## Virginia View Curriculum

<table>
<thead>
<tr>
<th>Lesson Plan</th>
<th>Light Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Level</td>
<td>High School, Earth Science</td>
</tr>
<tr>
<td>Applicable Virginia SOL</td>
<td>ES 14</td>
</tr>
</tbody>
</table>

### Summary
This activity examines the issue of light pollution and the changes of the night time sky illumination by using GIS data over a period of eight years. Students will make observations and make connections about how man-made changes have affected both our view of the night sky and the implications it might have for other animals.

### Classroom Materials
This lesson is best completed with computers with internet access and ArcGIS installed. There are also options for no ArcGIS access and no computer access.

### Submitted by
Alison Goforth, Science Teacher, Auburn High School, Riner, VA

### Contact Information

<table>
<thead>
<tr>
<th>James Campbell</th>
<th>John McGee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia View</td>
<td>Virginia View</td>
</tr>
<tr>
<td><a href="mailto:jayhawk@vt.edu">jayhawk@vt.edu</a></td>
<td><a href="mailto:jmcg@vt.edu">jmcg@vt.edu</a></td>
</tr>
<tr>
<td>540-231-5841</td>
<td>540-231-2428</td>
</tr>
</tbody>
</table>
Teacher Guide

Applicable Virginia SOL:

ES.3 The student will investigate and understand how to read and interpret maps, globes, models, charts, and imagery. Key concepts include
   a) maps (bathymetric, geologic, topographic, and weather) and star charts;
   b) imagery (aerial photography and satellite images);

ES.14 The student will investigate and understand scientific concepts related to the origin and evolution of the universe. Key concepts include
   a) nebulae;
   b) the origin of stars and star systems;
   c) stellar evolution;
   d) galaxies; and
   e) cosmology including the big bang theory.

Background:

Increasing population and urbanization has lead to the problem of light pollution."Light pollution is largely the result of bad lighting design, which allows artificial light to shine outward and upward into the sky, where it's not wanted, instead of focusing it downward, where it is. Ill-designed lighting washes out the darkness of night and radically alters the light levels—and light rhythms—to which many forms of life, including ourselves, have adapted" (Klinkenborg, Verlyn, "Our Vanishing Night Skies", National Geographic Magazine, November 2008). http://ngm.nationalgeographic.com/2008/11/light-pollution/klinkenborg-text/1

Aside from blocking out the view to the night sky, light pollution is a waste of energy and resources. No one benefits from shining the street light up to the sky at night and there are numerous disadvantages to such practices. It is not just cities and urban areas that are contributing to light pollution. The problem is a global issue. "In the south Atlantic the glow from a single fishing fleet—squid fishermen luring their prey with metal halide lamps—can be seen from space, burning brighter, in fact, than Buenos Aires or Rio de Janeiro"(Klinkenborg, 2008).

Many birds have had their migratory patterns disrupted due to light pollution. "The effect is so powerful that scientists speak of songbirds and seabirds being "captured" by searchlights on land or by the light from gas flares on marine oil platforms, circling and circling in the thousands until they drop. Migrating at night, birds are apt to collide with brightly lit tall buildings; immature birds on their first journey suffer disproportionately." (Klinkenborg, 2008). Other nocturnal animals and insects are also adversely affected by our need to have lighted areas at night. Sea turtle hatchlings will run to street lights instead of towards the ocean and get run over by cars." In the end, humans are no less trapped by light pollution than the frogs in a pond near a brightly lit highway. Living in a glare of our own making, we have cut ourselves off from our evolutionary and cultural patrimony—the light of the stars and the rhythms of day and night. In a very real sense, light pollution causes us to lose sight of our true place in the universe, to forget the scale of our being, which is best measured against the dimensions of a deep night with the Milky Way—the edge of our galaxy—arching overhead." (Klinkenborg, 2008)
Teacher Preparation:

Review background information with students

Student worksheets from the appropriate section (see below)

Student worksheet key (one key for all 3 sections, attached at the end of the exercise).

Select one of the following options for completing the exercise, and follow the Procedure and Student Worksheet that applies to your classroom materials:

- Working with computers with ArcGIS and internet access (Section 1)
- Working with computers with internet access (Section 2)
- Working without computers (Section 3)

Section 1: For Working computers with ArcGIS and internet access

Procedure: (For Teacher and Students)

1. Make sure your CPU’s are loaded with ArcEditor or ArcMap.
2. Open up ArcMap with an empty map.
3. Click on (+) or go under File; add data
4. In the pop up window "Look in", click on the drop down arrow/menu and choose "GIS Servers" * it may be down at the bottom of the list, so keep looking, then Click Add
   *If using ArcGIS 10, in catalog click on drop down menu to "GIS Servers". In window in catalog expand folder “GIS Server”s, double click “Add ArcGIS Server”. On the first window of the wizard, select “Use GIS Services.” Click “next” and follow number 7 below.
5. In the next window, select: "Add ArcGIS Server", Click add, a new pop up window "Add ArcGIS Server" appears.
6. Select "use GIS services", click next
7. A new pop up window "General" appears
   Select "internet" and type or paste URL in window: http://arc.gis.vt.edu/arcgis/services
8. Leave Authentication (optional) info blank, click "finish"
9. You will see the name arcgis on arc.gis.vt.edu as a listing/choice in the "Add Data" pop up window
10. Close the "General" window
11. In the "Add Data window, click on arcgis on arc.gis.vt.edu and make sure in the name field it says "arcgis on arc.gis.vt.edu", and the Show of type says "Datasets and layers (.lyr) In the new "Add Data window", click/select the folder "VA View", then ADD
12. Select : "Lights_at_night_VA" to add the Lights at night in Virginia data layer.
13. Click (+) or File add data and add "Lights_at_night_US" to add the Lights at night in US data layer.
14. Click (+) or File add data and add "Lights_at_night_comparison" to add the Lights at night in 1992/1993 and 2000.
15. Expand all the data layers (click on the + box next to each name). You should get the following:

17. Be sure to name and save your map frequently. Under Map Document Properties- Click on Data Source Options. Make sure that "Store Relative pathnames to data sources" is selected and "Make relative the default for new map documents I create" (not on ArcGIS 10 dialog) is checked.
Student Worksheet (Section 1: ArcGIS Users)

Light Pollution

Name _____________________________  Partner's Name _____________________

1. Turn Off the "VA View/Lights_at_night_Comparison" and "VA View/Lights_At_Night_US" layer (uncheck the box next to the names)

What areas of Virginia have the most lights at night? (Ex: Coastal Region, Northern VA)

_________________________________________________________________________

2. Make sure you have expanded the menu in "VA View/Lights_at_night_VA". Turn off the "interstates" layer. Observe the pattern of lights in Virginia. Turn back on the "interstates" layer. Do you notice a connection? _______________ If so, what is the connection?

_________________________________________________________________________

3. Use the zoom (+ magnifyer) button to zoom into the Northern VA/ Washington DC area.

4. Expand the Light Patterns layers (click the +). Examine the values listed. What is the highest light value (color and number) listed? _______________________ What is the lowest light value (color and number) listed? _______________________.

5. In ArcMap go under File; "Add Data from ArcGis online". In the “search” box, enter US topo Maps. Add the USA Topographic Maps map service by ESRI to your map. Click and drag Us topo Maps to the top of all the other layers in the list. Right click "US topo Maps" and click on properties. Click on the display tab (Advanced tab in ArcGIS 10) and set the transparency to 50%. What counties in Northern VA have the highest light value(s)?

_________________________________________________________________________

6. Zoom into Shenandoah County area of Virginia. Where do you notice that the light values are the brightest? ____________________________________________ How do you think this effects the behavior/patterns of the wildlife in the Shenandoah Valley?

_________________________________________________________________________
7. List three nocturnal animals that would live in the Shenandoah Valley and describe how they would be effected by the light pollution?

<table>
<thead>
<tr>
<th>Animal</th>
<th>Effects of Light Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Collapse (click the - minus sign) for the Lights Patterns in the VA View/Lights_At_Night_VA layer. Turn off (uncheck) the USA_Topo_Maps layer.

9. Turn on the **VAView/Lights_At_Night_US** layer. Click on the box and it puts a check in the box. Zoom out until you can see all of North America on your map. What is the general pattern of lights in the United States?

______________________________________________________________________________

_________

10. How does the East Coast compare to the West Coast?

______________________________________________________________________________

_____

11. What states in the West Coast have the most light pollution?

______________________________________________________________________________

_____

12. Turn on the "**VAView/Lights_At_Night_Comparison**" layer (click on the box and a check appears). Turn OFF the "**VAView/Lights_At_Night_US**" layer and the
"VAView/Lights_At_Night_VA" layer. Turn the "USA_topo_maps" layer back on. Zoom into the State of Virginia.

13. Expand (click the +) the layers "1992/1993" and "2000" to show the light value scales. Turn off the 2000 layer. Zoom into the Richmond/Petersburg Area. Click on the measuring tool (the ruler). Select the area icon in the "Measure" pop up window. Click on the drop down arrow and change the area units to Miles. Click on and drag the tool to measure the area in miles of lights in the Richmond/Peterburg/Hopewell. What is the area in square miles in 1992/1993? ________________________________.

14. Turn off the "1992/1993" layer and turn on the "2000" layer. Use the area tool to determine the miles of lights in the Richmond/Petersburg/Hopewell area in 2000. What is the area in square miles in 2000? ______________

15. Calculate the percent increase in area of lights in the Richmond/Petersburg/Hopewell area from 1992-1993 to 2000. Show all work!

16. Zoom back out to the view the whole state of Virginia. What county do you live in? _____________________ Calculate the percent increase in light pollution in your county from 1992/1993 to 2000. Show all work!

Conclusion:

1. Is light pollution a problem in your county? _______________ in Virginia? ______________ in the U.S.? ______________

2. Describe some solutions to remedy the light pollution increases in your county? in Virginia? in the US?
Section 2: Internet Access only

Procedure: Students and Teacher

1. Open your web browser
2. On separate tabs, open each of the following links:
   b. Repeat the above steps for the “Change in Nighttime Lights” map on the Interactive Web Mapper from Virginia View.
   c. Open the link to http://gep.frec.vt.edu/Digital_Atlas_PDFs/Virginia_Lights.pdf (a static map, not a web mapper).
3. Use the interactive web mapper links and the map you just opened to complete the following exercise.
Student Worksheet (Section 2: Internet Access)

Light Pollution

Name _____________________________  Partner's Name _____________________

1. Open the tab for Lights At Night in Virginia.

What areas of Virginia have the most lights at night? (Ex: Coastal Region, Northern VA)
_________________________________________________________________________

2. Make sure you have expanded the menu in "VA View/Lights_at_night_VA". (under Map Contents on the left). Turn off the "interstates" layer. Observe the pattern of lights in Virginia. Turn back on the "interstates" layer. Do you notice a connection? ________________
If so, what is the connection? _____________________________

3. Use the zoom (+ magnifier) button to zoom into the Northern VA/ Washington DC area.

4. Expand the Light Patterns layers (click the +). Examine the values listed. What is the highest light value (color and number) listed? _______________________  What is the lowest light value (color and number) listed? ________________________.

5. Still zoomed in to Northern Virginia, click the Identify tool (i in a circle on the top toolbar). Click on a county, and on the drop-down menu that appears, select VA (Counties). Scroll down to the County Name in the table that appears. What counties in Northern VA have the highest light value(s)? ___________________________________________

6. Zoom into Shenandoah County area of Virginia. Where do you notice that the light values are the brightest? ______________________________________________________ How do you think this effects the behavior/patterns of the wildlife in the Shenandoah Valley?
______________________________________________________________________________
7. List three nocturnal animals that would live in the Shenandoah Valley and describe how they would be effected by the light pollution?

<table>
<thead>
<tr>
<th>Animal</th>
<th>Effects of Light Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>


_________________________________________________________________________________________

________

9. How does the East Coast compare to the West Coast?

_________________________________________________________________________________________

________

10. What states in the West Coast have the most increase in light pollution?

_________________________________________________________________________________________

_____

11. Go to the *Lights_At_Night_Comparison* map.

12. Expand (click the +) the layers "1992/1993" and "2000" to show the light value scales. Turn off the **2000 layer**. Zoom into the Richmond/Petersburg Area. Click on the measuring tool (the ruler). Select the polygon icon in the "Measure" pop up window. Click on and drag the tool to measure the area in square miles of lights in the Richmond/Peterburg/Hopewell. What is the area in square miles in 1992/1993? ________________________________.

13. Turn off the "1992/1993" layer and turn on the "2000" layer. Use the area tool to determine the miles of lights in the Richmond/Petersburg/Hopewell area in 2000. What is the area in square miles in 2000? ____________

14. Calculate the percent increase in area of lights in the Richmond/Petersburg/Hopewell area from 1992-1993 to 2000. **Show all work!**
15. Zoom back out to the view the whole state of Virginia. What county do you live in? __________________________ Calculate the percent increase in light pollution in your county from 1992/1993 to 2000. Show all work!

**Conclusion:**

1. Is light pollution a problem in your county? ________________ in Virginia? ________________ in the U.S.? ________________

2. Describe some solutions to remedy the light pollution increases in your county? in Virginia? in the US?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Section 3: No computer access

Procedure for teacher’s preparation:

1. Print out the maps at:
2. You will need a dot grid, planimeter, or other area measurement tool for the students.
Student Worksheet (Section 3: No Computer Access)

Light Pollution

Name _____________________________  Partner's Name _____________________

1. Look at the map, “Lights at Night in Virginia”.

What areas of Virginia have the most lights at night? (Ex: Coastal Region, Northern VA)

_________________________________________________________________________

2. Look at the map of Virginia Interstates below. Observe the pattern of lights in Virginia. Do you notice a connection? _______________ If so, what is the connection?

_________________________________________________________________________

3. Look at the map, “Change in Night-time Lights” and focus on the Northern Virginia area.

4. What is the highest light value (color and number) listed? ________________________

What is the lowest light value (color and number) listed? ________________________

5. Look at the county key below. What counties in Northern VA have the highest light value(s)?

___________________________________________
6. Look at the Shenandoah County area of Virginia. Where do you notice that the light values are the brightest? ______________________________________________________ How do you think this effects the behavior/patterns of the wildlife in the Shenandoah Valley?

______________________________________________________________________________

________________________
7. List three nocturnal animals that would live in the Shenandoah Valley and describe how they would be effected by the light pollution?

<table>
<thead>
<tr>
<th>Animal</th>
<th>Effects of Light Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. What is the general pattern of lights in the United States?

______________________________________________________________________________

_________

9. How does the East Coast compare to the West Coast?

______________________________________________________________________________

_________

10. What states in the West Coast have the most increase in light pollution?

______________________________________________________________________________

_____

11. Look again at the “Lights at Night in Virginia.”

12. Look at the Richmond/Petersburg area. Using a dot grid or other area measurement tool, what is the area in square centimeters on the map of the lights in 1992/93?

______________________________________________________________________________

13. Use the same technique to determine the area of lights in the Richmond/Petersburg area in 2000. What is the area in square centimeters on the map in 2000? __________

14. Calculate the percent increase in area of lights in the Richmond/Petersburg/Hopewell area from 1992-1993 to 2000. **Show all work!**
15. Using the same techniques, calculate the percent increase in light pollution in your county from 1992/1993 to 2000. **Show all work!**

**Conclusion:**


2. Describe some solutions to remedy the light pollution increases in your county? in Virginia? in the US?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

______________________________________________________________________________
Student Worksheet (Key)

Light Pollution

Name _____________________________  Partner's Name _____________________

1. Turn Off the "VA View/Lights_at_night_Comparison" and "VA View/Lights_At_Night_US" layer (uncheck the box next to the names)

What areas of Virginia have the most lights at night? (Ex: Coastal Region, Northern VA)

Northern Virginia, Richmond, Tidewater areas

2. Make sure you have expanded the menu in "VA View/Lights_at_night_VA". Turn off the "interstates" layer. Observe the pattern of lights in Virginia. Turn back on the "interstates" layer. Do you notice a connection? **yes** If so, what is the connection? **Light pollution is occurring along the interstates**

3. Use the zoom (+ magnifier) button to zoom into the Northern VA/Washington DC area.

4. Expand the Light Patterns layers (click the +). Examine the values listed. What is the highest light value (color and number) listed? **-63 to -24 (red)** What is the lowest light value (color and number) listed? **29.1-63 (blue)**.

5. In ArcMap go under File; "Add Data from ArcGis online". Add **US topo Maps** to your map. Click and drag Us topo Maps to the top of all the other layers in the list. Right click "US topo Maps" and click on properties. Click on the display tab and set the transparency to 50%. What counties in Northern VA have the highest light value(s)? **Prince William County, Loudoun County, Warren County, etc**

6. Zoom into Shenandoah County area of Virginia. Where do you notice that the light values are the brightest? **along Interstate 81** How do you think this effects the behavior/patterns of the wildlife in the Shenandoah Valley? **Disrupts the biological clocks/behavior of nocturnal animals in the Shenandoah Valley**
7. List three nocturnal animals that would live in the Shenandoah Valley and describe how they would be effected by the light pollution?

<table>
<thead>
<tr>
<th>Animal</th>
<th>Effects of Light Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>opossum</td>
<td>Opossums would be attracted to the lights and get killed on the interstate</td>
</tr>
<tr>
<td>bats</td>
<td>Bats would go after insects that are attracted to the lights</td>
</tr>
<tr>
<td>skunks</td>
<td>Skunks would be attracted to the lights and get killed on the interstate.</td>
</tr>
</tbody>
</table>

8. Collapse (click the - minus sign) for the Lights Patterns in the VA View/Lights_At_Night_VA layer.

9. Turn on the VAView/Lights_At_Night_US layer. Click on the box and it puts a check in the box. Zoom out until you can see all of North America on your map. What is the general pattern of lights in the United States? **Light pollution is concentrated on the coastal areas of the United States, and the larger cities. It follows the population centers.**

10. How does the East Coast compare to the West Coast? **East Coast has more areas effected by light pollution. Light pollution on the West Coast of US is concentrated in a few states.**

11. What states in the West Coast have the most light pollution? **California, Portland Oregon (city), Seattle Washington (city)**

12. Turn on the "VAView/Lights_At_Night_Comparison" layer (click on the box and a check appears). Turn OFF the "VAView/Lights_At_Night_US" layer and the "VAView/Lights_At_Night_VA" layer. Make sure the "US topo maps" layer is still checked (is ON). Zoom into the State of Virginia.
13. Expand (click the +) the layers "1992/1993" and "2000" to show the light value scales. Turn off the 2000 layer. Zoom into the Richmond/Petersburg Area. Click on the measuring tool (the ruler). Select the area icon in the "Measure" pop up window. Click on the drop down arrow and change the area units to Miles. In ArcMap 10 use the dropdown arrow next to the sum symbol to change the area units to miles. Click on and drag the tool to measure the area in miles of lights in the Richmond/Peterburg/Hopewell. What is the area in miles in 1992/1993? approximately 524 sq miles (depends upon how much you zoomed in!)


15. Calculate the percent increase in area of lights in the Richmond/Petersburg/Hopewell area from 1992-1993 to 2000. Show all work!

\[
\frac{639-524}{524} \times 100 = 22\% \text{ increase in light pollution}
\]

16. Zoom back out to the view the whole state of Virginia. What county do you live in? _________________ Calculate the percent increase in light pollution in your county from 1992/1993 to 2000. Show all work!

Conclusion:

1. Is light pollution a problem in your county? Depends on where students live. Most counties will have a problem. in Virginia? yes in the U.S.? yes
2. Describe some solutions to remedy the light pollution increases in your county? in Virginia? in the US?

Answers will vary. Here are some possibilities. Design lights that point downward instead of upward to the night sky. Have lights on a timer so that they are not on ALL night long, just peak times. In neighborhoods have lights rotate on and off (every other light on or off in a row). Reduce the number of street lights. Turn lights off!
Resources


A map-based resource designed for Virginia teachers. The Digital Atlas contains many different maps pertinent to Virginia in several accessible formats.


A Federal source of national-scale maps and geographic data of many different themes, including base maps.


Article quoted at beginning of exercise. Useful for overview of Light Pollution and its ramifications.