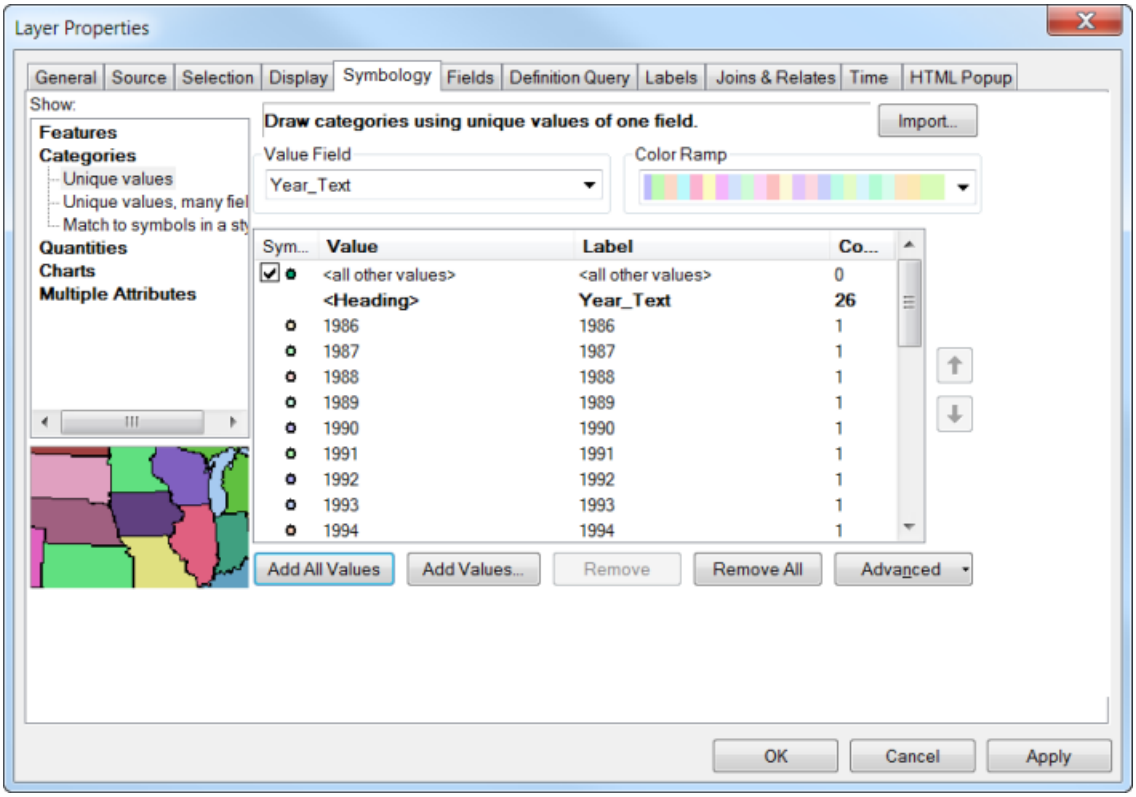
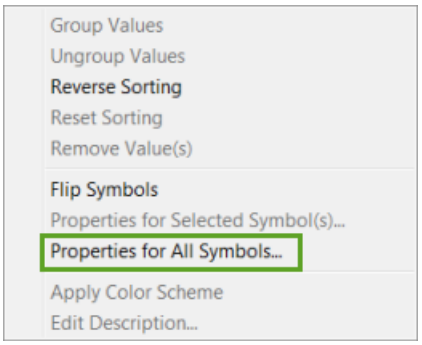


You'll change the default symbology to a circle symbol with a dot in the center. Then you'll change the colors of the symbols to match the ellipses.

5. Right-click next to <all other values> and click Properties for All Symbols.



6. Scroll down and select the Circle 3 symbol in the ESRI style.

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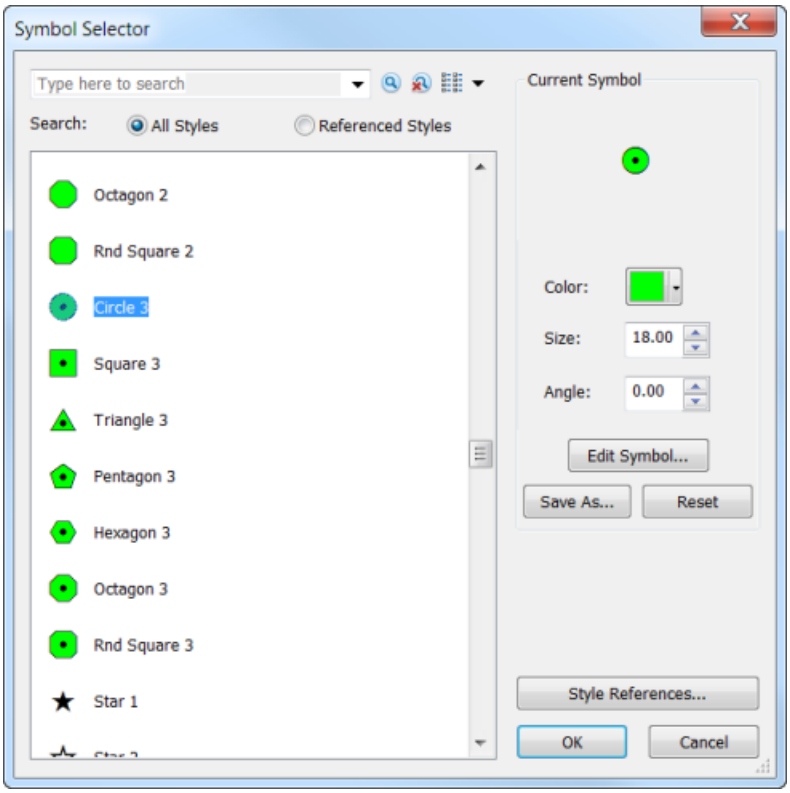
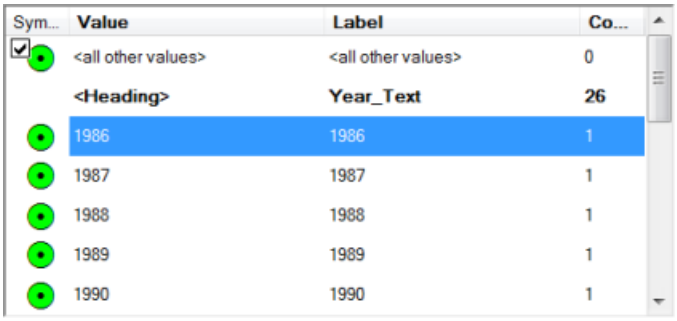


Note that the symbol size is 18 points so that the symbols will be visually prominent.

7. Click OK.

8. Click the heading for 1986 so that it is highlighted.



Sym...	Value	Label	Co...
	<all other values>	<all other values>	0
	<Heading>	**Year_Text**	**26**
	1986	1986	1
	1987	1987	1
	1988	1988	1
	1989	1989	1
	1990	1990	1

9. Scroll to the bottom and, while holding down the Shift key, click the heading for 2011.

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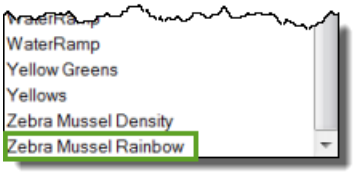
All the symbols will now be selected. You'll change their color using a color ramp in the Zebra Mussels style that matches the colors used for the ellipses.

10. Right-click the drop-down arrow next to the color ramp to toggle off Graphic View.

11. Click the down arrow and scroll to the bottom to select the Zebra Mussel Rainbow color ramp.



The colors for the point symbols will be updated with the colors in the color ramp.

12. Check the check box next to <all other values> to turn off the display for these features.

13. Click OK.

14. Click OK on the Layer Properties dialog box.

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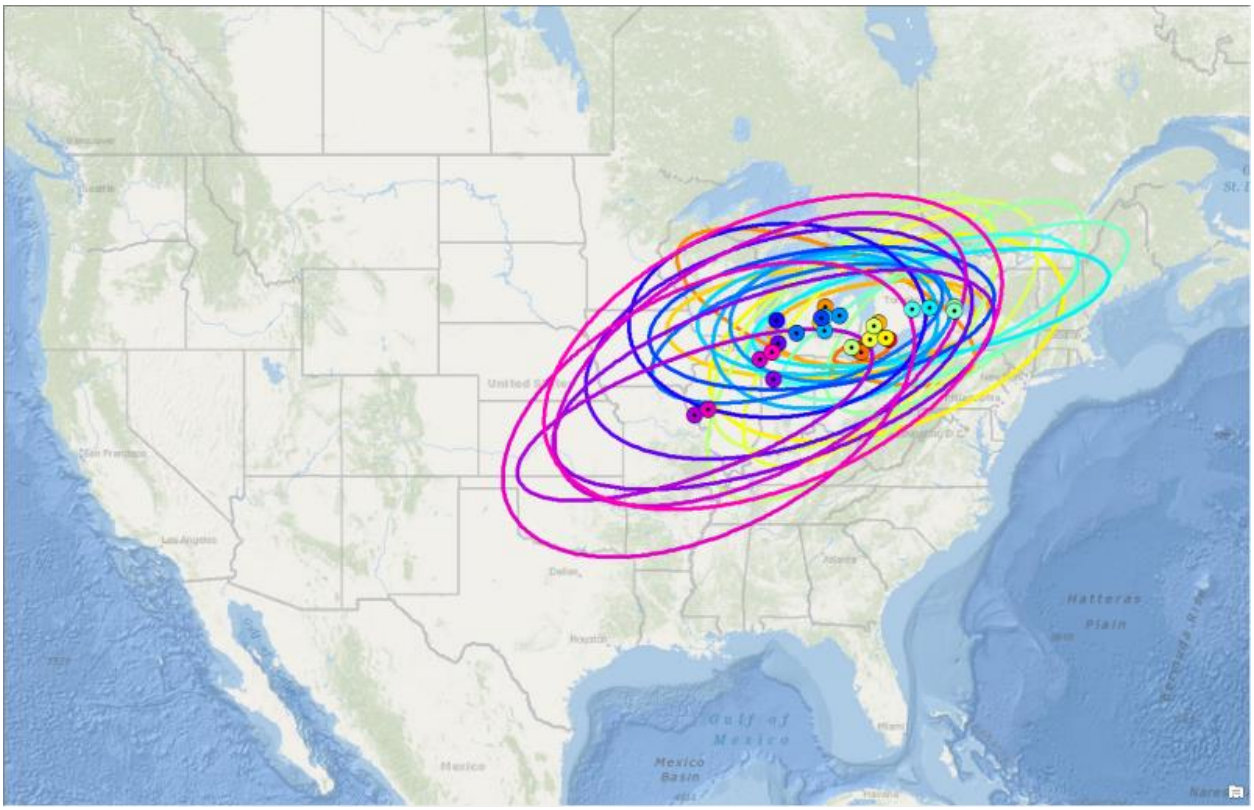

The mean center points can now be associated with the standard deviational ellipses by their color.

15. Save the map.

Step 5: Display the ellipses and points over time

In this step, you'll set the time properties on the Mean_Center_Points, Zebra Mussel Sightings, and Standard_Deviational_Ellipses layers. Then you'll use the Time Slider window to display the layers over time.

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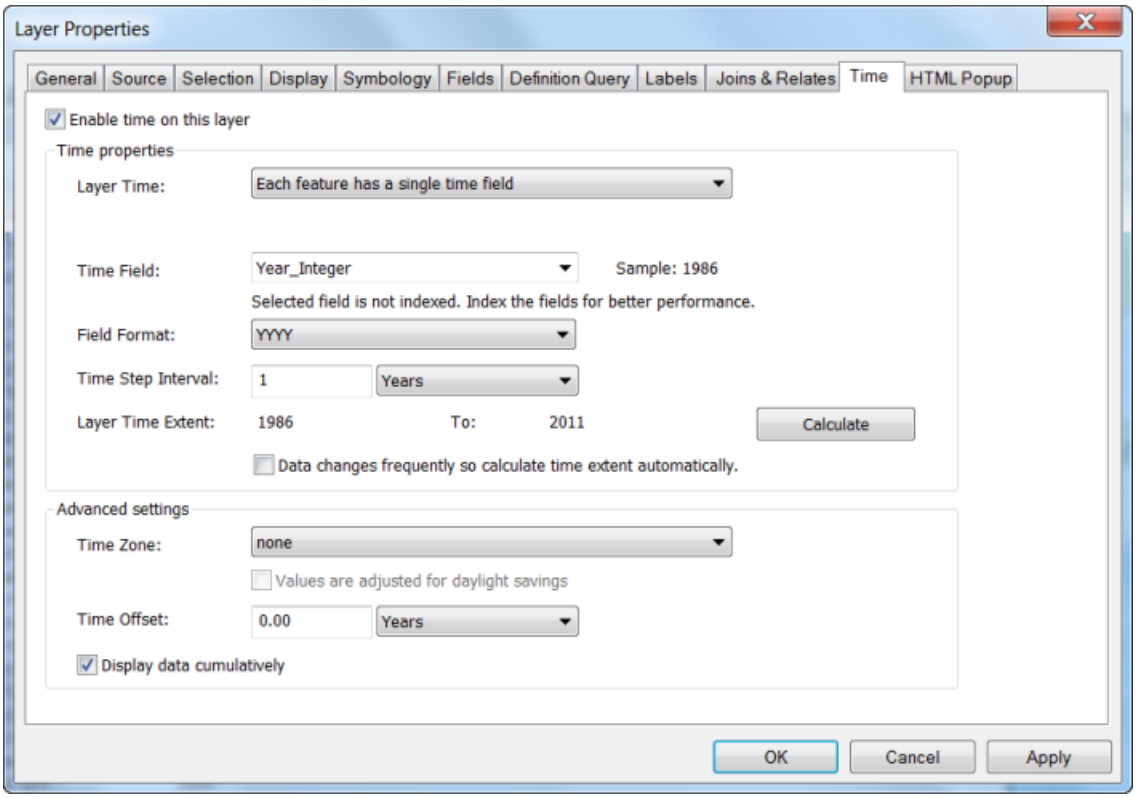
1. Set the Time properties for the Mean_Center_Points layer as shown below:

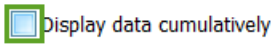


2. Do the same for the Standard_Deviational_Ellipses layer.

3. Turn on the Zebra Mussel Sightings layer.

4. Open the layer properties for the Zebra Mussel Sightings layer.

5. On the Time tab, uncheck the Display data cumulatively check box.



6. Click OK.

7. Open the Time Slider window and click the first button in the upper left corner to enable time on the map.

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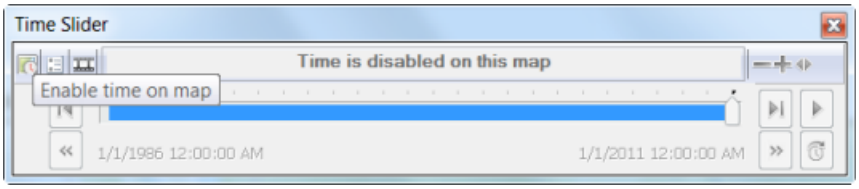
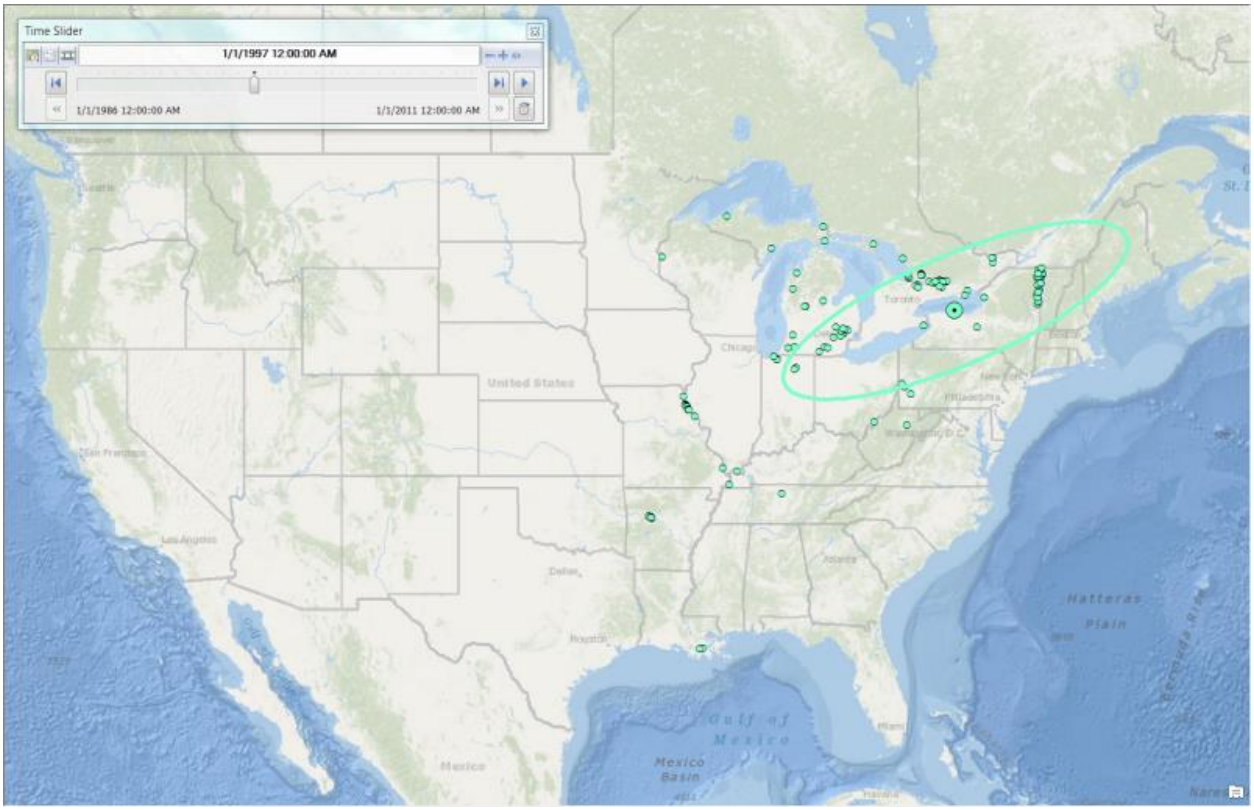


8. Use the Time Slider window to explore how the features change over time.



On these maps, you can easily distinguish the mean center points from the zebra mussel sightings by their color. You can also see that the ellipses encompass the majority of the sightings. However, it is difficult to compare year to year because you have to rely on memory to recall the previous displays.

You can remedy that by displaying the ellipses for the previous time periods. To ensure that the focus remains on the current time period, you can use a "ghosted," or grayed-out, display of the ellipses for previous time periods.

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Step 6: Create a ghosted copy of the ellipses

In this step, you'll copy the Standard_Deviational_Ellipses layer and change its symbology. Then you'll set the time properties on the layer so that the data is displayed cumulatively.

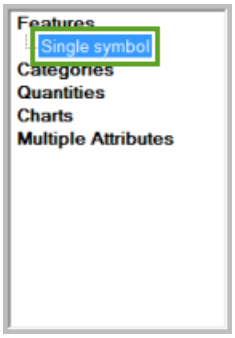
1. Right-click the Standard_Deviational_Ellipses layer and click Copy.

2. Right-click the data frame name (Layers) and click Paste Layer(s).

3. Move the copied layer under the original layer.

4. Change the copied layer name to **Ghosted Ellipses**.

5. Open the layer properties, and on the Symbology tab, in the Show pane, click Features and choose Single symbol.



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6. Click the symbol.

7. On the Symbol Selector dialog box, click Fill Color.

8. Click No Color.

9. Change the Outline Width to 2.25 points.

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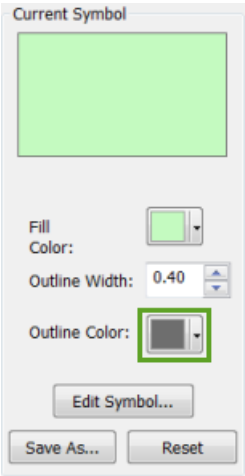
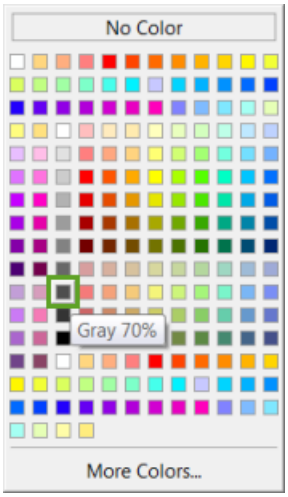
10. Click Outline Color.



11. Click Gray 70%.



12. Click OK.

13. On the Display tab, set the Transparent value to 70 percent.

14. Click OK.

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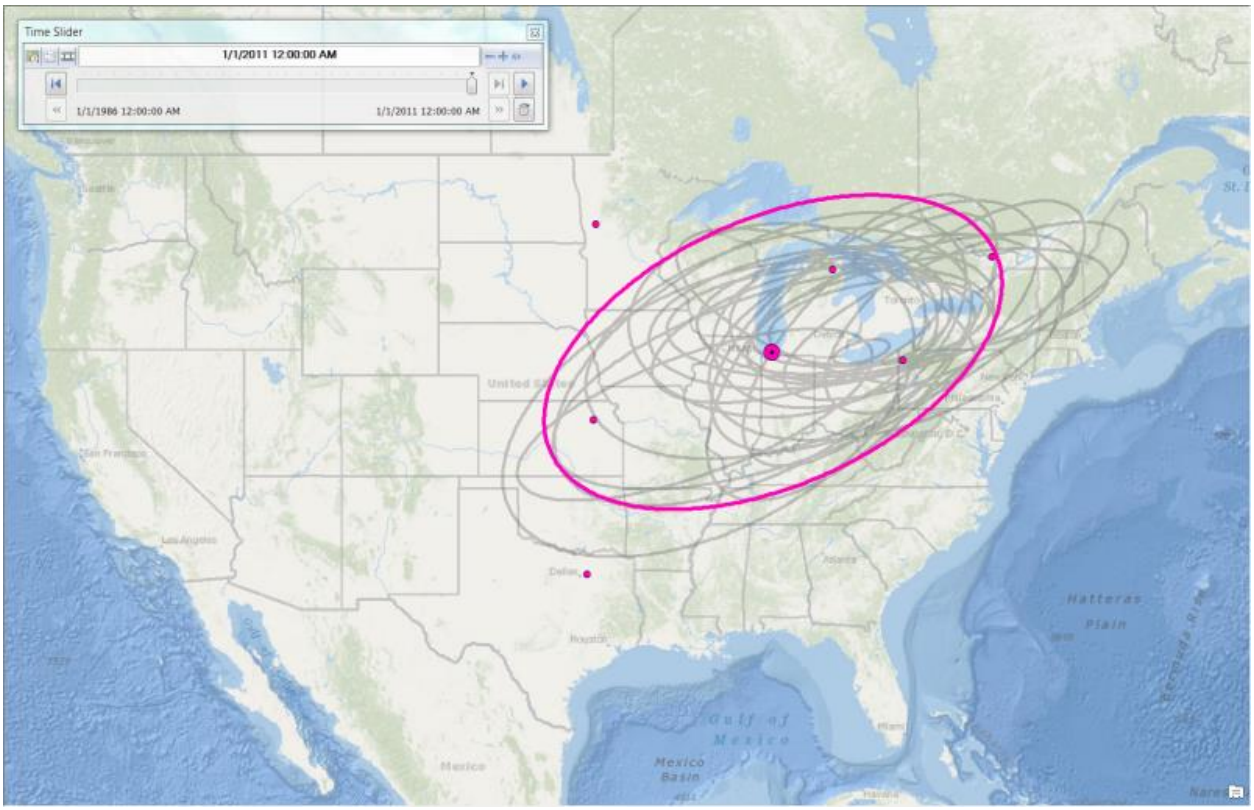

Interpret: Displaying the data over time, you can see that, except for 1989, when there were sightings in the lower Great Lakes and in western Lake Superior, all ellipses trend southwest to northeast. This indicates that the zebra mussels moved from the Great Lakes to the northeast (primarily down the Saint Lawrence River) and the southwest (down the Ohio, Illinois, and other rivers) into the Mississippi and other rivers and lakes.

For the early time periods, the size of the ellipses is smaller. For later time periods, larger ellipses were generated. This is an indication that the spatial extent of zebra mussels is growing over time (i.e., their range is increasing).

15. Move the Time Slider control to 1988, the first year for which an ellipse was generated.

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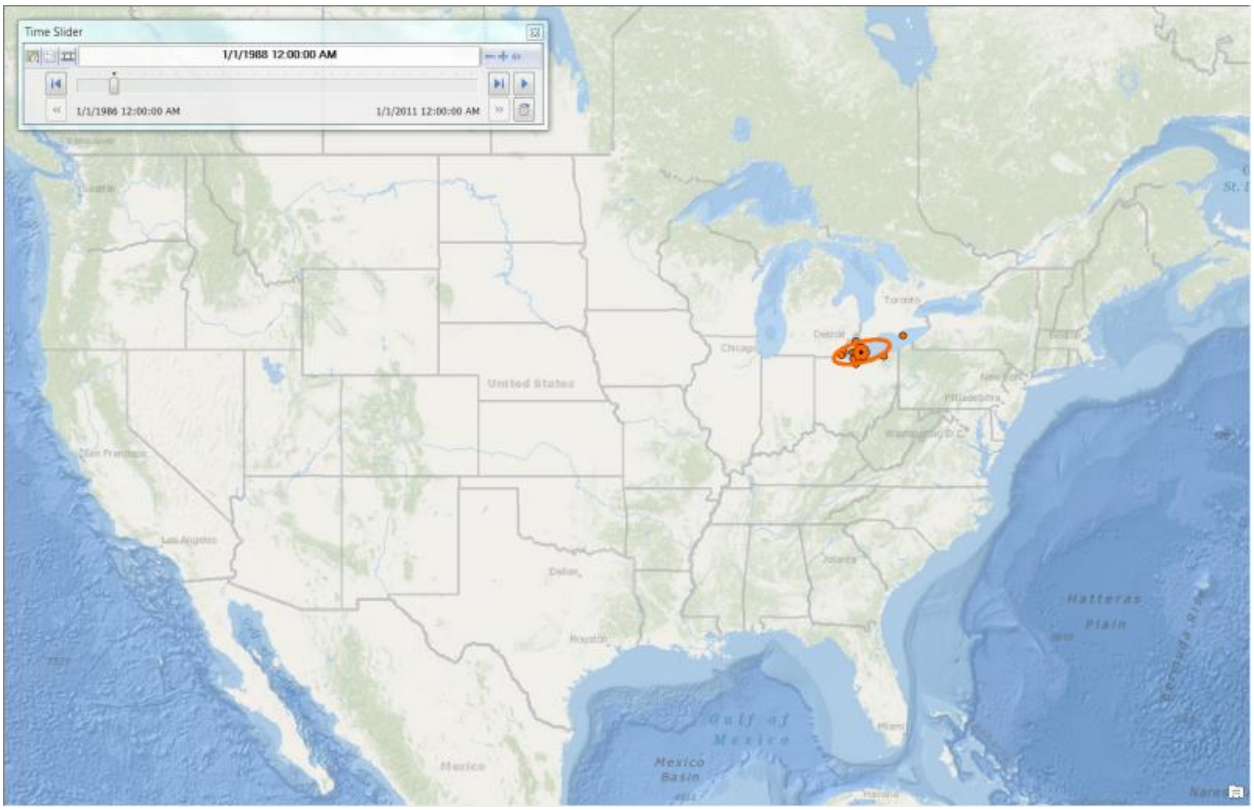

Interpret: In 1988, the zebra mussels were concentrated in western Lake Erie, having spread from the southwest where they were originally sighted in 1986. The northeast to southwest trend of spreading that is evident in this year will be repeated in most other years as well.

16. Look at the map for 1989.

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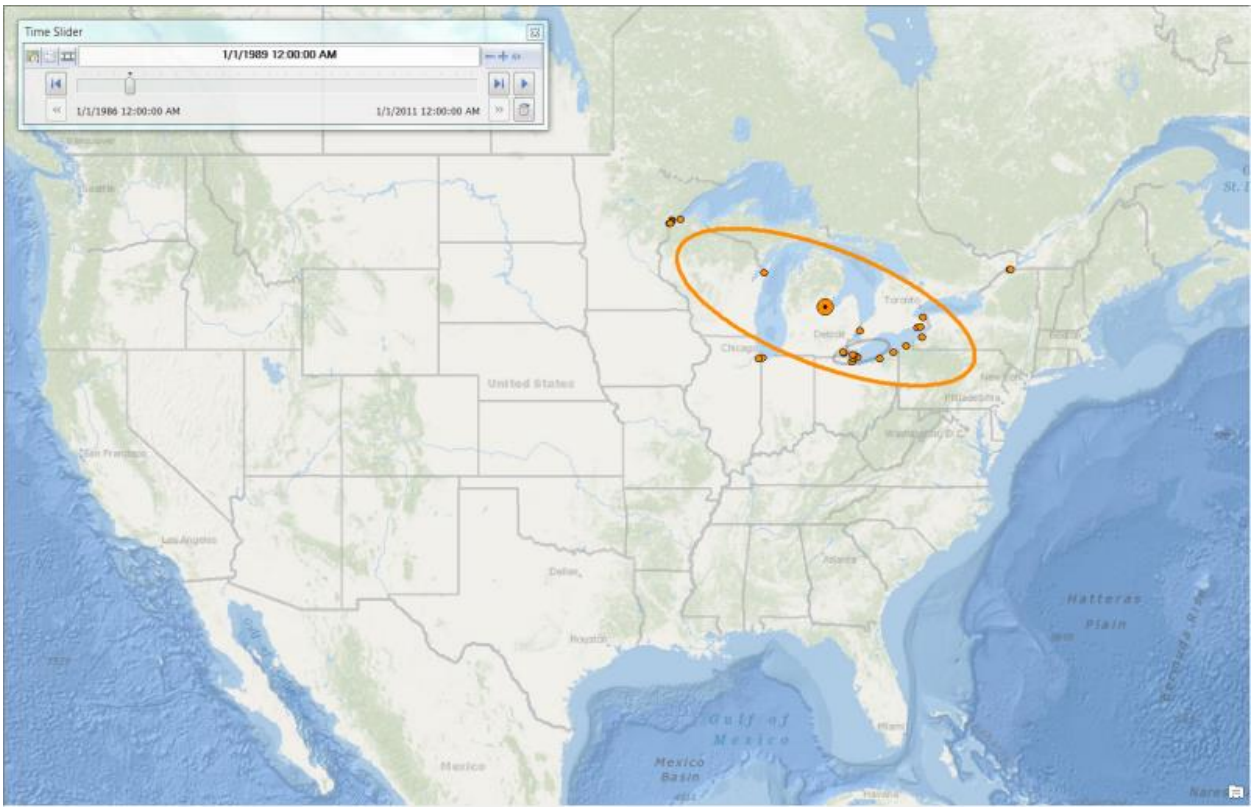

Interpret: In 1989, the zebra mussels had spread east through Lake Erie and into Lake Huron. They were also sighted in western Lake Ontario near Duluth. This is the only year in which the directional trend of spreading was northwest to southeast.

17. Look at the maps for 1990 and 1991.

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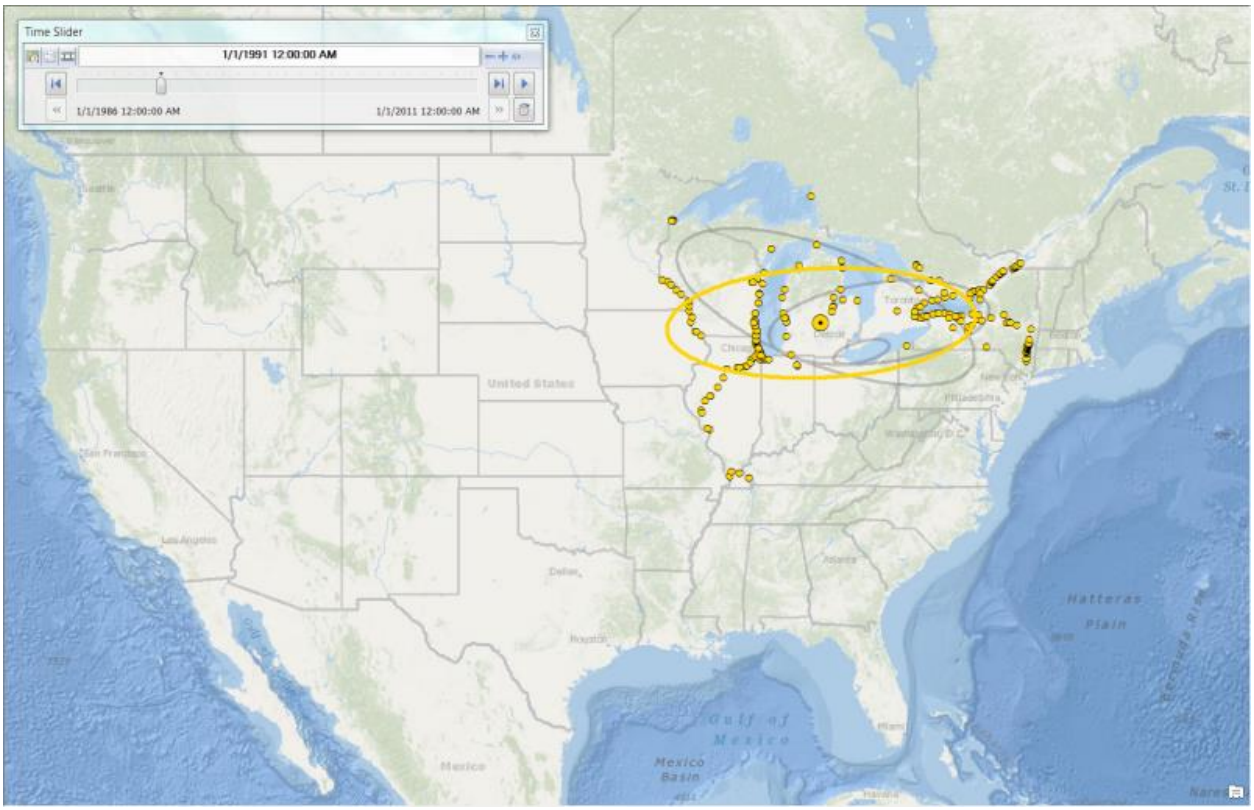

Interpret: In these years, the zebra mussels spread throughout the Great Lakes and moved into a number of river systems. Also, the spread was primarily in the easterly and westerly directions.

18. Look at the maps for 1992 to 1999.

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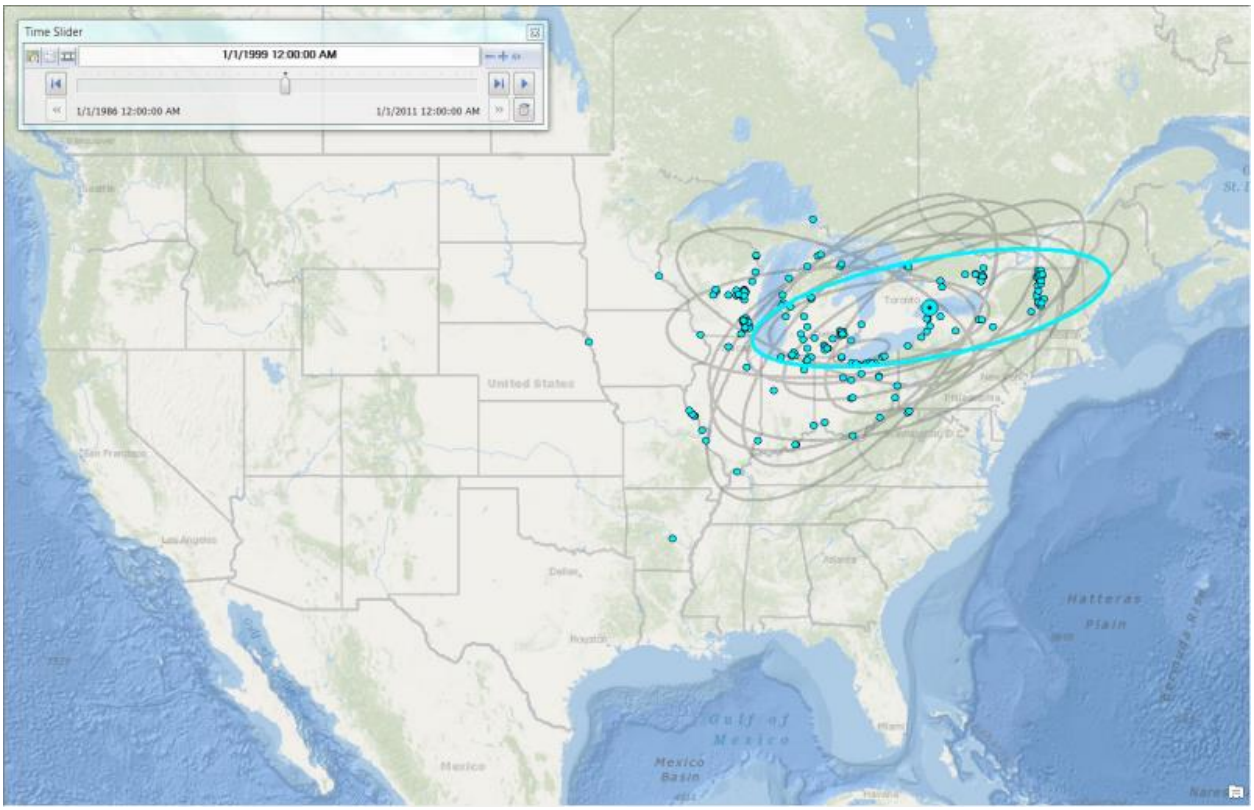

Interpret: From 1992 to 1999, the directional trend was northeast to southwest, and the extent of sightings grew. For these years, the ellipses are long and narrow, indicating that the spread was primarily toward the northeast (into New England and Lake Champlain) and the southwest (down many major waterways, even as far as the mouth of the Mississippi River.

19. Look at the maps for 2000 to 2002.

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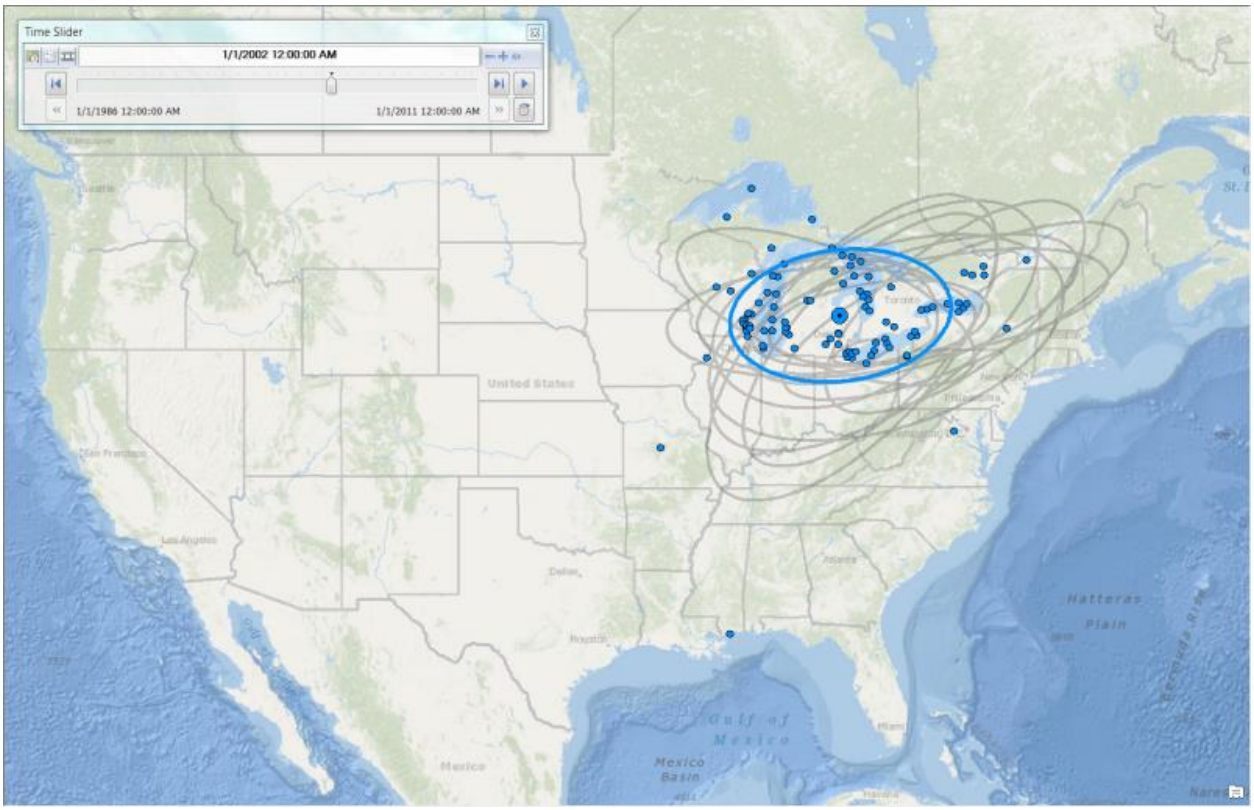

Interpret: From 2000 to 2002, the concentration was primarily in the Great Lakes area. The roundness of the ellipses indicates that there was not a strong directional trend in these years.

20. Look at the maps for 2003 and 2004.

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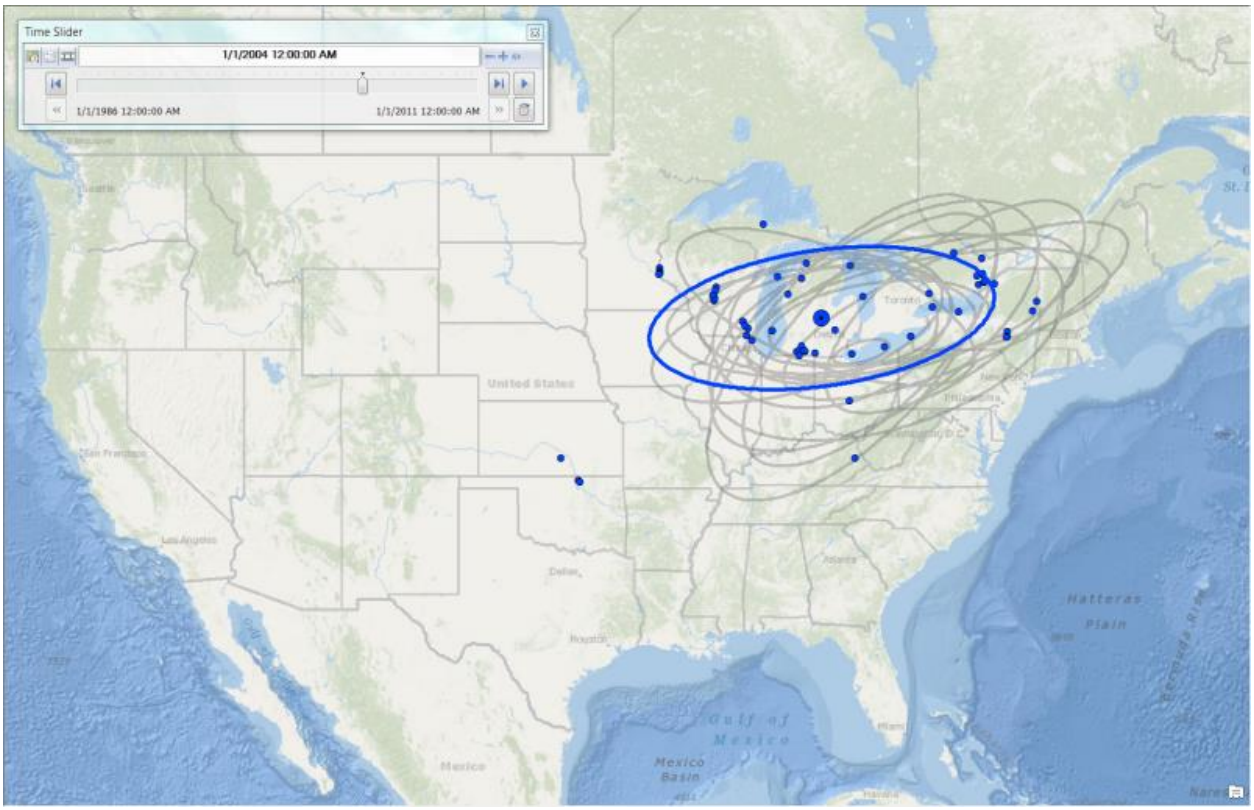

Interpret: The pattern of spreading in these years is similar to the pattern for 1992 to 1999, with a directional trend going from northeast to southwest.

21. Look at the map for 2005.

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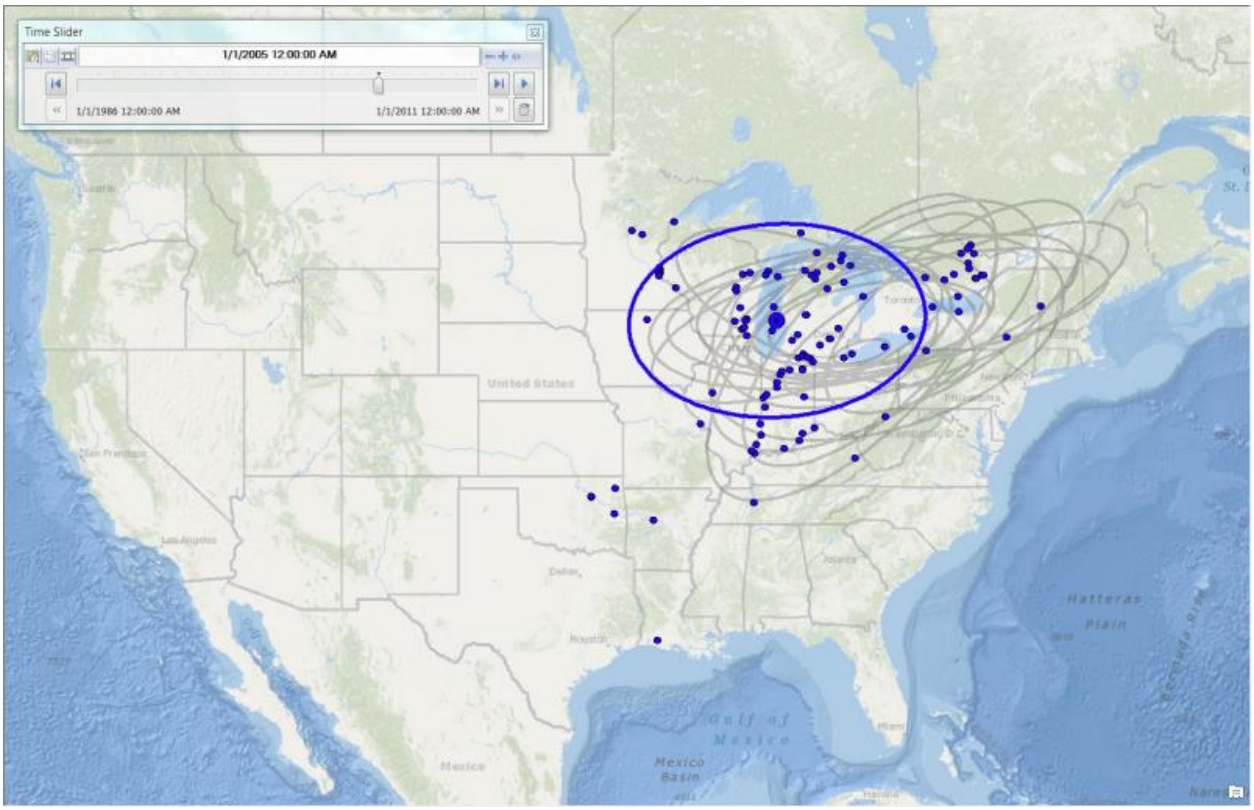

Interpret: The ellipse for 2005 is similar to those for 2000 to 2002, indicating the lack of a strong directional trend; however, the ellipse for 2005 is larger, indicating that the extent of the zebra mussel has grown.

22. Look at the maps for the remaining years.

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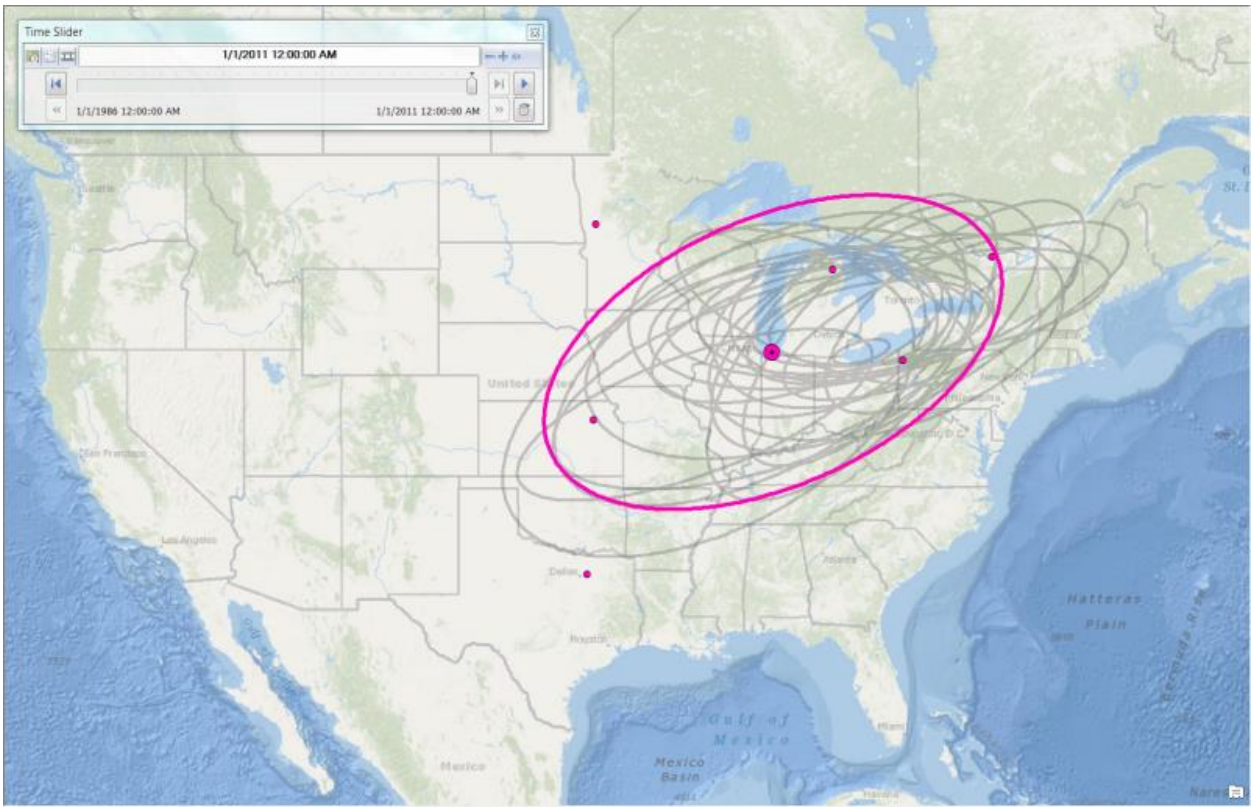

Interpret: From 2006 to 2011, the ellipses continued to be oriented northeast to southwest, although they were much larger for these years. This is an indication that the extent of the zebra mussels continued to grow. The mean center shifted west, as far as western Indiana in 2008 and 2010, indicating that spread of zebra mussels in these years was primarily to the southwest rather than the northeast.

23. Save the map.

You've now answered the last question, are the zebra mussels spreading? Having addressed all the questions you set out to answer, you'll evaluate the results of the analyses you performed and the maps you made. This is the topic of the next lesson.

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Lesson 6: Review the spatial questions and evaluate the results

In this lesson:

- Review the spatial questions.
- Evaluate the results.

In the previous lessons, you performed a number of analyses—some visual, others statistical—to address the spatial questions you set out to answer. This brings you to the next step—examining and interpreting the results. You'll evaluate whether the results provide a satisfactory explanation or answer to the spatial questions you asked.

Step 1: Review the spatial questions

Start by reviewing the questions you set out to answer:

1. Where are the zebra mussels?
2. Where did the zebra mussels come from?
3. Are there more zebra mussels in some areas than in others?
4. Are the zebra mussels spreading?

Did you find the answers?

Step 2: Evaluate the results

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Think back to the various maps you made and analyses you performed to determine whether your findings make sense and your questions have been answered. Your findings are noted in the Interpret sections of each lesson and summarized here.

Question 1: Where are the zebra mussels?

The sightings are concentrated in the Great Lakes area, but zebra mussels have also been found throughout the Midwest from Appalachia to Colorado. Sightings have also been recorded in the Southwest, though there are fewer of them.

Zebra mussels have been reported in 9 of the 10 longest rivers in the conterminous United States—the Missouri, Mississippi, Saint Lawrence, Arkansas, Atchafalaya, Ohio, and Red Rivers east of the Continental Divide and the Colorado River in the West. Only the Rio Grande has escaped invasion to this point.

They have also invaded some smaller rivers, such as the Wabash in Indiana and the Cumberland in Tennessee, and lakes, like the Finger Lakes in New York, that are connected to these larger river systems.

There have been sightings in most US states and in two Canadian provinces. There have not yet been any sightings in the Northwest (Washington, Oregon, Idaho, Montana, Wyoming, and South Dakota), nor have zebra mussels been sighted in the Southeast (North Carolina, South Carolina, Georgia, and Florida). A few other states along the Eastern Seaboard have also escaped invasion (Maine, New Hampshire, Rhode Island, New Jersey, and Delaware).

Of the 18 major hydrologic regions in the conterminous United States, 14 have been invaded by zebra mussels—only the Rio Grande (HUC 2-12), Lower Colorado (HUC 2-15), Great Basin (HUC 2-16), and Pacific Northwest (HUC 2-17) regions remain uninfected.

Question 2: Where did the zebra mussels come from?

Zebra mussels are hypothesized to have been introduced to North America in the ballast water of a ship that had traveled from Europe to the Great Lakes.

Although others have reported that zebra mussels were discovered in North America in 1988 in Lake St. Clair, those accounts are wrong. Zebra mussels were actually sighted two

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years earlier in a different lake altogether! They were first sighted in 1986 in Lake Erie—one sighting was in the east end of the lake, and the other was in the west.

By 1990, only four years after being introduced to North America, zebra mussels had been sighted in all the Great Lakes and were moving into the Saint Lawrence River.

By 1991, zebra mussels escaped the Great Lakes and found their way farther down the Saint Lawrence River and down the Mohawk to the Hudson River in New York. They also reached the Mississippi River via the Illinois River.

By 1992, zebra mussels had made their way to the mouth of the Saint Lawrence at Quebec. They had also been sighted in the waters of the Arkansas, Cumberland, Ohio, and Tennessee Rivers and were making their way down the Mississippi to the Gulf of Mexico.

Only eight years after their introduction to North America in the Great Lakes, zebra mussels had found their way to the sea via the Saint Lawrence, Hudson, and Mississippi Rivers. They were found in the water bodies in or adjacent to 16 US states (Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Mississippi, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Vermont, and West Virginia) and 2 Canadian provinces (Ontario and Quebec).

In 1999, they were found in the Missouri River between Iowa and Nebraska. In 2001, they were reported further downstream in the Missouri River in the state of Kansas. In 2003, they invaded Virginia as well as other water bodies of Nebraska. In 2008, they were in the upper reaches of the Arkansas River in Colorado. This same year, they were also sighted on the other side of the Continental Divide, at the headwaters of the Colorado River in Utah; they had also found their way to California. In 2009, they invaded Texas and Massachusetts. In 2010, they moved into North Dakota. By 2011, they had been sighted in 30 US states and still only 2 Canadian provinces.

Question 3: Are there more zebra mussels in some areas than in others?

Some of the highest-density areas are around the Great Lakes, where zebra mussels first invaded North America's freshwater systems. There are a couple of surprises though, such as the very high densities in Minneapolis and midstate Missouri, other high-density areas in Duluth, at the southern tip of Illinois, and at the mouth of the Mississippi River. The density of sightings in these areas was not apparent on the point symbol maps.

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By 1990, there was a high concentration of zebra mussel sightings in the west end of Lake Erie, but even more zebra mussels were sighted in the east end of the lake and the west end of Lake Ontario. There were also concentrated sightings in lower Lake Michigan.

A year later, the concentration of sightings in Lake Michigan was moving north. There was also a concentration of sightings in Lake Superior near Duluth and in the Hudson River of New York.

By 1992, the concentration of zebra mussel sightings in Lake Ontario spread down the Saint Lawrence River to its mouth. At this time, evidence of their spread can be seen along waterways in the linear pattern of some of the concentrations. Note the connected concentrations from Lake Erie to Lake Ontario to the mouth of the Saint Lawrence River in Montreal. Also, note the linear concentration along the Mississippi River in southeast Minnesota.

By 1995, zebra mussel sightings were also concentrated further downstream in the Mississippi River at the southern tip of Illinois and in the river's delta at the Gulf of Mexico. Lower concentrations are also evident in other rivers including the Hudson, Ohio, Tennessee, Arkansas, and Illinois Rivers, giving the impression that these river systems provided opportunities for zebra mussels to spread downstream.

By 1996, the highest concentrations were found in Lake Champlain, a pattern that was repeated in all remaining time periods. In 2007, a separate concentration was found in the Lake of the Ozarks in Missouri. Recall that zebra mussels can be transported to new waters on recreational boats, fishing gear, and other objects. Perhaps this is how zebra mussels first got into the waterways of the Ozarks.

Question 4: Are the zebra mussels spreading?

Except for 1989, when zebra mussels were in western Lake Superior, all standard deviational ellipses trended southwest to northeast. This indicates that the zebra mussels moved from the Great Lakes to the northeast (primarily down the Saint Lawrence River) as well as the southwest (down the Ohio, Illinois, and other rivers) into the Mississippi and other rivers and lakes.

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For the early time periods, the size of the ellipses is smaller. For later time periods, larger ellipses were generated. This is an indication that the spatial extent of zebra mussels is growing over time (i.e., their range is increasing).

The centers of concentration also changed over time, further indicating spread. From 1986 to 1995, the mean centers were located in or near Lake Erie, indicating that the highest concentration of sightings remained in the lower Great Lakes. From 1996 to 1999, the mean center shifted east to locations around Lake Ontario. In these years, zebra mussels moved down the Saint Lawrence River toward its mouth at Quebec. They also moved into Lake Champlain, where large numbers of sightings were reported. From 2000 to 2004, the mean centers were in Michigan, indicating that zebra mussels were concentrated throughout the Great Lakes. From 2005 to 2011, the mean centers shifted west, even as far as western Indiana in 2008 and 2010, indicating that the highest concentrations of zebra mussels were spreading west.

Now you have satisfactory answers to your questions, so you can share your findings with others.

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Lesson 7: Add a timeline to the map (optional)

In this lesson:

- Create the features for the timeline.
- Symbolize the timeline.
- Label the timeline.
- Create a ghosted copy of the timeline.
- Display the timeline over time.

Although you can use the information in the Time Slider window to track the progression of the distributions through time, a timeline allows you to do this more efficiently because it's part of the map display, and the features in the timeline are visually associated with those on the map. Using the same symbology for the timeline as you did for the zebra mussel sightings allows the timeline to also serve as a legend for the map. Additionally, the display of the features in the timeline can be similar to the features on the map, thereby creating a visual relationship between the two types of features. For example, on the map, zebra mussels were introduced in the north and then they moved south; on the timeline, the first year is at the top and the last is at the bottom.

In ArcMap, the only way to show temporal change is to enable time on a layer of geographic features, so you'll need to create the timeline as a set of geographic features. Then you'll enable time on the layer with those features and use the Time Slider window to visualize both the timeline and map over time.

In this lesson, you'll create the timeline as a set of point features generated with the Create Fishnet tool. You'll change the symbology of the points so that they look like the features in the Zebra Mussel Sightings layer. You'll label the timeline points with the year. Then you'll display the points over a ghosted copy of the timeline. The ghosted timeline will not change over time, so it will provide information about the entire time extent to set the context for the time-enabled timeline.

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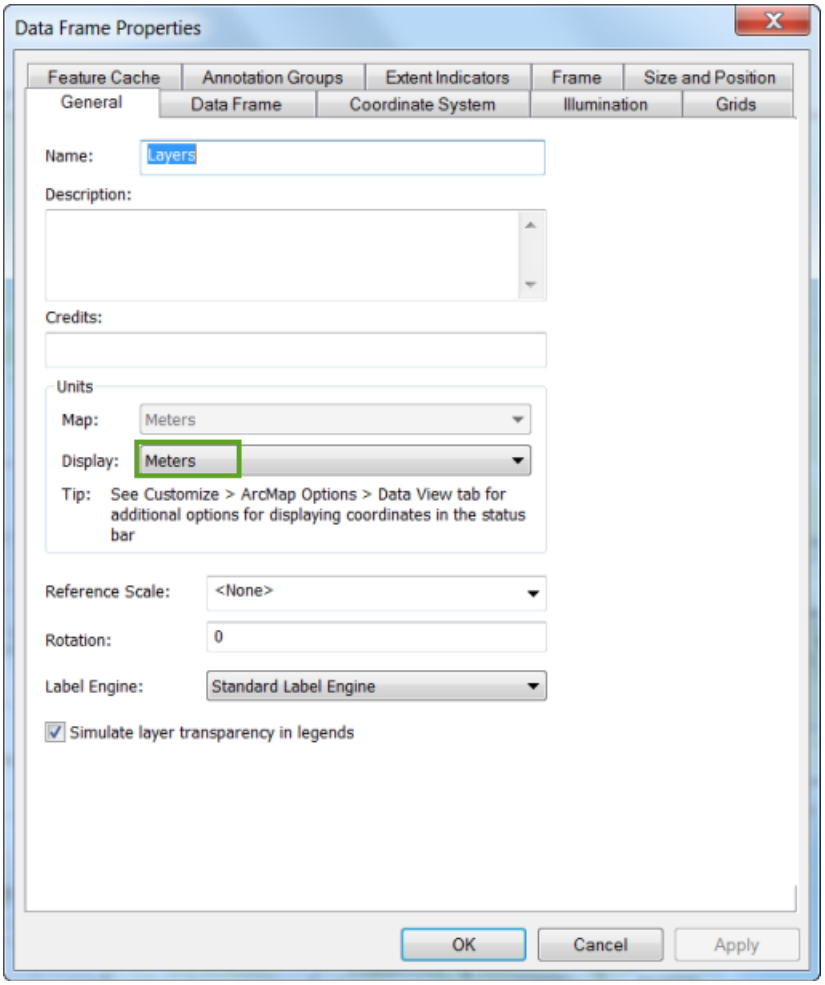
Step 1: Create the features for the timeline

First, you'll gather some information about the measurement units on the map and the coordinates of the desired location of the timeline. You'll use that information in the Create Fishnet tool.

1. Right-click the data frame name and click Properties.

2. On the General tab, note that Display units are meters.



3. Click Cancel to close the Data Frame Properties dialog box.

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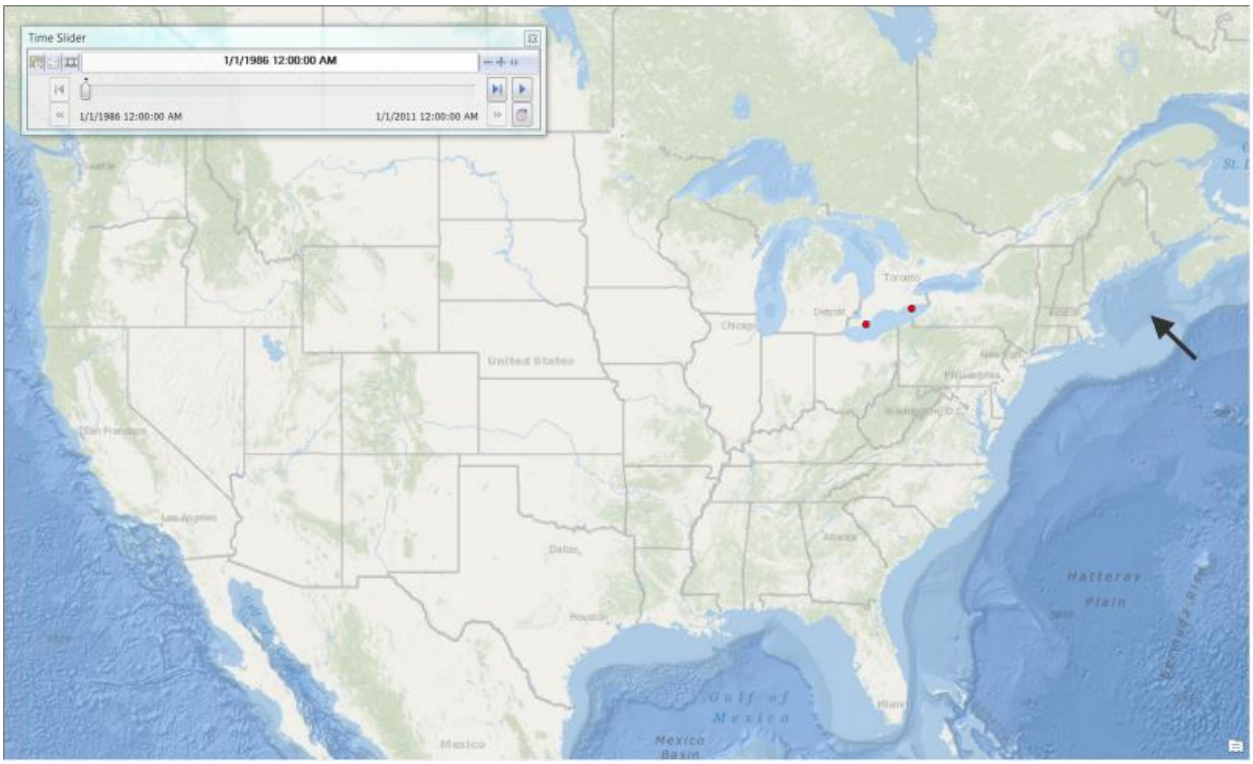
4. Move the pointer over a location in the Atlantic Ocean off the coast of Massachusetts.



5. Note from the display at the bottom right of the ArcMap window that the coordinates are around -7500000, 5200000.

-7503322.735 5208212.43 Meters

6. Move the pointer directly south to a location off the coast of Miami.

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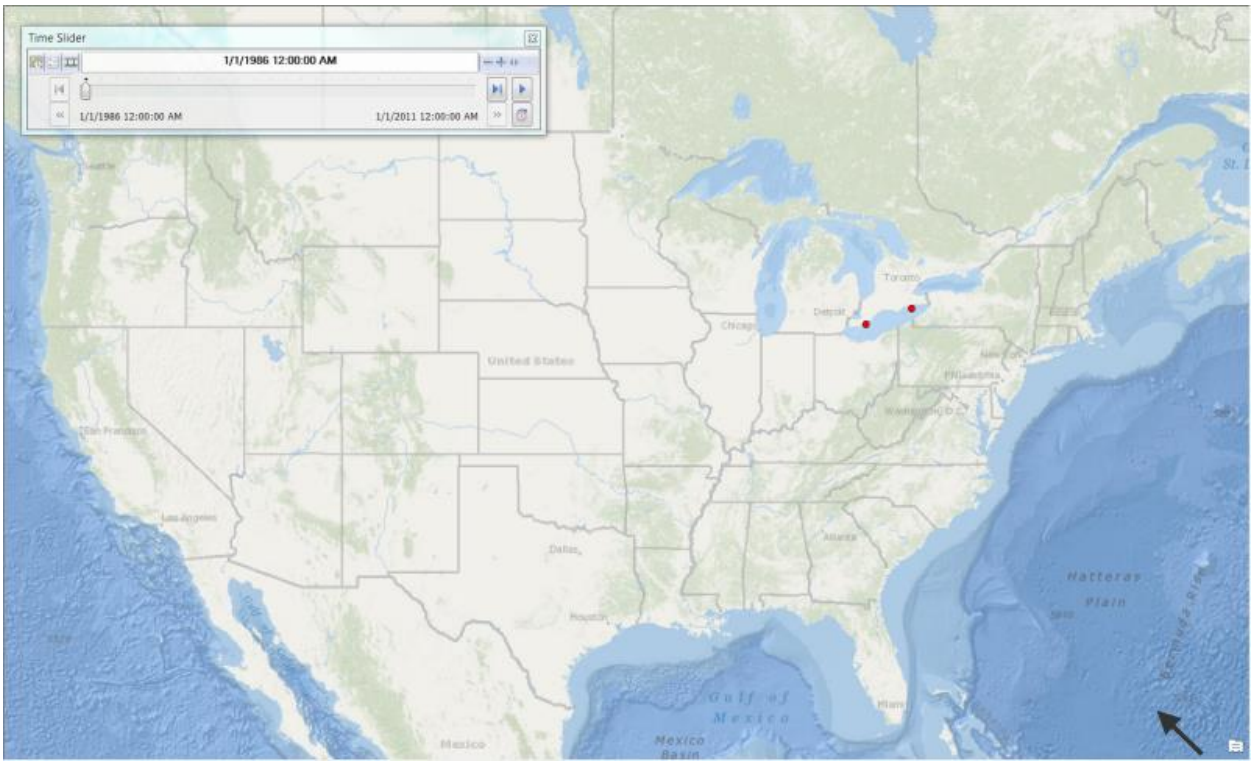
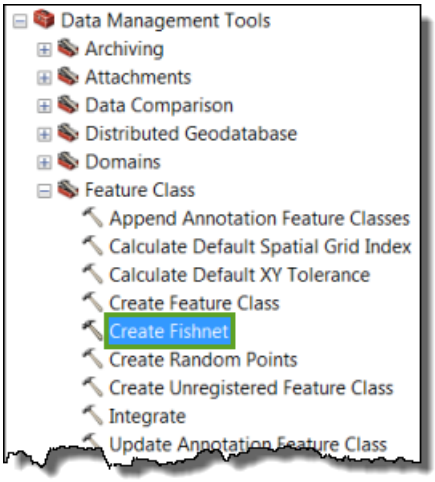


Note that this location has coordinates of about -750000, 300000.

7. Open the ArcToolbox window.

8. Expand the Data Management Tools toolbox and, in the Feature Class toolset, double-click the Create Fishnet tool.



The Create Fishnet tool will open.

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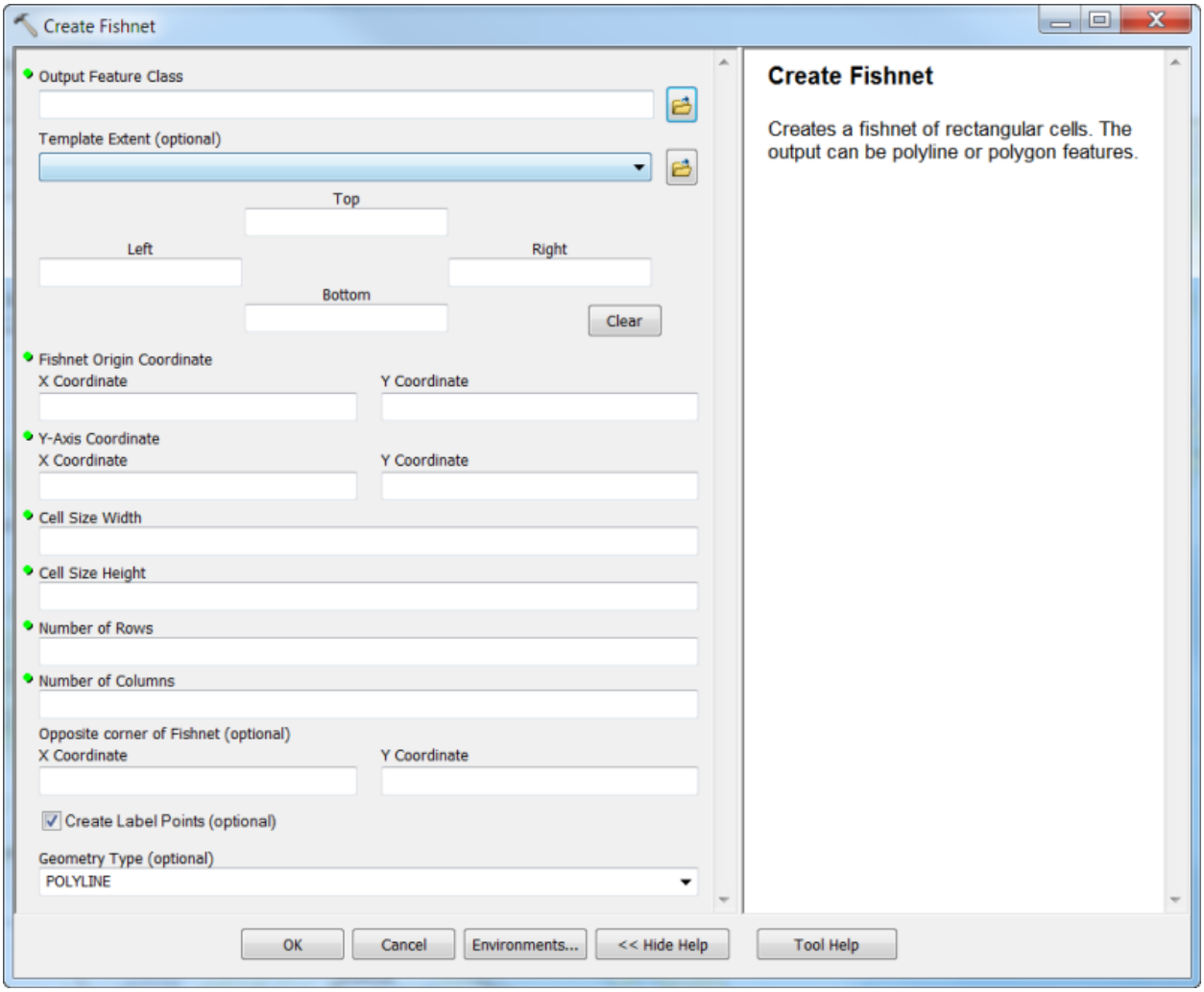
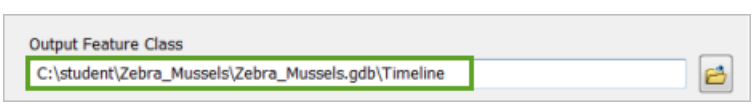
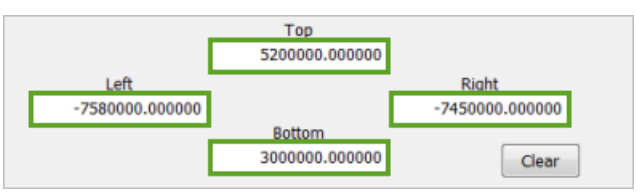


9. Set the Output Feature Class to Timeline in the C:\student\Zebra_Mussels\Zebra_Mussels geodatabase.



10. Type the coordinates shown below to set the template extent.



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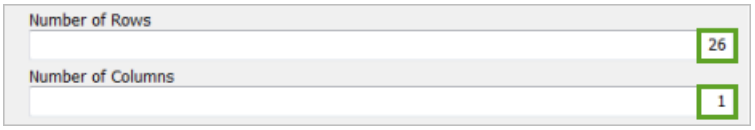
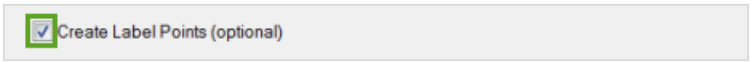
Tip: Type the Left coordinate first, as that will activate the other coordinate text boxes.

Note: These coordinates will be used to generate timeline polygons at a height-to-width ratio of 2:3, which is commonly used for legend boxes.

11. Set the number of rows to 26 (one for each year) and the number of columns to 1 (so that there's one feature per year).



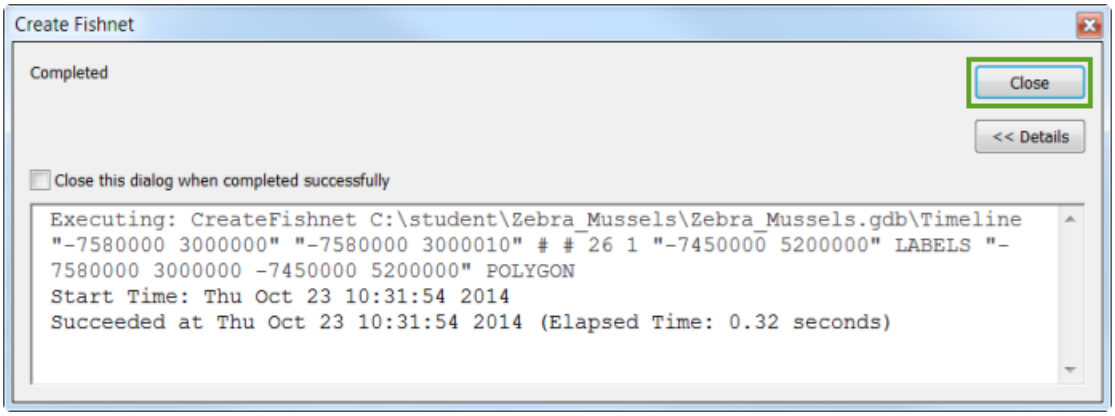
12. Check the Create Label Points check box so that a point feature will be created at the centroid of each fishnet cell.



13. Change the Geometry Type from POLYLINE to POLYGON so that polygon features will be created instead of line features.

14. Click OK.

15. Click Close on the Create Fishnet results dialog box.



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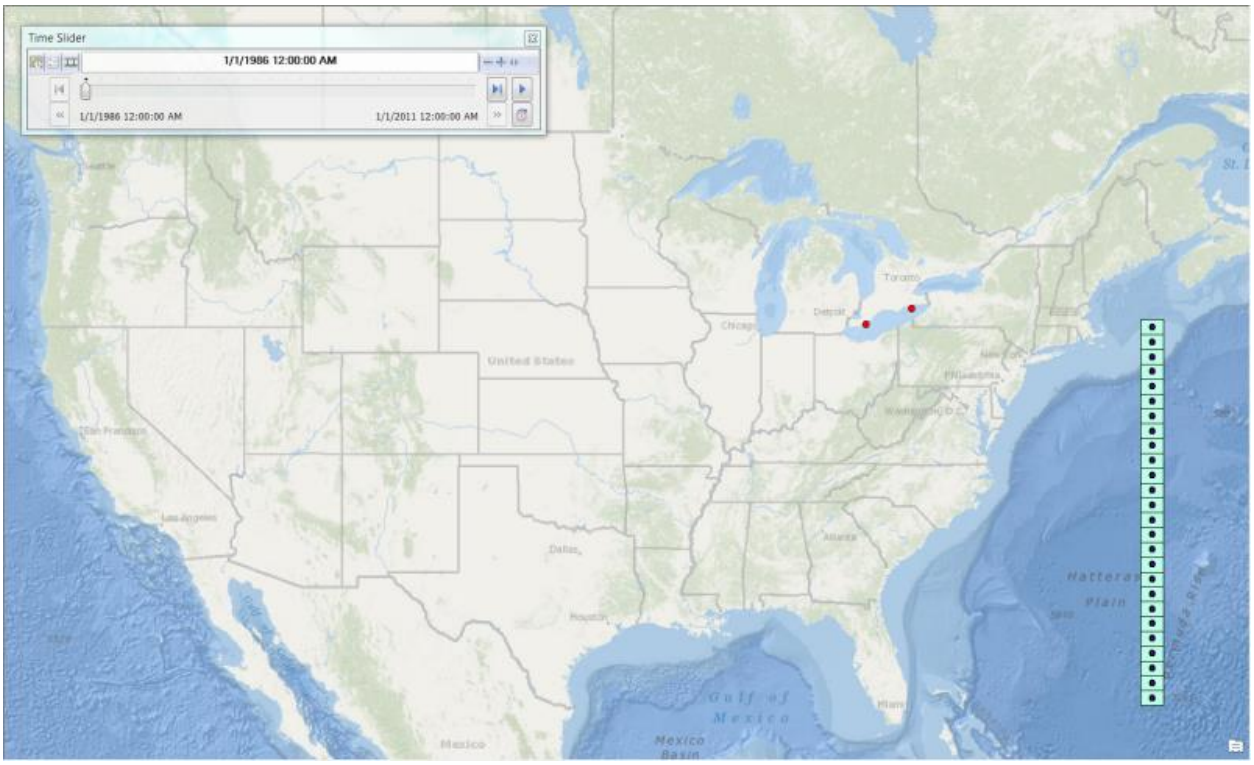
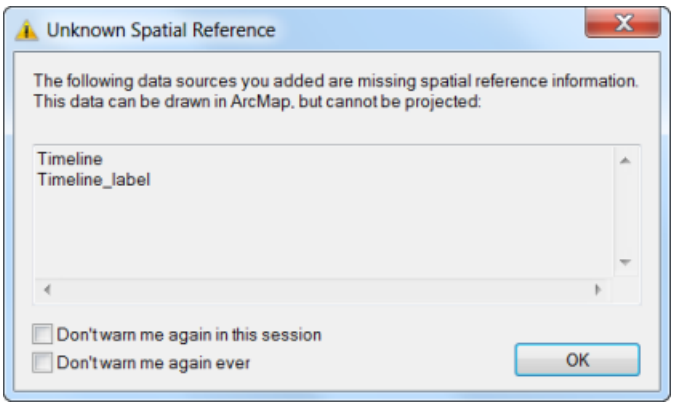
The Timeline label points and polygons will be added to the map and the table of contents.



If you try to add these features to a map in the future, you'll get a warning that the data sources are missing spatial reference information.



You'll use the Define Projection tool to update the coordinate system information stored with the datasets.

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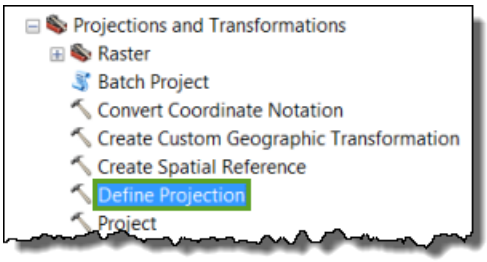
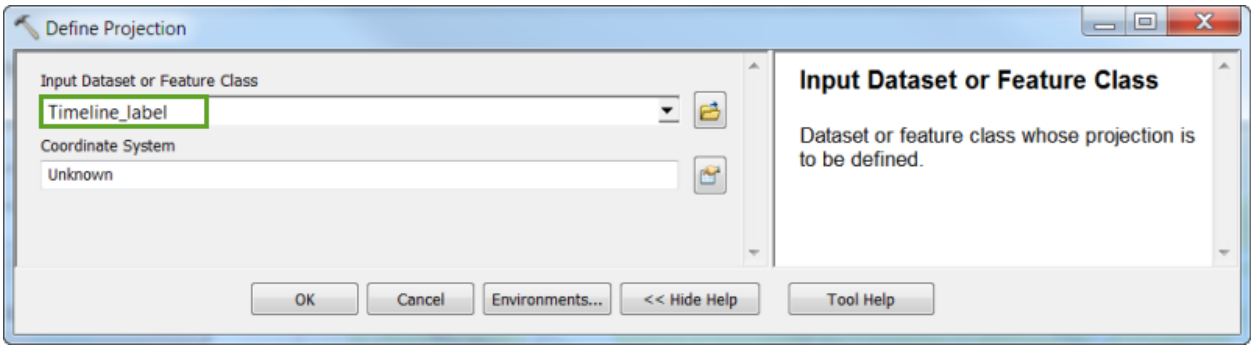
16. Open the ArcToolbox window. In the Data Management toolbox, expand the Projections and Transformations toolset and double-click the Define Projection tool.



17. Set the Input Dataset or Feature Class to Timeline_label.



18. Click the browse button for the Coordinate System parameter and select the WGS 1984 Web Mercator (auxiliary sphere) projection, which is in the Projected Coordinate Systems > World folder.

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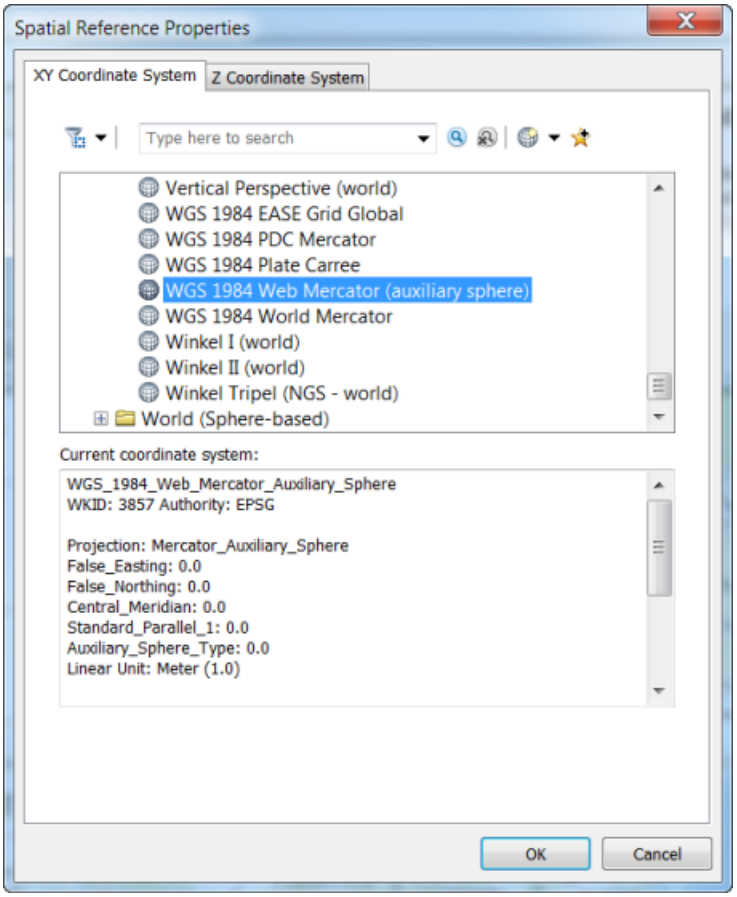

19. Click OK on the Spatial Reference Properties dialog box.

20. Click OK to run the tool.

21. Close the results dialog box.

22. Repeat steps 1 through 21 to define the projection of the Timeline polygon feature class.

23. Save the map.

In the next step, you'll symbolize the timeline features.

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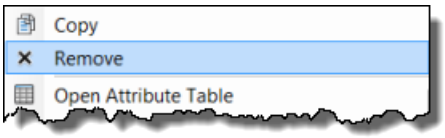
Step 2: Symbolize the timeline

In this step, you'll change the symbology of the timeline points so that they are the same as the Zebra Mussel Sightings layer. When the timeline and the layer are displayed at the same time, there will be an intuitive visual association between the two.

You don't need to use the Timeline polygon layer, so you'll start by removing that from the table of contents.

1. Right-click the Timeline layer and click Remove.



2. Rename the Timeline_label layer **Timeline**.

3. Open the attribute table for the Timeline layer and add a Year_Text field, as you did for the Mussel Sightings layer in Lesson 3.

4. Calculate the Year_Text values to equal the ObjectID ([OID] - 2012) * -1, as shown below.

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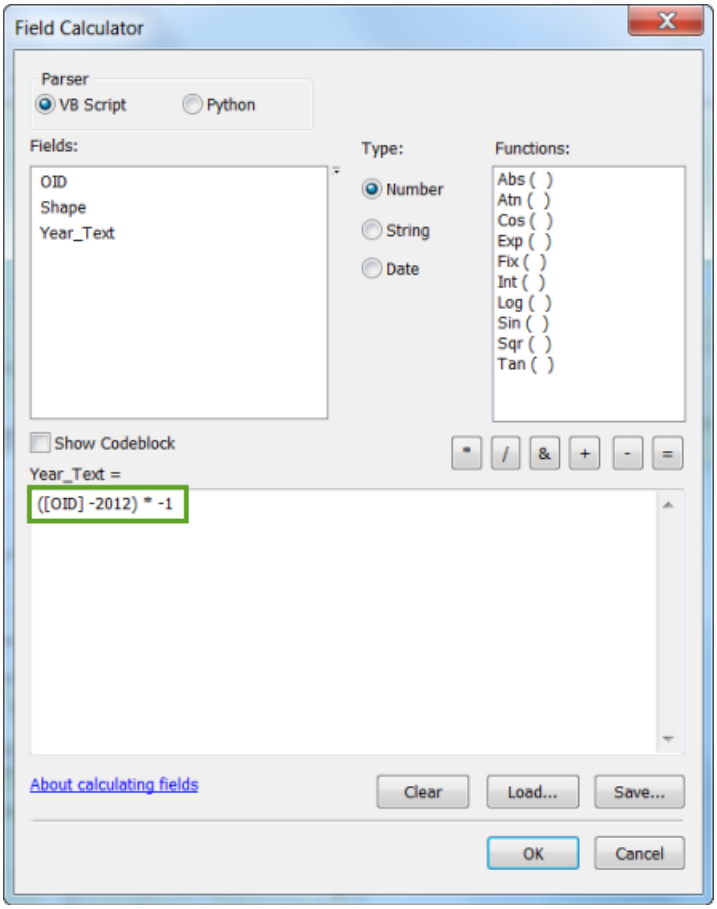

Tip: The ObjectIDs of the features in the array generated with the Create Fishnet tool are numbered starting with the feature at the bottom left. So the feature with an ObjectID [OID] of 1 is at the bottom. You want to display the features in the timeline in a north-to-south order, much like the overall pattern of zebra mussel sightings over time on the map. Using the expression above ensures that the first time step is shown at the top.

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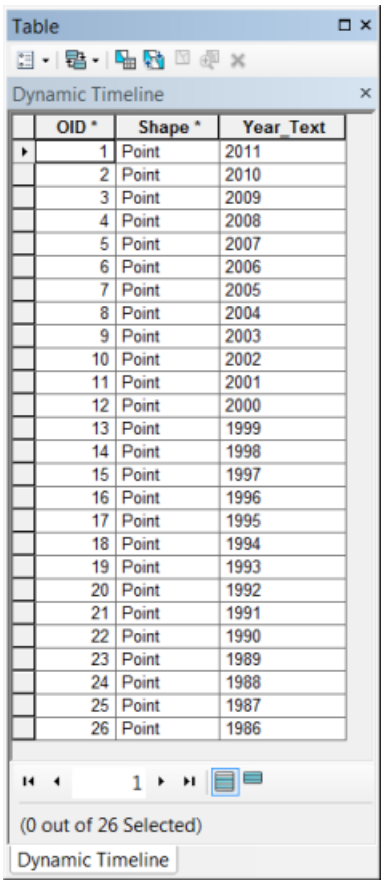
5. Click OK and check that the values range from 2011 to 1986.



OID *	Shape *	Year_Text
1	Point	2011
2	Point	2010
3	Point	2009
4	Point	2008
5	Point	2007
6	Point	2006
7	Point	2005
8	Point	2004
9	Point	2003
10	Point	2002
11	Point	2001
12	Point	2000
13	Point	1999
14	Point	1998
15	Point	1997
16	Point	1996
17	Point	1995
18	Point	1994
19	Point	1993
20	Point	1992
21	Point	1991
22	Point	1990
23	Point	1989
24	Point	1988
25	Point	1987
26	Point	1986

6. Close the attribute table.

7. Change the symbology of the Timeline layer using the option Match to symbols in a style, as you did in Lesson 3, so that the points are symbolized in the same way as the Mussel Sightings layer.

8. Turn off the display for <all other values>.

9. Close the Layer Properties dialog box.

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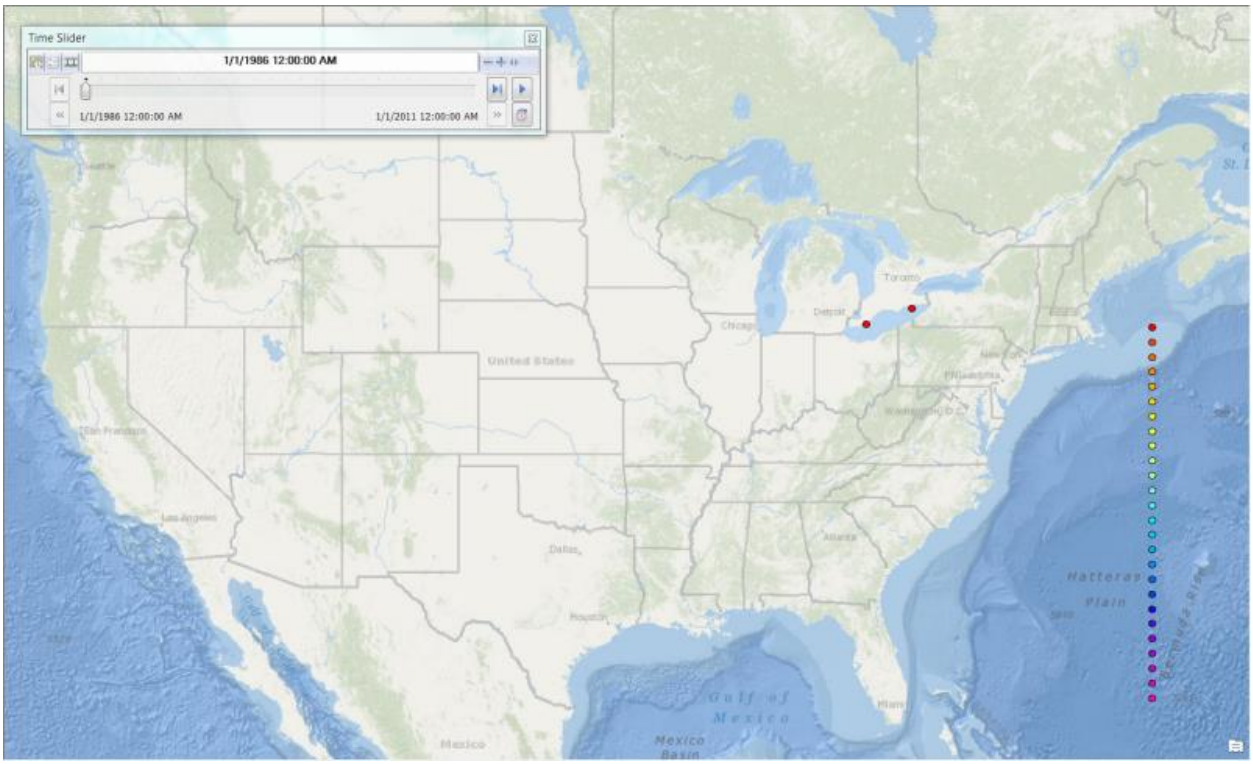

The points are now symbolized correctly.

10. Save the map.

Now that the timeline is displayed correctly, the next step is to label it.

Step 3: Label the timeline

In this step, you'll label the timeline points so that it's possible to track which year is being shown in the display.

Before labeling the points, you'll change the Standard Label Engine to the Maplex Label Engine so that you have more control over the label placement.

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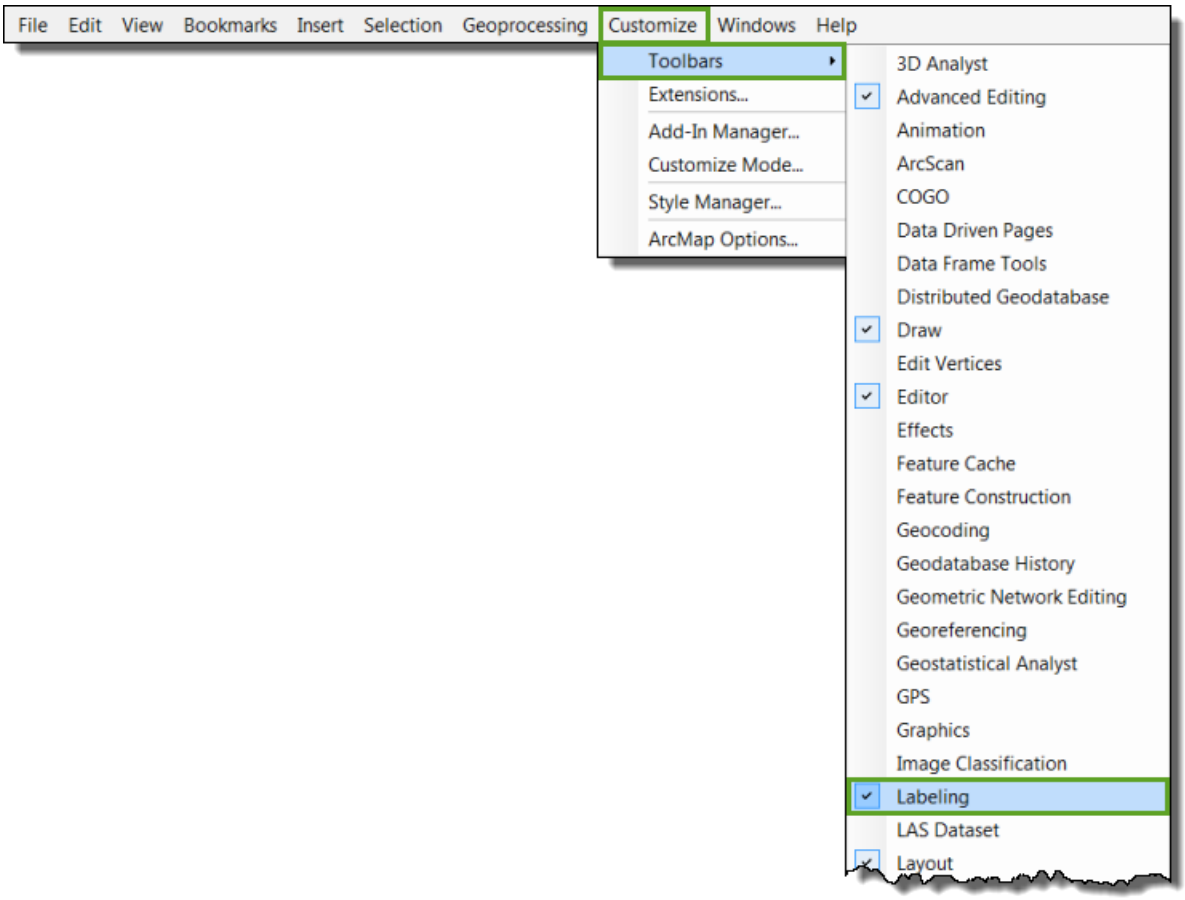
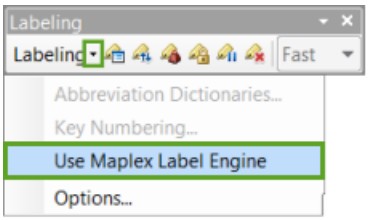
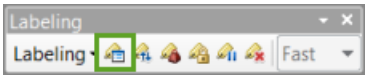
1. Click Customize > Toolbars and check the Labeling toolbar to add it to ArcMap.



2. On the Labeling toolbar, click the Labeling drop-down arrow and choose Use Maplex Label Engine.



3. Click the Label Manager button to open the Label Manager.



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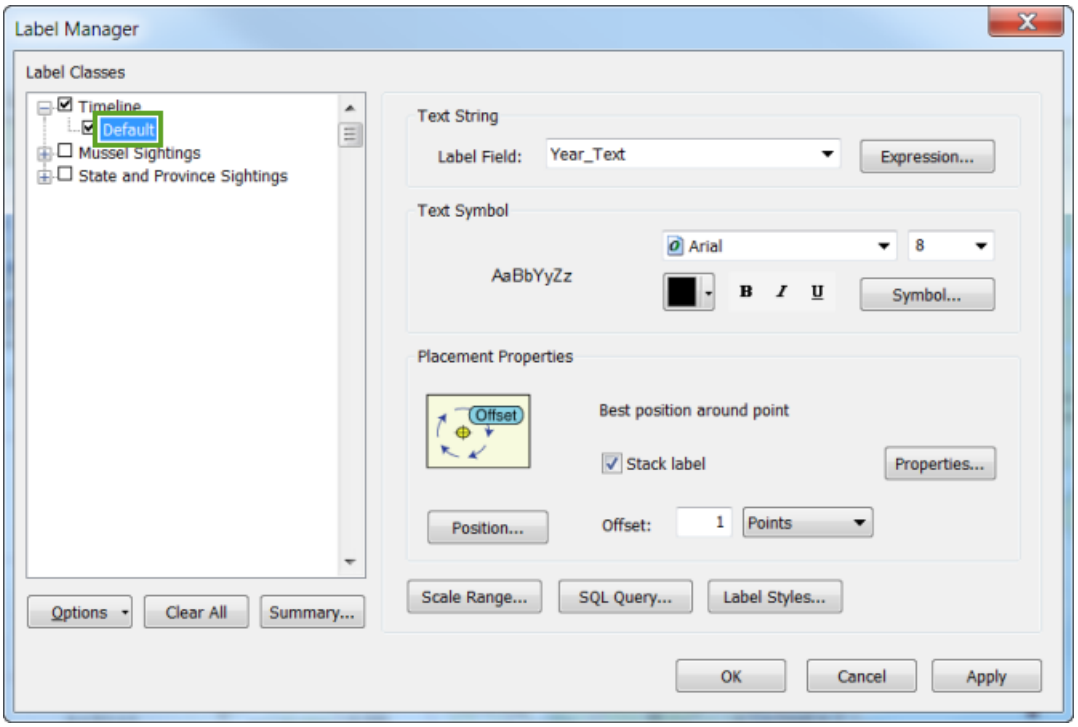
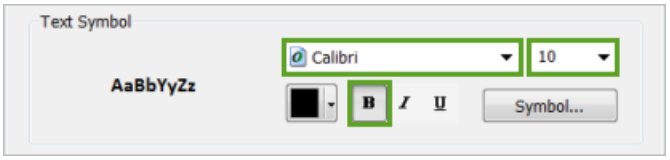
4. Check the box to the left of the Timeline layer and expand this layer's view. Click the Default label class to select it.

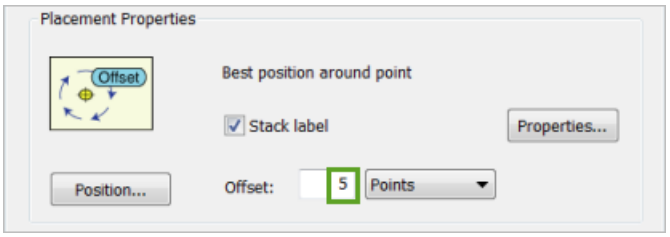


Note that the Label Field is automatically set to Year_Text.

5. Change the Text Symbol to Calibri 10 points Bold.



6. Set Offset to 5 Points.



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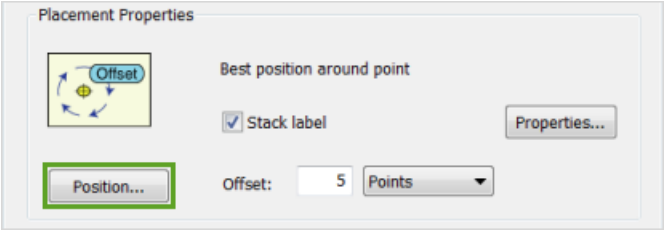
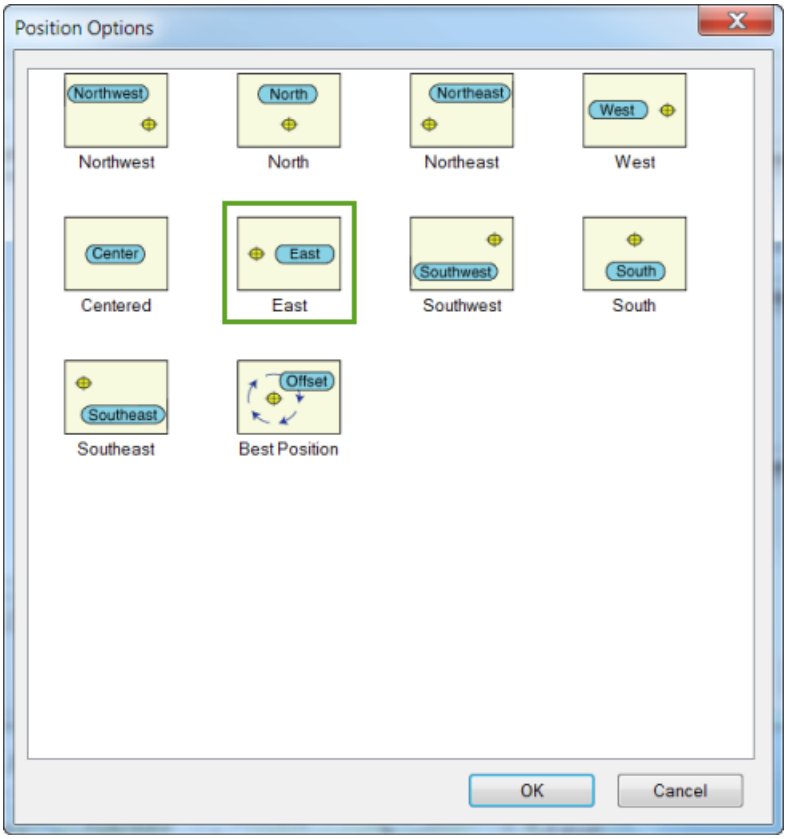
7. Click the Position button.



8. On the Position Options dialog box, select East and click OK.



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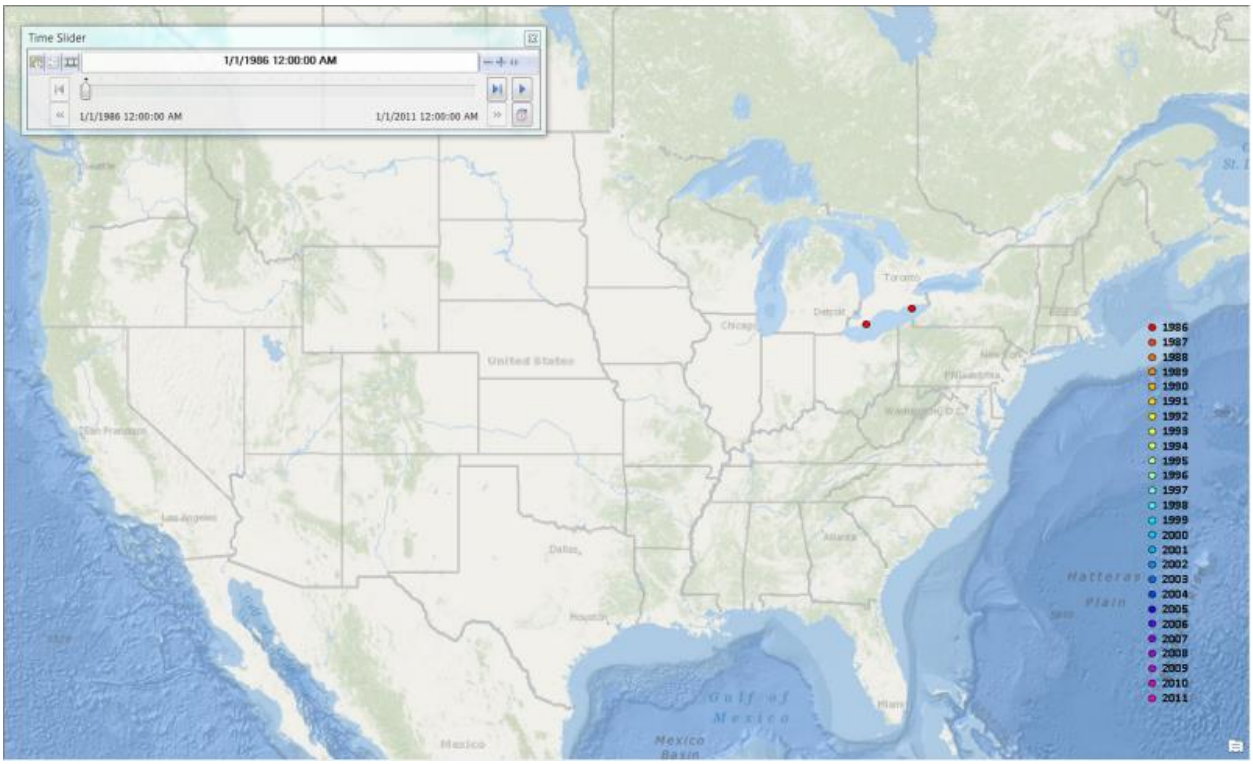
9. Click OK to see the labels.



10. Save the map.

The next step is to create a ghosted copy of the timeline.

Step 4: Create a ghosted copy of the timeline

In this step, you'll copy the Timeline layer and change its symbology and labels. Then you'll disable time properties on the layer so that it is shown at all times.

1. Right-click the Timeline layer and click Copy.

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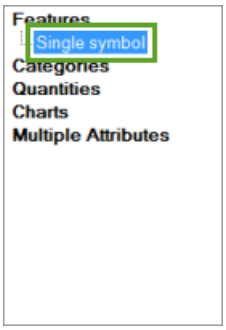
2. Right-click the data frame name (Layers) and click Paste Layer(s).

3. Move the copied layer under the original layer.

4. Change the copied layer name to **Ghosted Timeline**.

5. Open the layer properties and, on the Symbology tab, in the Show pane, click Features and choose Single symbol.



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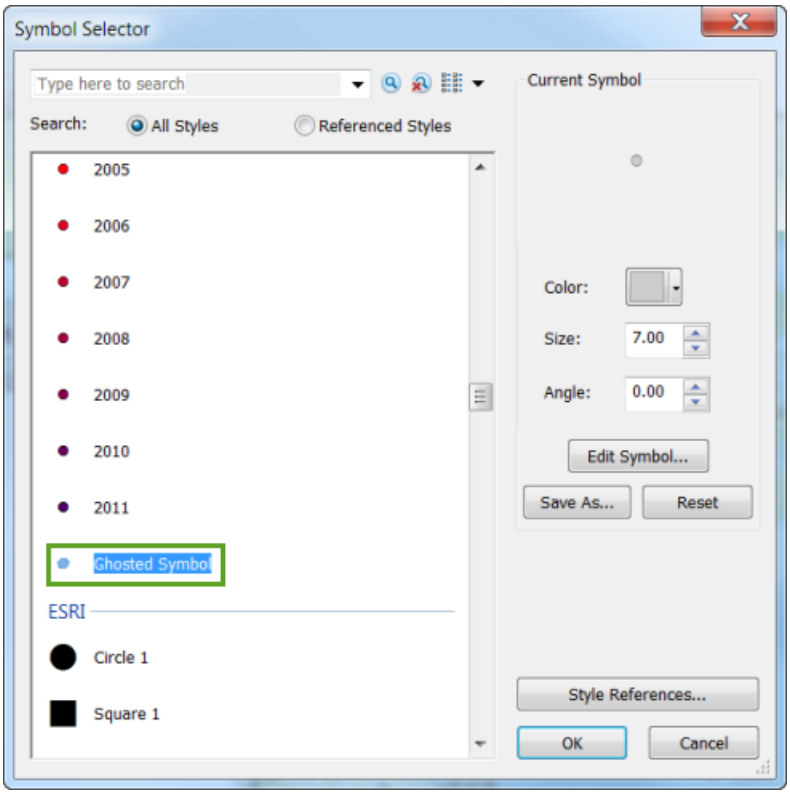
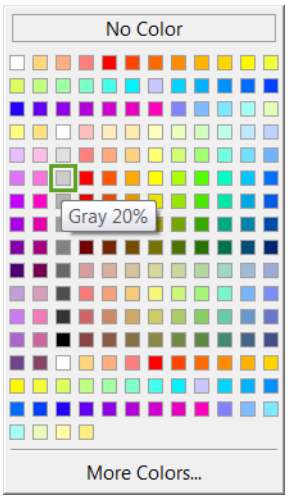
6. Click the symbol and scroll down to select Ghosted Symbol in the Zebra Mussels style.



7. Click OK.

8. On the Labels tab, change the color of the Text Symbol to Gray 20%.



9. Click OK.

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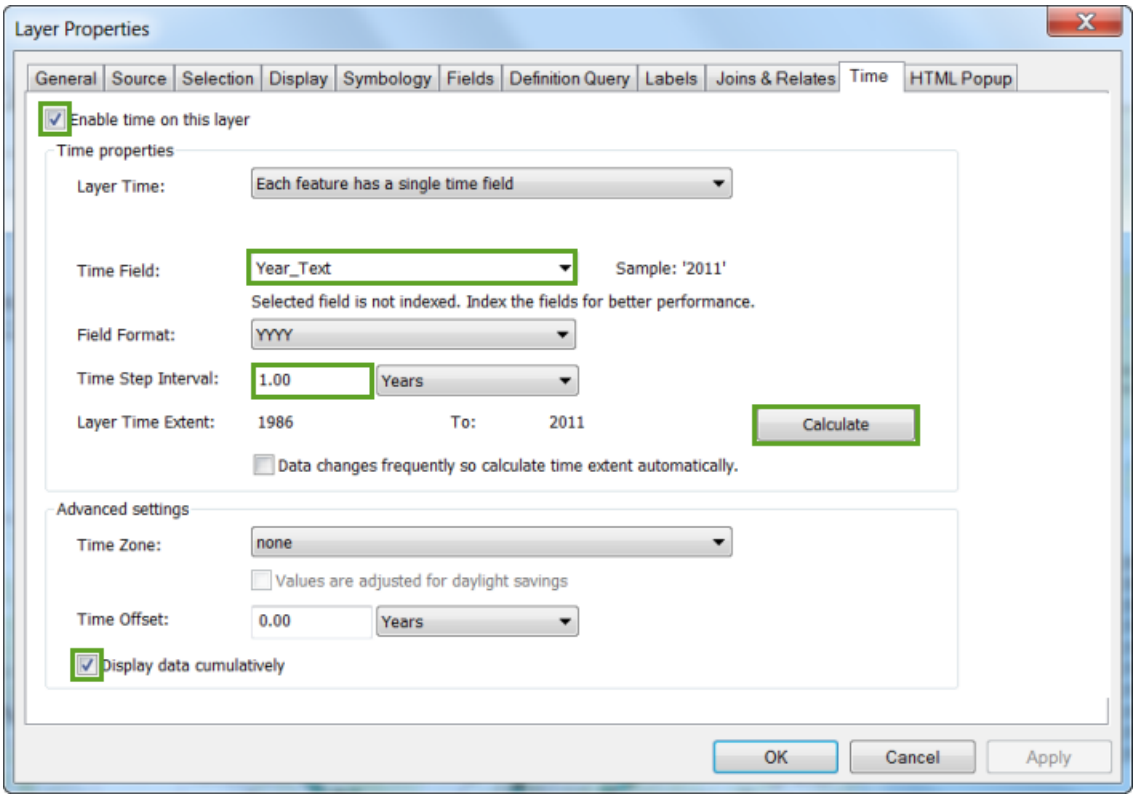
10. Save the map.

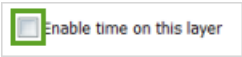
Now you're ready to display the timeline over time.

Step 5: Display the timeline over time

1. Set the Time properties for the Timeline layer as shown below.



2. For the Ghosted Timeline layer, on the Time tab of the Layer Properties dialog box, uncheck Enable time on this layer and click OK.



3. Use the Time Slider window to display the timeline over time.

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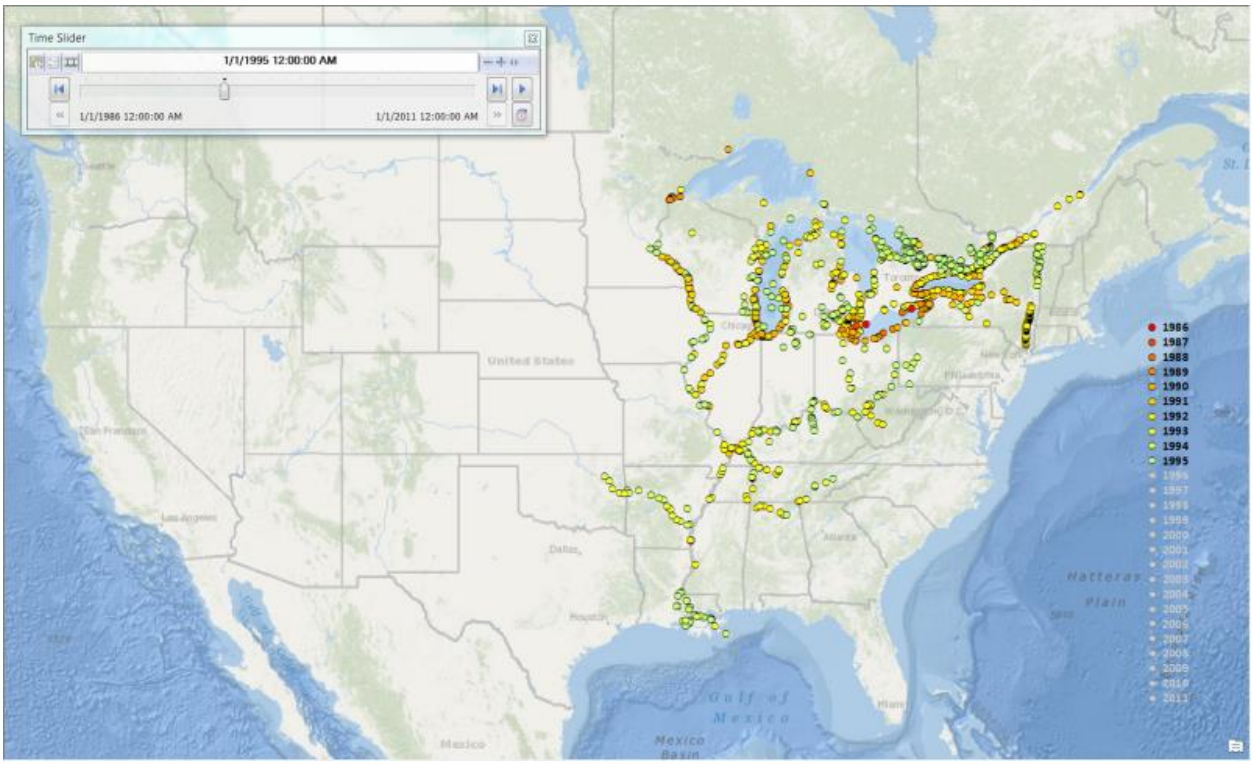

On this map, it's much easier to track the progression through time. Because the point symbols in the timeline are the same as the zebra mussel sighting symbols on the map, the timeline also acts as a legend.

4. Save the map.

This method for creating a timeline can be modified to create horizontal timelines, timelines constructed of rectangular polygons instead of points, and more. The first step is to determine where you want the timeline to be placed. Then create the fishnet features. Finally, symbolize and label the features. The choices you make about which features to use and how to symbolize and label them can result in a wide variety of timelines.

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Lesson 8: Add ellipses to the timeline (optional)

In this lesson:

- Convert the ellipse features to graphics.
- Resize and reposition the ellipse graphics.
- Label the ellipse graphics.
- Convert the ellipse graphics to features.
- Display the timeline over time.

For the map showing standard deviational ellipses over time, it will help map readers to see a small replica of the ellipses in the timeline. The timeline ellipses will offer a condensed view of the mapped ellipses, allowing better year-to-year comparison. Because the ellipses in the timeline are the same color and shape as those on the map, the timeline also acts as a legend.

In ArcMap, the only way to show temporal change is to enable time on a layer of geographic features, so you need to visualize the timeline ellipses as a set of geographic features. These will be small replicas of the ellipses on the map, repositioned at their appropriate locations along the timeline.

In this lesson, you'll convert the ellipses on the map to graphics. You'll resize and reposition the graphics and you'll label them in the timeline. Then you'll convert the graphics back to features. After adding a time field to the attribute table of the timeline ellipse features, you'll change the symbology and enable time on the layer. Then you'll visualize both the timeline and the map over time.

Step 1: Convert the ellipse features to graphics

In ArcMap, you can convert a layer's features to graphics (and vice versa). You'll do this so that you have the ellipse graphics you need for the timeline.

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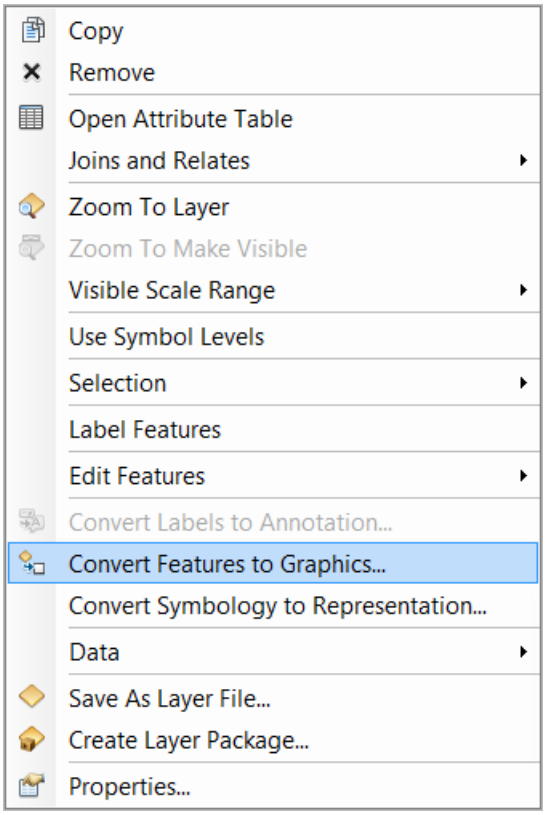
1. Make sure that time is not enabled on the map.

   Tip: If time is enabled, only those features that are displayed for the current time step will be processed.

2. Right-click the Standard Deviational Ellipses in the table of contents and choose Convert Features to Graphics.



3. Click All to convert all the features in the layer to graphics and select the option to Draw the converted graphics and draw the features.

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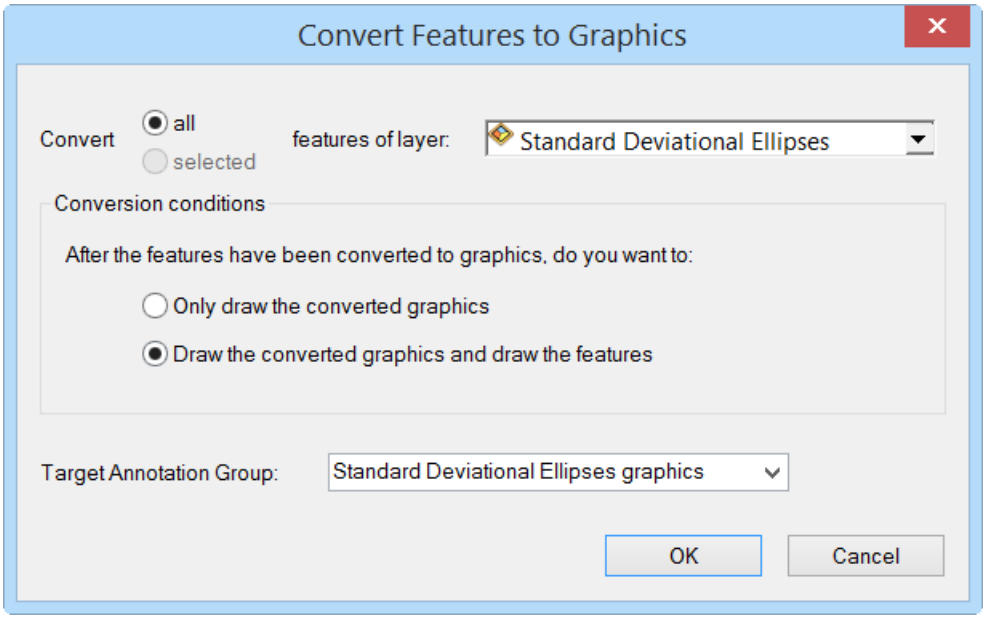

Tip: If you keep the default option to only draw the converted graphics, you will no longer see the features on the map.

In the next step, you'll modify the size and position of the timeline ellipses.

Step 2: Resize and reposition the ellipse graphics

1. In the table of contents, turn off the visibility for the Standard Deviational Ellipses layer.

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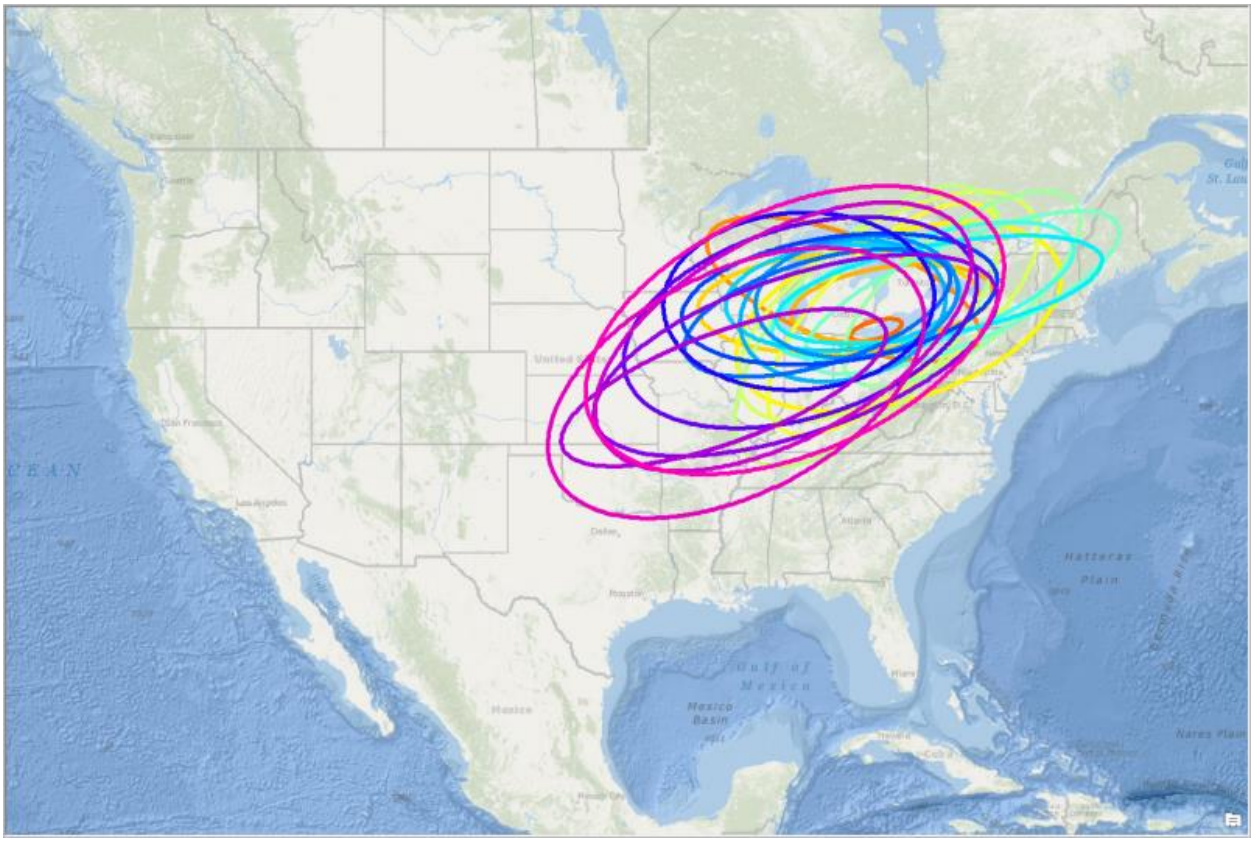

The ellipses will still be drawn on the map, but these are the graphic ellipses, not the geographic features.

2. To see where to position the ellipses, turn on the Timeline layer.

3. Move your pointer over the timeline point for the 2011 time step in the Timeline. Note that in the lower right corner of the ArcMap window, the coordinates are about -7520000 and 3040000 meters.

4. On the Drawing toolbar, click the Select Elements button.

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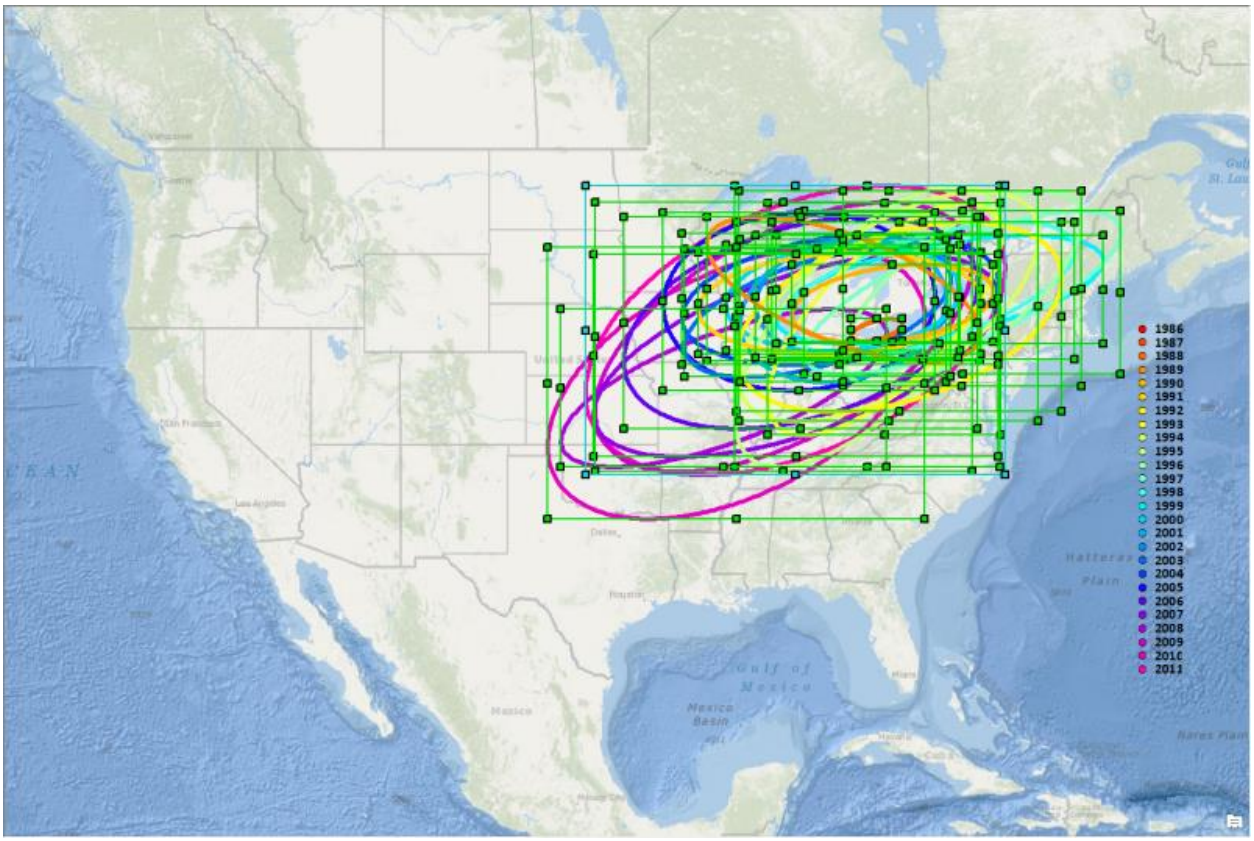
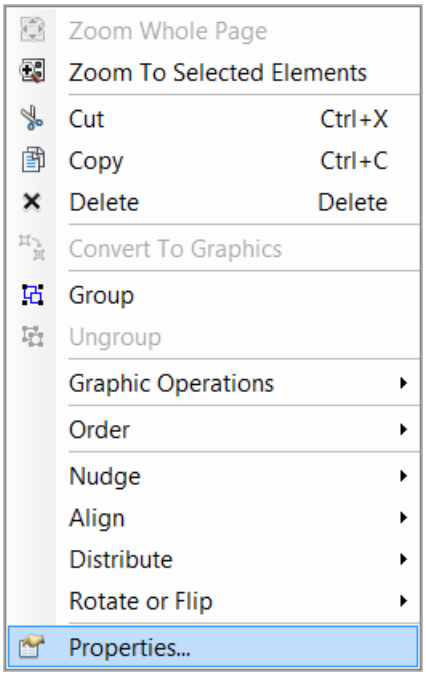
5. Hold down the Shift key while drawing a box around all the ellipses to select them.



6. In the ArcMap window, right-click and choose Properties.



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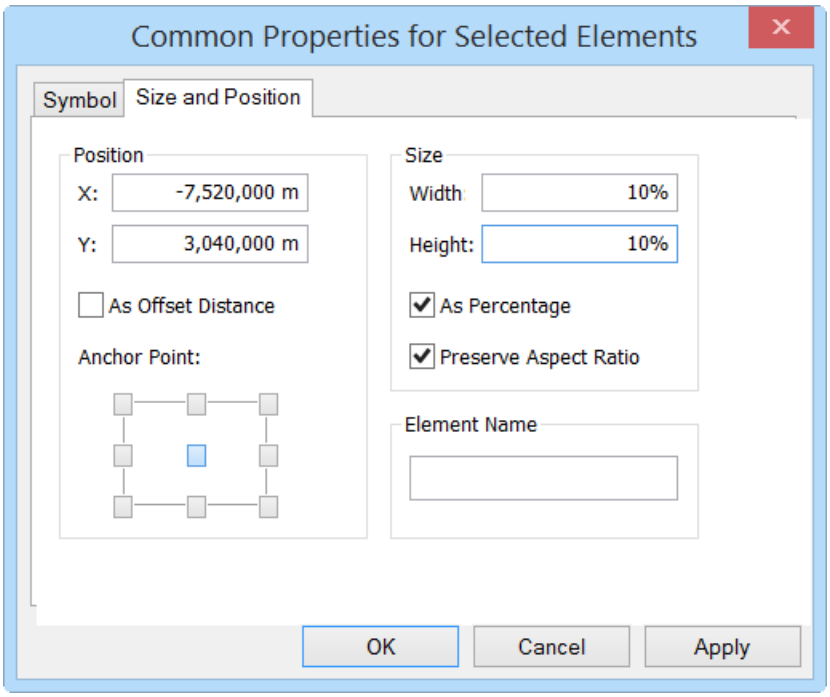
7. On the Size and Position tab of the Common Properties for Selected Elements dialog box, set the X position to -7,520,000 and the Y position to 3,040,000, set Anchor Point to the center position, check the As Percentage and Preserve Aspect Ratio check boxes, and set the Width and Height parameters for Size to 10%.



8. Click OK to keep your changes.

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All the ellipses will be reduced in size and drawn at the position of the 2011 point in the timeline.

9. Click anywhere except on the ellipses to cancel the selection.

10. To spread out the ellipses so that you can select them more easily when you reposition them, select the ellipse on the top (the small, dark orange ellipse) and move it to the location of the point for the 1988 time step.

    Note: Recall that no ellipses were generated for the first two time steps because there were too few features to generate ellipses for these years.

11. Hold down the Ctrl key while drawing a box around the remaining ellipses to select all of them, including the 1988 ellipse.

12. Right-click and choose Distribute, then choose Distribute Vertically.

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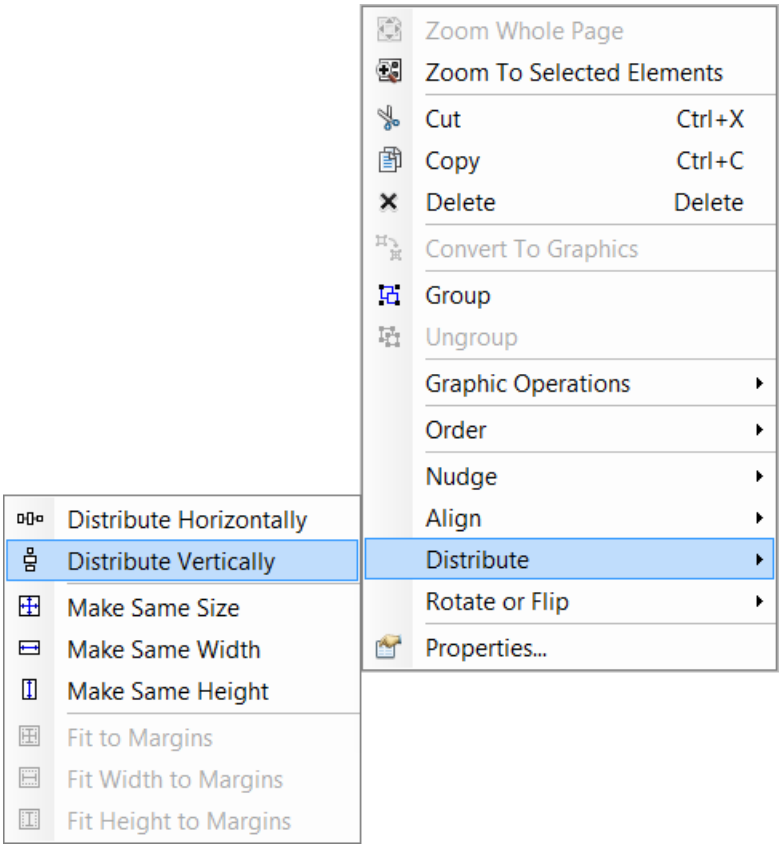

The ellipses will be spread out so that you can see them all, but they will not be in the correct order.

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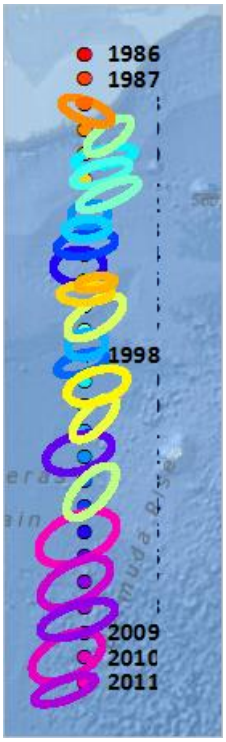

13. Reorder the ellipses, using the color and position of the Timeline points as a guide and centering each ellipse over its associated Timeline point, allowing the larger ellipses to overlap.

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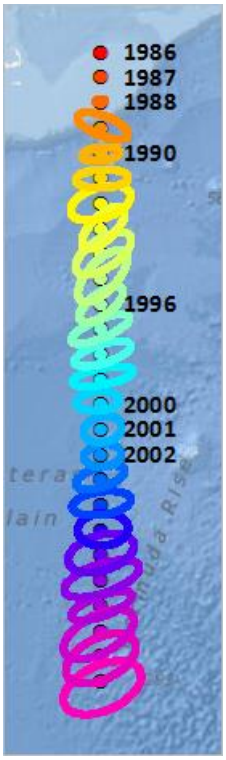

Tip: Zooming in to the Timeline area may help you more easily see where to position the ellipses.

14. Hold down the Shift key while drawing a box around all the ellipses to select them.

15. Right-click and choose Align, then choose Align Center.

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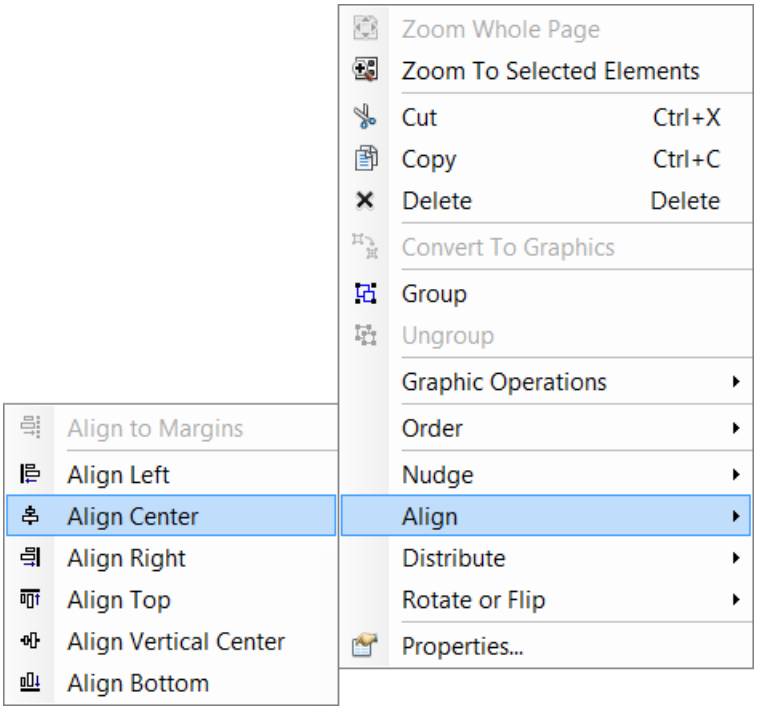
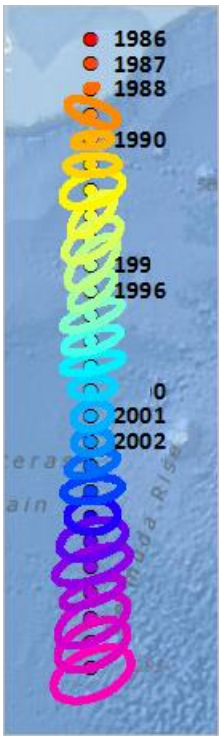


The ellipses will be lined up over the Timeline points.



The next step is to add the labels to the timeline.

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Step 3: Label the ellipse graphics

In this step, you'll copy the Timeline layer and use the copy to label the ellipses.

1. In the table of contents, right-click the Timeline layer and choose Copy.
2. Right-click the data frame name (Layers) and choose Paste Layers(s).
3. Rename the Timeline layer **SDE Timeline Labels**.
4. Turn off the Timeline layer.
5. Right-click the SDE Timeline Labels layer and choose Properties.

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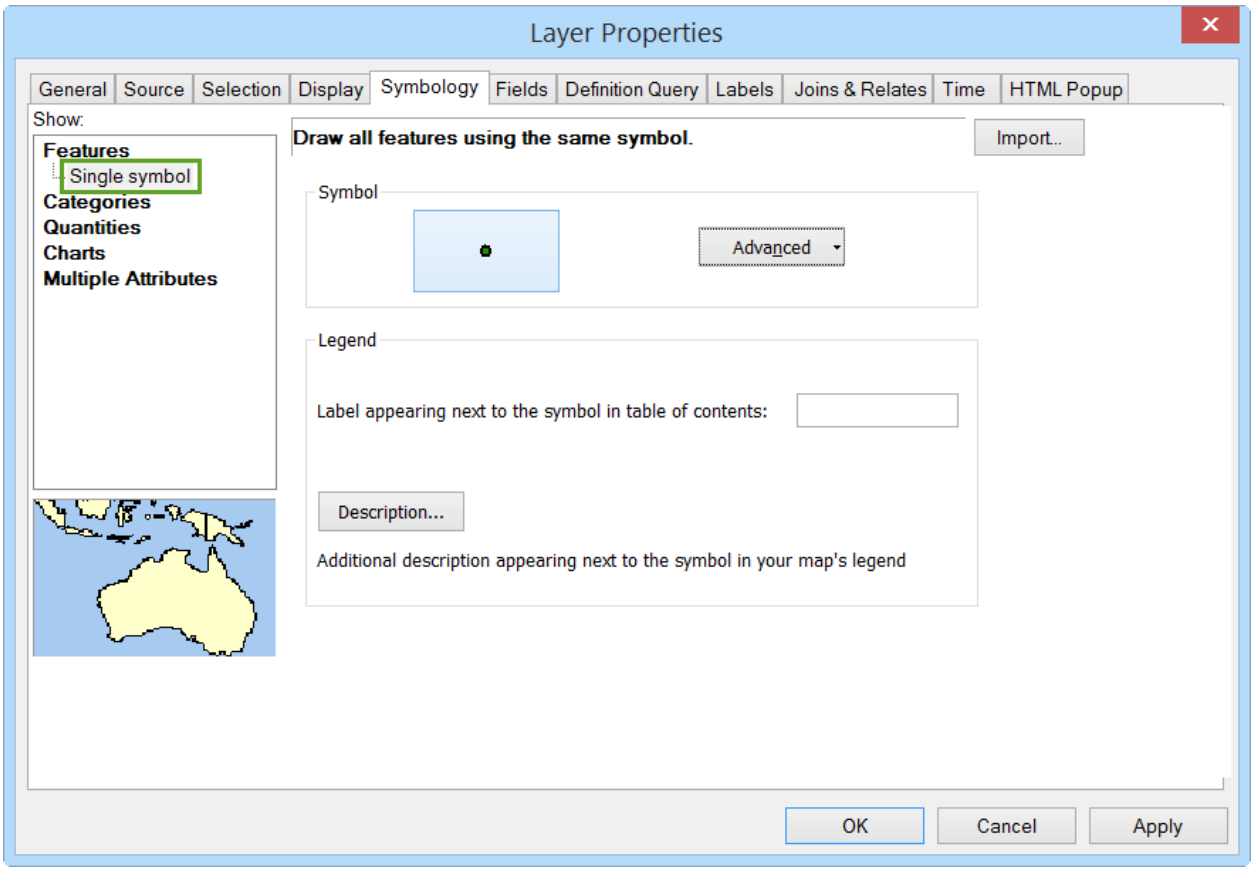
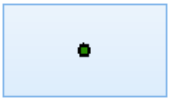
6. On the Symbology tab, in the Show pane, click Features and choose Single symbol.



7. Click the symbol.



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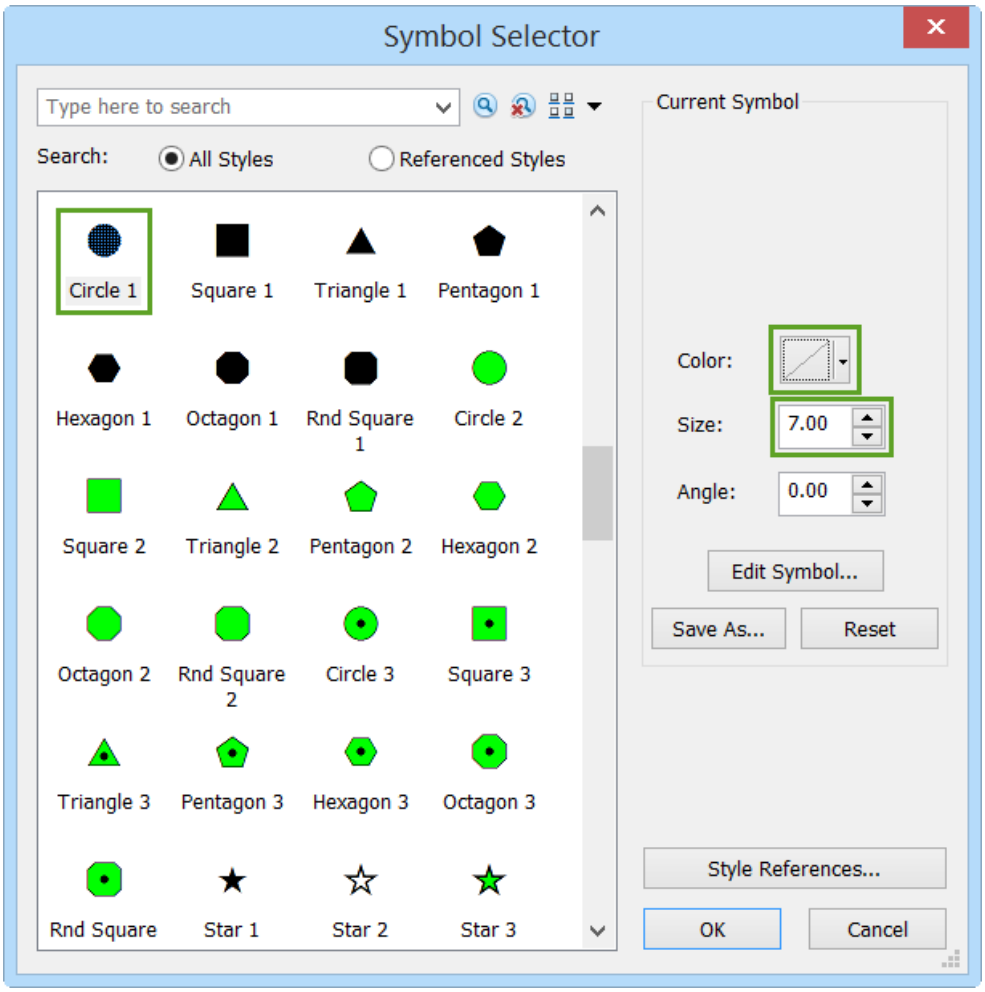
8. Set the symbol to Circle 1, change the color to No Color, and change the Size to 7.



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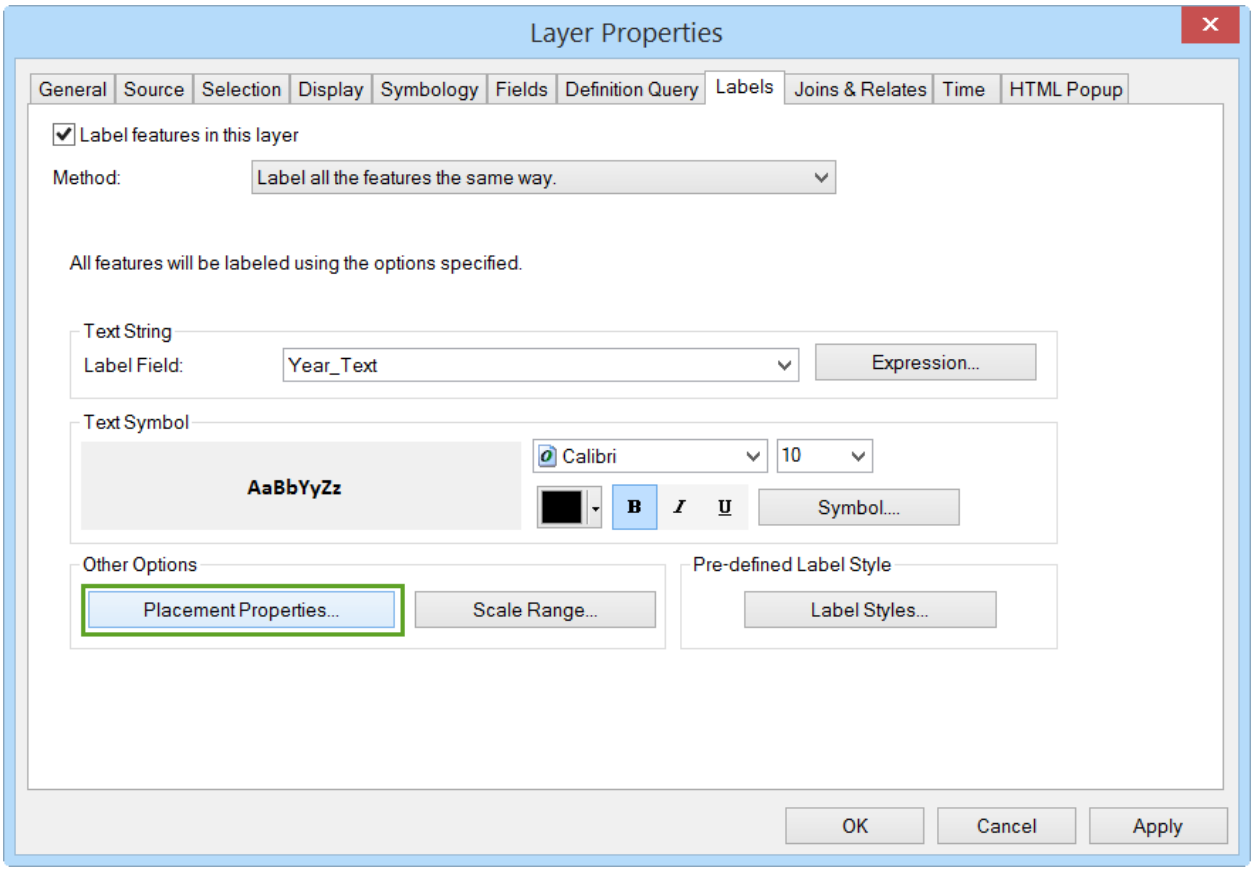
9. On the Labels tab, click the Placement Properties button.



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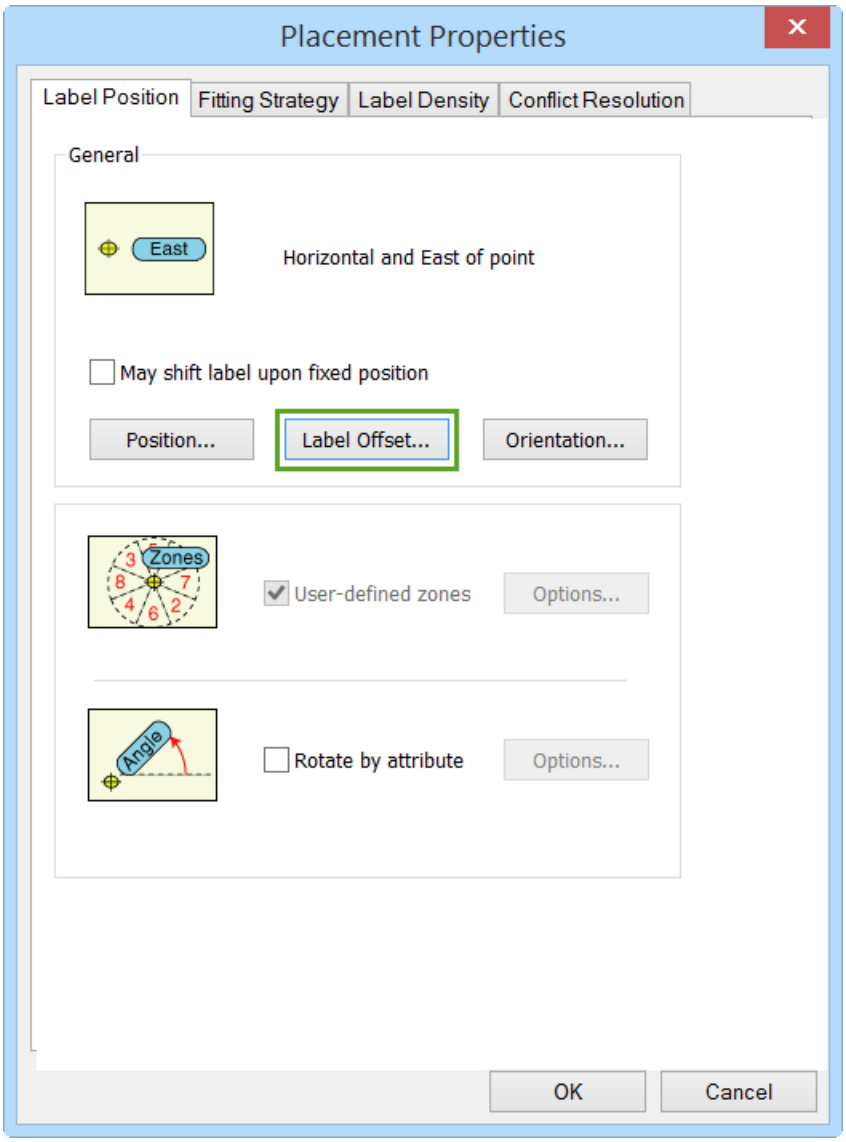
10. In the Placement Properties window, click the Label Offset button.



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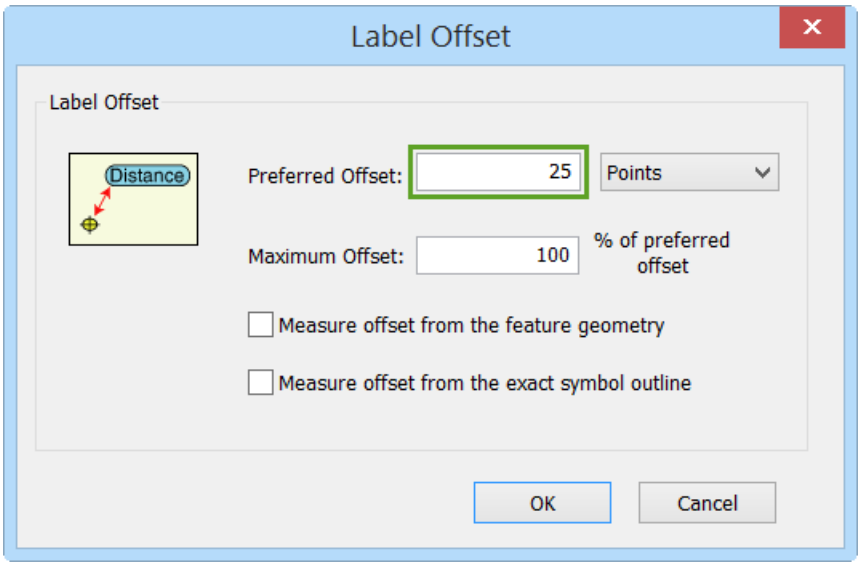
11. Set the Preferred Offset to 25 Points.



12. Click OK three times to keep your changes.

Step 4: Convert the ellipse graphics to features

In this step, you'll convert the ellipses back to geographic features so that you can ultimately enable time on the layer.

1. Hold down the Shift key while drawing a box around all the ellipses to select them.
2. In the table of contents, right-click the data frame name and choose Convert Graphics to Features.
3. On the Convert Graphics To Features dialog box, name the Output shapefile or feature class **SDE_Timeline_Features** and save it in the Zebra_Mussels geodatabase.

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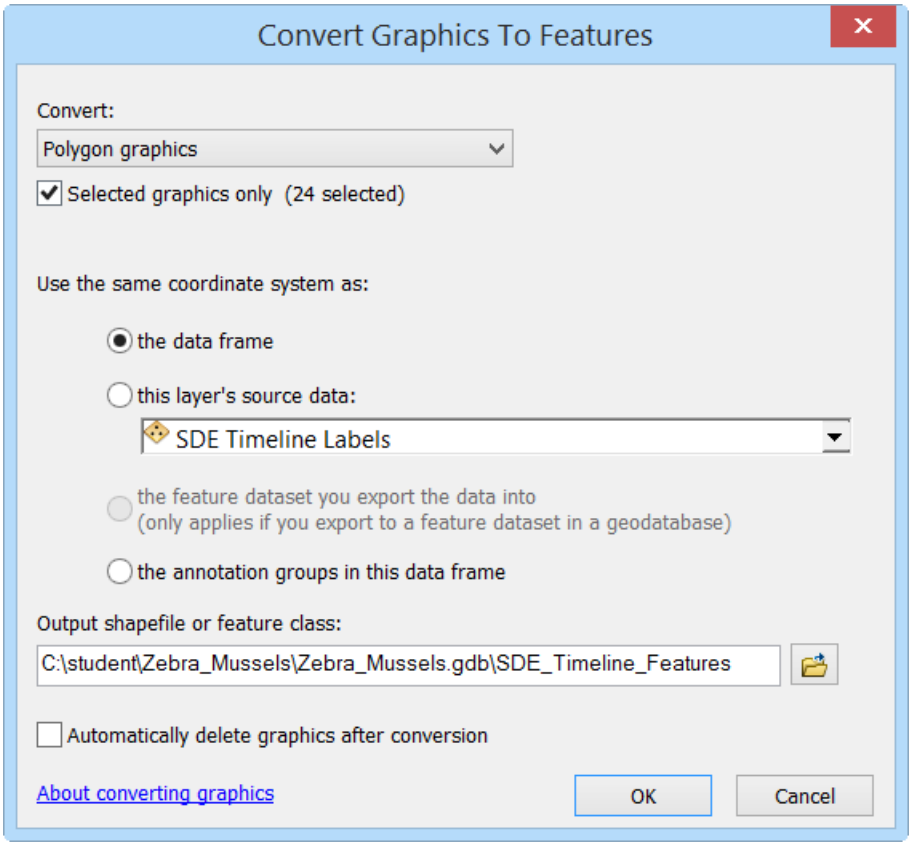

4. Check the check box to Automatically delete graphics after conversion.

Tip: Choosing the option to automatically delete graphics after conversion will remove the graphics from the map.

5. Click OK to convert the graphics to features.

6. Choose to add the exported data to the map as a layer.

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The layer will lose its symbology, so you'll have to add an attribute and reset the symbology using the option Match to symbols in a style, as you did for a number of other layers.

13. Open the attribute table for the SDE_Timeline layer and add a Year_Text text field with a length of 4, as you did for the Mussel Sightings layer in Lesson 3.

14. Calculate the values to equal [OID] + 1987.

    Note: The first timeline ellipse is for the year 1988, so adding 1987 to the ObjectID of all the features will give them the correct value for the Year_Text attribute.

15. Click OK and check that the values range from 1988 to 2011.

16. Close the attribute table.

17. Change the symbology of the SDE_Timeline layer using the option Match to symbols in a style, as you did in Lesson 3, so that the ellipses are symbolized in the same way as the standard deviational ellipses layer.

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18. Turn off the display for <all other values>.

19. Close the Layer Properties dialog box.

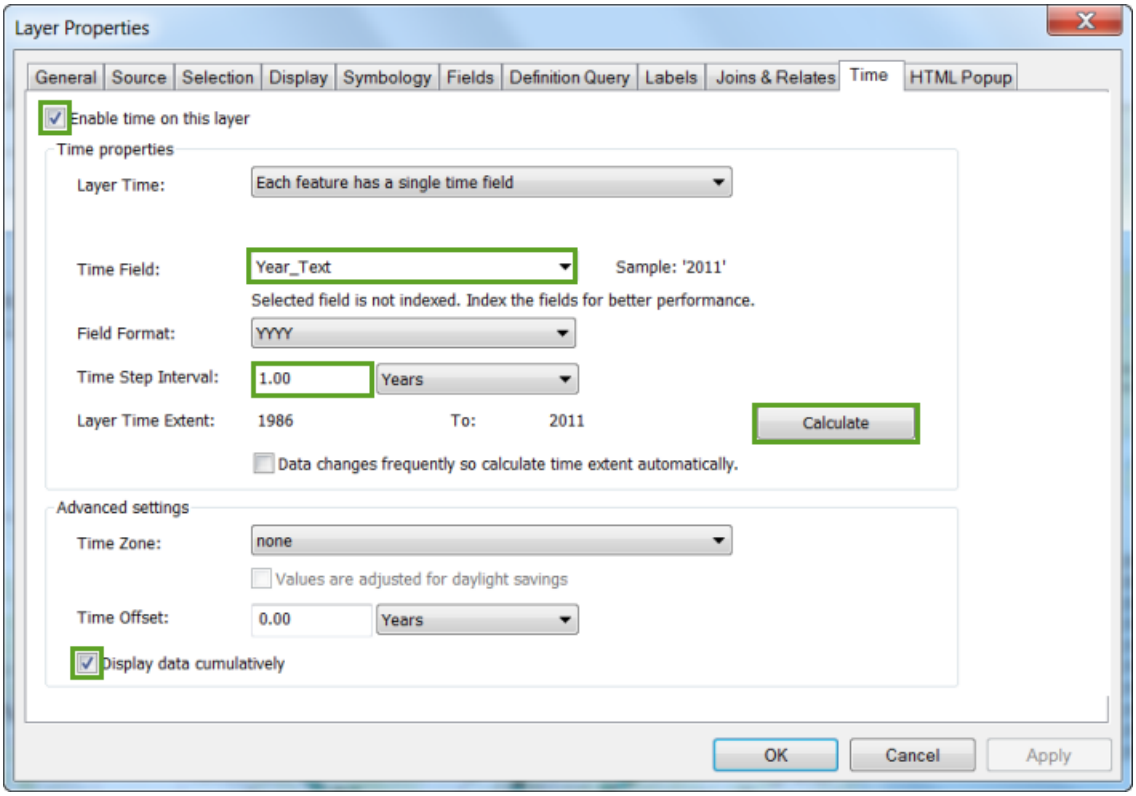
    The ellipses are now symbolized correctly.

20. Save the map.

Now that the timeline is displayed and labeled correctly, you're ready to display the ellipses in the timeline over time.

Step 5: Display the timeline over time

1. Set the Time properties for the SDE_Timeline_Features layer as shown below.



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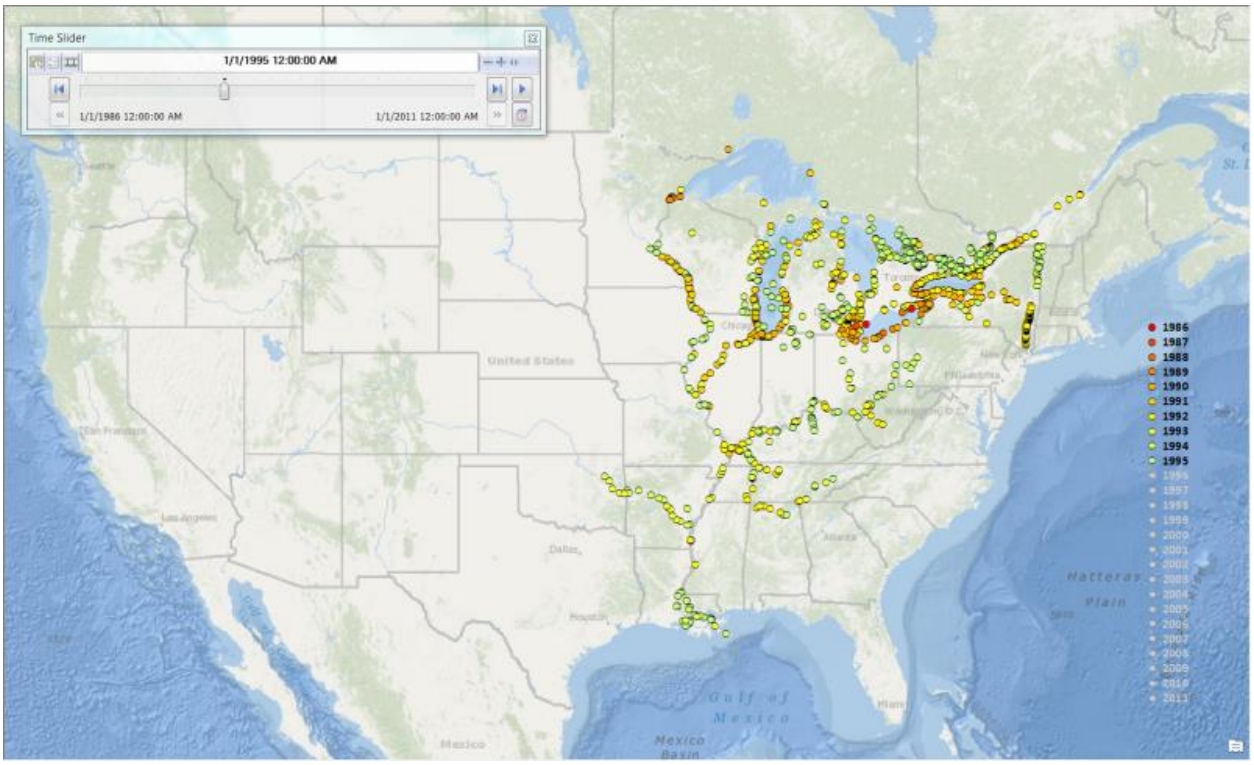
2. Use the Time Slider window to display the timeline along with the standard deviational ellipses, mean centers, and associated points over time.



On this map, it's much easier to track the progression through time. Because the ellipses in the timeline are the same colors and shapes as those on the map, the timeline also acts as a legend.

3. Save the map.

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