2017

# How Green Is It? Learning Light and Electromagnetic Spectrum Properties By Measuring Algae. Subjects: Physical Science, Chemistry, Environmental Science, Life Science Grades: 9-12

Alice Besterman
*University of Virginia*

# HOW GREEN IS IT?

## LEARNING LIGHT AND ELECTROMAGNETIC SPECTRUM PROPERTIES BY MEASURING ALGAE

**Alice Besterman**
University of Virginia

**Grade Level**
High School

**Subject area**
Physics, Biology, or Environmental Science

*This work is sponsored by the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center.*




1. **Title:**
   How Green Is It? Learning Light and Electromagnetic Spectrum Properties by Measuring Algae

2. **Focus:**
   Light and the Electromagnetic Spectrum: Absorption, Reflection, Color

3. **Grade Level/Subject:**
   High School or Advanced Middle School
   Physics, Biology

4. **Virginia Science Standards Addressed:**

   **PH.8** The student will investigate and understand wave phenomena. Key concepts include a) wave characteristics; and c) light and sound in terms of wave models.

   **PH.9** The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include a) the properties, behaviors, and relative size of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays; and c) current applications based on the respective wavelengths.

   **BIO.2** The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

   **BIO.4** The student will investigate and understand life functions of Archaea, Bacteria and Eukarya. Key concepts include c) how the structures and functions vary among and within the Eukarya kingdoms of protists, fungi, plants, and animals, including humans

5. **Learning Objectives:**
   a) Students will learn how colors correspond with visible light wavelengths by coloring
   b) Students will plot reflectance and absorbance curves based on data
   c) Students will calculate % reflectance from % absorbance data
   d) Students will consider how shading affects photosynthesis
   e) Students will learn through an example calculation how absorbance is used as a proxy for biomass in vegetation surveys
   f) Students will hear about the application of the electromagnetic spectrum, absorbance and reflectance data to ecological research
   g) Students will consider how seaweed growth affects ecosystem health

6. **Total length of time:**
   90 minute block class

**Key Words**

**Electromagnetic Spectrum**- the entire range of frequencies and wavelengths over which electromagnetic radiation exists

**Wavelength**- the distance between one trough and the next trough for a wave
**Frequency**- the number of waves that pass a given point per second
**Wave period**- the length of time it takes for an entire wave to pass; also equal to 1/frequency
**Nanometer**- a unit of length equal to one billionth of a meter
**Infrared**- radiation occurring just after the visible light spectrum, between 700 nm and 1 mm wavelengths
**Visible Light**- radiation visible to humans, from about 390 nm to 700 nm wavelengths.
**Reflectance**- the proportion of incoming radiation that bounces off of (or is reflected from) an object or surface
**Transmission**- the proportion of incoming radiation that passes through an object or surface
**Absorbance**- the proportion of incoming radiation that is absorbed by an object or surface
**Spectrophotometer**- device that can be used to measure transmittance or reflectance of solutions
**Mudflat-** unvegetated, coastal areas composed of soft and wet sediments that sit below mean sea level and are exposed and covered daily by the tide
**Macroalgae**- multicellular organisms that are photosynthetic and live in aquatic or semi-aquatic ecosystems; colloquially referred to as “seaweeds”. Generally divided into red, green, and brown macroalga groups
**Invasive organism**- an organism that has established itself in an ecosystem where it is not native; usually negative consequences for other organisms are associated with the introduction and establishment of invasive species ***Gracilaria vermiculophylla***- a species of red macroalgae native to east Asia that
has invaded ecosystems around the world; it has become the dominant macroalga in many coastal areas on the east coast of the United States
**Microalgae**- single-celled organisms that are photosynthetic and live usually live in aquatic or semi-aquatic ecosystems
**Chlorophyll**- green substance in plants that absorbs energy and allows photosynthetic organisms to make sugars from sunlight and carbon dioxide **Remote Sensing**- scanning of earth surfaces by satellites or other aircraft in order to obtain information

## 7. Background Information

The electromagnetic spectrum is a method of organizing the types of energy found in the universe (Coulson and Kennedy). This energy travels as a transverse wave, and the spectrum can be divided into sections of characteristic waves (Cortez, Coulson and Kennedy, "Light Waves and Color"). These characteristic waves have a signature length and frequency ("Light Waves and Color"). Wavelength is the distance between one crest and the next; for the electromagnetic spectrum wavelengths are measured in nanometers (one billionth of a meter) (Cortez). Human vision includes wavelengths between about 400 and 700 nm ("Light Waves and Color"). This section is called Visible Light. Each color we see corresponds with a section of wavelengths within the Visible Light spectrum. White light is the combination of all of the wavelengths of visible light, and black light is the absence of all wavelengths. Materials can absorb, reflect, or transmit wavelengths of energy. A material absorbs wavelengths of light when the molecules in the material use the energy from those wavelengths. Reflectance involves wavelengths bouncing off the surface of an object. Transmission means the wavelengths pass through the object. Different materials absorb, reflect and transmit different wavelengths depending on their physical and chemical properties. The color we see when we look at an object is the combination of the light reflected and transmitted by that object. (Coulson and Kennedy, "Light Waves and Color").

Plants use light to make the sugar they need to survive, grow and reproduce (a process called photosynthesis). Pigments in molecules called chloroplasts absorb certain wavelengths of light and use that energy to make sugar. These pigments called chlorophyll absorb and reflect characteristic wavelengths. Therefore, researchers can learn about where plants are and are not using spectral information. Measuring the cover and quantities of photosynthetic biomass using light spectral data can be used for ground sampling or remote sensing. Remote Sensing is the process of surveying the earth by satellites or aircraft to obtain information. Remote sensing can be used to measure cover and quantities of vegetation by measuring the wavelengths of light reflected from a surface by a sensor on the aircraft or satellite. On the ground, samples of sediments can be collected to measure the biomass of photosynthetic organisms by extracting chlorophyll from the sample and measuring the percent absorbance in a spectrophotometer. A spectrophotometer is a device that measures the absorbance of a material at set wavelengths, or produces an absorbance spectrum. (Hambrook and Canova, 2007; Bryson et al. 2013).

One application of this method used by ecologists is to detect the amount algae found in an ecosystem or landscape (Hambrook and Canova, 2007; Bryson et al. 2013). Algae are simple photosynthetic organisms. Algae can either be large and multicellular (macroalgae, or "seaweed") or microscopic and unicellular (microalgae). Algae are increasing in coastal areas globally due to water pollution and invasive species ("Harmful Algal Blooms"). One invasive species of algae is called *Gracilaria vermiculophylla*. It is from East Asia and grows in thick mats on coastal areas called mudflats (Thomsen, et al. 2006). Mudflats are covered and uncovered by water each day by tides, and are muddy ecosystems without any large rooted plants. However, they are an important habitat for many animals and microalgae living on the surface of the mud. The growth of *Gracilaria vermiculophylla* may shade microalgae living on the surface of the mud, preventing these organisms from receiving the light they need to photosynthesize (Hardison et al. 2013).

However, some algae can survive low light environments (Hardison et al. 2013). In this activity students will apply the knowledge of the electromagnetic spectrum to detect the presence of *Gracilaria vermiculophylla* mats and determine whether it is negatively affecting the survival of microalgae living on the mud beneath the mats.

Literature Cited


Bryson M, Johnson-Roberson M, Murphy RJ, Bongiorno D (2013) Kite Aerial Photography for Low-Cost, Ultra-high Spatial Resolution Multi-Spectral Mapping of Intertidal Landscapes. PLoS ONE 8(9): e73550.

Cortez, Krystal. "Middle School Science Help: PARTS OF WAVES." *Mathxscience*. Web. 06 July 2016. <http://mathxscience.com/wave_parts.html>.

Coulson, Tracy L., and Karen Kennedy. "The Electromagnetic Spectrum: Waves of Energy." *Discovery Education*. Discovery,Web. 06 July 2016.

<http://www.discoveryeducation.com/teachers/free-lesson-plans/theelectromagnetic-spectrum-waves-of-energy.cfm>.

Hambrook Berkman, J.A., and Canova, M.G., 2007, Algal biomass indicators (ver. 1.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A7, section 7.4, August, available online only from http://pubs.water.usgs.gov/twri9A/.

Hardison, A. K., Canuel, E. A., Anderson, I. C., Tobias, C. R., Veuger, B., and Waters, M. N.: Microphytobenthos and benthic macroalgae determine sediment organic matter composition in shallow photic sediments, Biogeosciences, 10, 5571-5588.

"Harmful Algal Blooms." *Marine Pollution.* Science Education through Earth Observation for High Schools. Web. 06 July 2016. http://lms.seos-project.eu/learning_modules/marinepollution/marinepollution-c03-p02.html

"Light Waves and Color: Lesson 2- Color and Vision." *The Physics Classroom*. The Physics Classroom, Web. 06 July 2016. <http://www.physicsclassroom.com/class/light/Lesson- 2/The-Electromagnetic-and-Visible-Spectra>.

Thomsen, M. S., Gurgel, C. F. D., Fredericq, S. and McGlathery, K. J. (2006), *Gracilaria vermiculophylla* (Rhodophyta, Gracilariales) in Hog Island Bay, Virginia: ACryptic Alien and Invasive Macroalga and Taxonomic Correction. Journal of Phycology, 42: 139–141.


**8. Handouts and materials**

- "How Green Is It? Worksheet"
- "Reflectance and Absorbance Data"
- "The Problem Card"
- "The Electromagnetic Spectrum Tutorial": http://school.discoveryeducation.com/lessonplans/interact/electromagneticspectrum.html
- Visible Light Spectrum Picture
- "How Green Is It? Powerpoint"

**Note depending on group size the teacher may choose to print more or fewer copies of the worksheet, data, and problem card per group. In groups all students will need access to page 1 and 6 of the worksheet, the Reflectance and Absorbance Data, and the Problem Card. In groups students will split up pages 2-5 of the worksheet where one sub-group tackles pages 2-3, and the other sub-group works on pages 4-5. It is up to the teacher's discretion whether each student receives their own packet of all of the pages, a subset of pages, or one packet could be distributed per group for students to divide as needed.

**9. Materials and Supplies**

- Colored pencils or Crayons (set per group)
- Either printed copies of the Visible Light Spectrum picture, or a projector to put the image on the board for all students to see

**10. Classroom set-up**

Students should have enough table or desk space to work together in a group of four and have coloring utensils in a place accessible to all four students. If the classroom has individual desks clustering them into groups of four would be helpful. Students will only be coloring worksheets so they do not need any space for demonstrations or supplies.

**11. Procedure**

**Advanced Prep**: **(30 minutes)** Acquire coloring utensils, print worksheets.

**Set-Up**: **(5 minutes)** Place appropriate coloring utensils, one problem card and one worksheet packet at the center of each table or cluster of desks

**Introduction: (25 minutes)** The teacher should introduce the concepts of absorbance, transmission, and reflectance of electromagnetic radiation. The activity assumes students have already been introduced to the parts of a wave, the electromagnetic spectrum, and the concepts of wavelength, frequency, wave period etc. Then, the class should read the "Problem Card" together (either in groups, to themselves, read along with the teacher, or students take turns reading paragraphs to the entire class). In groups students should answer the questions on page 1 of the worksheet.

**Activity: (65 Minutes)**

1. Instruct students to break into teams of two in their groups. One team will study Willis Wharf and one will study Oyster Harbor.
2. Students should begin by coloring in the boxes labeled with visible light wavelengths at the top of the data table on the Reflectance and Absorbance Data sheet. This color code will serve as a key. The teacher should provide the visible light spectrum picture as a print out for each group, or just project it for the whole class to see.
3. Instruct students to work through the first part of the worksheet where they use reflectance data to figure out which of the two mudflats has *Gracilaria* growing on it. The students should first plot the data from the data table on page 1 of their worksheet packet on the appropriate plots. Sections are labeled on the mudflat and on the plot diagram. Make sure students understand how to plot a coordinate point on a coordinate plane using the x and y axes, and that the students recognize the labels on each axis. After plotting their points and drawing a curve to connect them they should color the mudflat picture appropriately.
4. Students then complete the second part of the assignment using the absorbance data from the data sheet.
5. After completing the plots and figures students should analyze their results and draw conclusions by working through the questions in the "Analysis and Discussion" section. These should be completed in the smaller groups. Then the class should come back together and all

go over the answers. Consider asking a designated "scribe" student from each group to write the group's answers on the board. Another student designated "presenter" can read the answers aloud. Questions 1 and 2 are simple while 3 and 4 are more thought provoking. Leave extra time to discuss 3 and 4 as a class.

**Assessment**

*Questions:*

1. Which color has the longest wavelength? Which color has the shortest? Higher frequency electromagnetic radiation has higher energy. Which color has the highest energy? Which color has the lowest energy?
2. Describe how an environmental scientist might use the electromagnetic spectrum in their research on seaweed.
3. Recall the equation for photosynthesis

   $6CO_2 + 6H_2O \rightarrow 6O_2 + C_6H_{12}O_6 + \text{heat}$

   Consider that heat is a product. Can you think of what other wavelengths may be emitted from photosynthetic organisms?

*Further Assessment*: Have students write their conclusions as if they are environmental scientists writing a report describing their findings. Their reports should include where they found *Gracilaria*, how they know it is there, and what effects it is having on the mudflat. They should emphasize the evidence they have supporting their claims.