Watershed Wonders

Standard Based Activities and Information About Water and Watersheds for Middle and High School Classrooms

Presented by the Algalita Marine Research Foundation
www.algalita.org

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Curriculum and materials funded by a grant from:
The American Honda Foundation

Distribution funded by:
The American Honda Foundation
California Coastal Commission – Whale Tail
Heller Charitable & Educational Fund

Acknowledgements

Some activities in this curriculum were adapted from educational materials produced by agencies and organizations concerned about marine and watershed conservation. The Algalita Marine Research Foundation would like to thank:

Project Wet Curriculum and Activity Guide. For further information contact the national office of Project Wet at (406) 994-5392 or www.watereducation.org

Waves, Wetlands and Watersheds. For further information contact the California Coastal Commission at (800) COAST-4U or coast4u@coastal.ca.gov

Mountains to the Sea Watershed Curriculum. For further information contact Project Clean Water at (805) 568-3546 or (805) 564-5574. Also, contact the Community Environmental Council in Santa Barbara at (805) 682-6113 or www.communityenvironmentalcouncil.org.

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About This Curriculum and Video

The Algalita Marine Research Foundation has brought to light the magnitude of the problems plastic debris pose for our oceans. Our watersheds are the source of most plastic debris in the ocean. The classroom is a great starting point for promoting a conservation ethic and creating a culture of stewardship.

Watershed Wonders is a hands-on curriculum that encourages teachers to engage students in conservation of their local watershed. The activities provide opportunities for teachers and students to go outside the classroom to discover what happens to water once it leaves our homes and school grounds.

The 32-minute DVD production titled "Watershed Wonders", located on the inside of the back cover of this book, provides teachers and students with a chaptered overview of watershed principles and conservation strategies. It is recommended that students watch the entire program prior to beginning any activity in this curriculum. Watershed Wonders gives students basic information they may use to formulate their thoughts about water and its use, but the program can also give students an emotional investment in sustainable living.

There are four chapters to select from in this DVD production.

Chapter 1:
What is a Watershed?

Watershed defined
The water cycle
The path of water in the watershed, from mountains to the ocean

Chapter 2:
Human Impact on the Watershed: Problems and Solutions

Trash in the watershed and how it affects the marshland ecosystem
Biodiversity defined
The human impact on kelp forests

Chapter 3:
Plastic Debris Research

Plastic debris affects Laysan Albatross at Midway Atoll
The work of the *Oceanographic Research Vessel Alguita*
Plastic pellets, called "nurdles", in the watershed

Chapter 4:
Sustainability Within the Watershed

Sustainability defined
Audubon Center: a model for sustainable architecture
New technologies to treat sewage and urban runoff
Interview with Bill Roley, Ph.D: Living a sustainable lifestyle
Our responsibility as stewards of our natural world

Chapter 1

What is a Watershed?

A watershed is an area that is drained by rivers and streams and includes geographical structures like mountains, valleys, and man-made structures like buildings, parking lots and highways, and it also includes a rich biodiversity that is supported by the ecosystems within.

Drop in a Bucket:
The Scarcity of Water

California Science Standard:
6th Grade, Ecology (6b)
Resources: Sources of energy and materials differ in amounts, distribution, usefulness, and time required for their formation.
9th –12th Grade, Investigation and Experimentation (1a,b,c,d,f,I,j,k,l,m)
Scientific progress is made by asking meaningful questions and conducting careful investigations.

Time: One 50-minute class period

Objectives:
Students will know that the Earth is covered with water, but only a small amount is available for human consumption.
Students will be able to explain why water is a limited resource, and appreciate its scarcity.
Students will understand percentages and how to use beakers and graduated cylinders to measure water.

Background Information:

Earth is a water planet, but when you break down the percentages, there isn't much clean water for us to use. Ironically, on a planet extensively covered with water, this resource is one of the main limiting factors for life on earth.

If all the clean, fresh water were distributed equally among all people, there would be about 1.82 million gallons (7 million liters) per person. While this is a large amount per individual, it is only about 0.003 percent of the total amount of water on Earth. For some, water may appear to be plentiful, but for others it is a scarce commodity. Where you live and how you use water makes the difference. Geography, climate, and weather affect water distribution. Agriculture, industry, and domestic use affect availability.

The water we drink and use every day comes from our watershed. In the U.S. 61% of our population relies on lakes, rivers, and streams as our source of drinking water. The other 39% rely on groundwater that they pump from the ground.

Materials:
1. Map or globe of the Earth
2. One 1000ml beaker filled with water
3. One 100ml graduated cylinder
4. One 10ml graduated cylinder
5. Large bucket or bowl
6. Eyedropper
7. Tablespoon of salt

Procedure:
1. Demonstration: The Scarcity of Usable Water.

a. Fill the 1000ml beaker with water and place it in front of the class. Have the other materials on the table as well. Tell students that 1000ml of water represents all of the water on the planet. Refer to the map to confirm for students the combined area of oceans, seas and lakes compared to land.
b. Pour 30ml from the large beaker into the 100ml graduated cylinder. Tell students that this amount of water represents 3% of the Earth's water that is fresh water. Put the tablespoon of salt into the 970ml left in the large beaker.
c. Ask students where they would go to find most of the Earth's fresh water? Polar ice is where 80% of the Earth's fresh water is concentrated. Pour 6ml of water from the 30ml in the large graduated cylinder into the small graduated cylinder. This represents non-frozen fresh water.
d. Explain to students that most of the remaining fresh water is underground in places too difficult to access. The fresh water that we have access to in rivers, lakes and near-surface wells is sometimes polluted. Ask students how much of the 6ml of water is potable (clean enough to drink)?
e. Take the eyedropper and remove a single drop of water from the 6ml of water in the small graduated cylinder. A single drop of water is approximately 0.03ml of water, which represents the clean, fresh water that is available for humans to use. That's only 0.003%!
f. Write 0.003% on the board and discuss this demonstration with the class.

2. Activity: Water Availability for Each Person on Earth
   a. Distribute a copy of "Water Availability Worksheet" to each student.
   b. Explain to students that if we were to divide the total amount of water to each of the 6 billion people on the planet, it would amount to 233.3 billion liters per person.
   c. Give students 15 minutes to complete the worksheet.
   d. Discuss the results with students.

Answer Key to "Water Availability Worksheet"	
100% of the Earth's water divided between 6 billion people	233.3 billion liters per person
Multiply 233.3 billion liters by 3% (or .03) to determine the amount of fresh water available per person	7 billion liters of fresh water available per person
80% of the available fresh water is frozen at the Earth's poles. Multiply 7 billion by 20% (or .2) to determine the amount of non-frozen available fresh water	1.4 billion liters of available fresh water on earth is not frozen.
99.9% of the available fresh water is inaccessible, being trapped in soil, too deep to reach, or polluted. Multiply 1.4 billion by .05% (or 0.0005)	Only 7 million liters of water is available for each person on Earth.

Questions:

1. Where is most of the usable fresh water located?
2. How does availability of water effect human population growth?
3. How do cities and states share fresh water resources, like the Colorado River?
4. How do nations share water, like the Rio Grande River?
5. How has this activity changed your mind about water use?

Water Availability Worksheet		
Quantity of Water to be Divided	Available Water for People	Percentage of Total Water
If all of the Earth's water was divided between 6 billion people, we would each have 233.3 billion liters to live with.	233.3 billion liters	100%
Remember, most of the Earths water is not potable (clean enough to drink). Only 3% of the Earth's water is clean, fresh water we can use. Calculate 3% of 233.3 billion liters. This is the amount of potable water available to each of the 6 billion people so far in this activity.		
What is at the poles of the Earth? Most of the fresh water on Earth is frozen. The Ice caps hold approximately 80% of the Earth's fresh water. That leaves 20% for 6 billion people on the planet to share. Calculate how many liters are left for each person.		
99.5% of the unfrozen fresh water is trapped in soil, buried too deep access, or is polluted. Only .5% is available for us to drink. Calculate the amount of fresh water remaining for each of the 6 billion people on Earth.		

Water Cycle Demonstration

California Science Standard:
<u>5th Grade, Earth Sciences (3e)</u>
Water on Earth moves between the oceans and land through the processes of evaporation and condensation.

Time: 20 minute setup by teacher

Objective:
Students will observe the relationship between evaporation and condensation in the water cycle.

Background Information:

All the water that has ever been available to our planet is on or in the earth right now. On the entire planet, there are 326 million cubic miles of water. If the earth were a globe 28 inches in diameter, all of the water on the planet would fill less than one cup. Of that amount, only .03% is in river systems and freshwater lakes. This means that only slightly more than one drop would fill all the rivers and lakes.

Waterways like rivers, lakes, and streams are a vital expression of the water cycle. All the rain and snow that falls on the land either seeps into the water table or is carried away to the sea. In addition, all along the way, water evaporates or finds its way through plants and transpires back into the atmosphere to form clouds and precipitation again.

With this picture of the scale and interconnectedness of our planet's freshwater resources in mind, it is apparent how fragile this vital substance is. Yet each day water is being damaged by pollution--pollution that stresses ecosystems beyond their capacities to support life.

This demonstration is an excellent example of how water transports through a watershed. The kettle represents any body of water (lake, river, ocean) that is heated by the sun and begins to evaporate. When the water vapor cools at high altitudes it forms clouds. The colder temperatures cause water to condense from gas to liquid, like a cloud moving into a colder region may condense and form rain. The plate that catches the precipitation represents a lake, thus the cycle continues.

Materials:

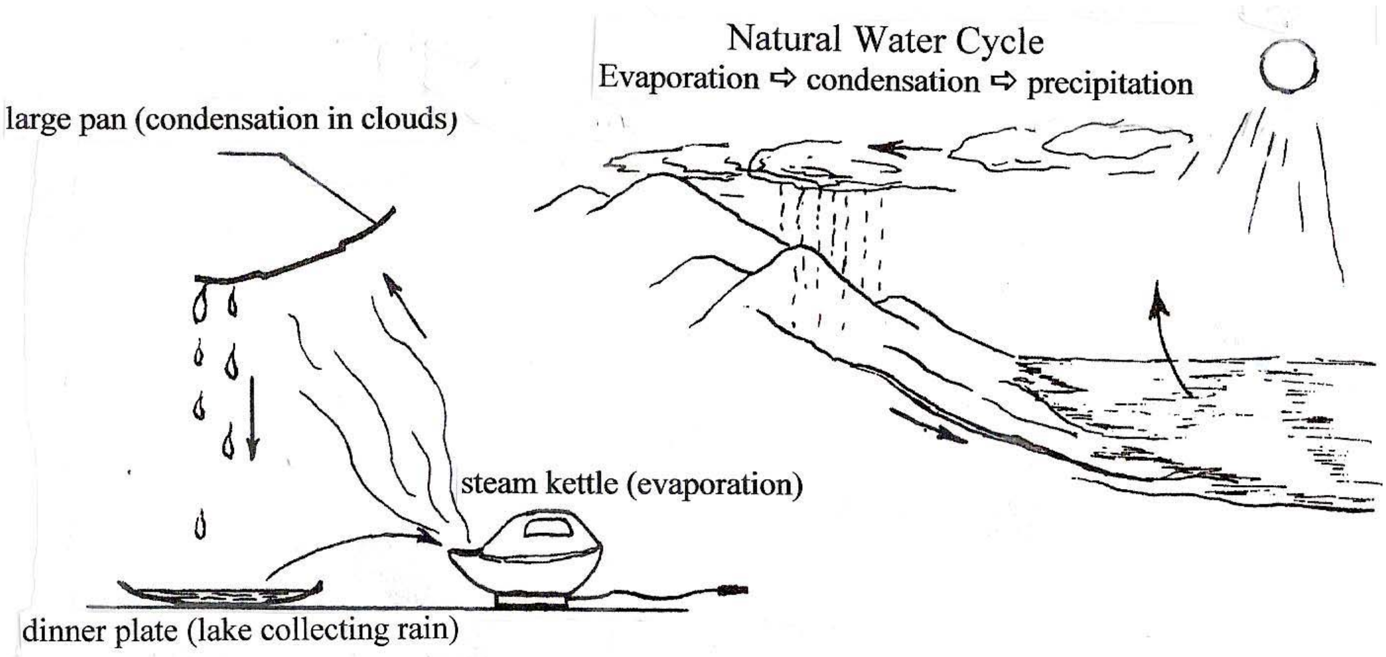
Two dinner plates or pie tins
Electric water kettle
Cup of sand

Procedure:

1. Put cup of sand (optional) and water in kettle and bring to boil. (The purpose of the sand is to show that evaporation doesn't carry sediment or salt.)
2. Elevate one of the plates on an angle above the cloud of steam that emerges from the kettle.
3. Position the other plate beneath the angled plate so that it catches the drips of water as they form.

Questions:

1. Why did the steam turn back into water?
2. Would droplets have formed on the plate if it were hot?
3. What makes water evaporate naturally?
4. What conditions make a rainfall from a cloud?
5. What was left in the kettle after the water had boiled away?



Web Extension:

This website has an online assessment about watersheds.
http://www.vanderbilt.edu/VirtualSchool/pollution.htm

Build a Watershed Model

California Science Standard:
5th Grade, Earth Sciences (3e)
Water on Earth moves between the oceans and land through the processes of evaporation and condensation.
9th-12th Grade, California Geology (9a,b,c)
The geology of California underlies the state's wealth of natural resources as well as its natural hazards.

Time: One 50-minute class period

Objective:
Students will understand the parameters of a watershed by building a model and running water through it.
Students will compare the quality of water in a watershed before and after human development, by running water through a watershed model before and after the introduction of simulated pollution (red dye and cocoa powder).
Students will recognize the difference between point source and nonpoint source pollution that travels through the watershed.

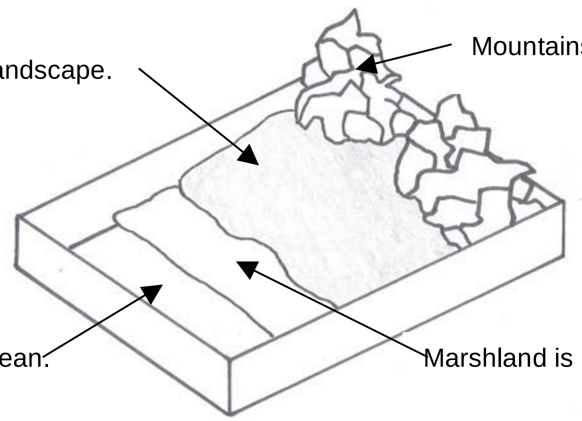
Background Information:
A watershed is an area that is drained by rivers and streams and includes geographical structures like mountains, valleys, and man-made structures like buildings, parking lots and highways, and it also includes a rich biodiversity that is supported by the ecosystems within. As water travels through the watershed many types of pollutants may be carried downstream to places where wildlife thrives.
Land-based marine pollution can either be from a "point source" or a "nonpoint source." Point source pollution originates from a specific place such as an oil refinery or a paper mill. Nonpoint source pollution, on the other hand, is contaminated runoff originating from an indefinite or undefined place, often a variety of places (e.g., farms, city streets and parking lots, yards and landscaping, construction sites, and logging operations). The soot, dust, oil, animal wastes, litter, sand, salt, pesticides and other chemicals that constitute nonpoint source pollution often come from everyday activities. They are washed from lawns and streets into storm drains that often lead directly to nearby bodies of water such as streams, rivers and oceans. Pollution from contaminated runoff can affect aquatic ecosystems and cause the ocean to be unsafe for people to swim in.
Nonpoint source pollution, contributed potentially by all of us in small quantities and from many different locations, is very difficult to track and stop. These small quantities add up to become the largest contributor to water pollution in our local environment.

Materials:
A cake pan for each student group
Sand
Red food coloring
Cocoa powder

Paper towels
Spray bottle
Newspaper
Assortment of items to represent developed land (pennies, plastic caps, buttons)
Aluminum foil (to represent paved areas in developed land)

Procedure:

1. Discuss the background information with students. Emphasize the definitions of: watershed, point source pollution, non-point source pollution.
2. Assign students to groups of 3-4 students and distribute materials.
3. Allow students 20 minutes to build their watershed.
    a. Lay down paper towels on one end of the pan to represent wetlands.
    b. Use crumpled newspaper to represent mountains.
    c. Sand can be used across the middle of the pan to represent urban and rural landscape.



4. THE FIRST RAINFALL (before human development)
    a. Using the spray bottle, soak the model.
    b. Let the water flow downhill and choose its own path through the sand to form rivers and streams.
    c. Describe the path of water through the model.
5. Build a city using pennies, plastic caps, buttons and other items to represent houses, streets and other buildings. Use pieces of aluminum foil to represent parking lots.
6. Place a drop of red dye on the street in front of each house, and on top of each parking lot to represent nonpoint source pollution.
7. Place a spoon full of cocoa power next to a river to represent point source pollution from a factory or landfill.
8. THE SECOND RAINFALL (after human development)
    a. Using the spray bottle, soak the model.
    b. Let the water flow off the urban landscape and into the river, marsh and ocean.
    c. Describe the path of water through the model.

Questions:

1. What is the relationship between elevation and the size of a watershed?
2. Of the ecosystems in a watershed, which are the most vulnerable to pollution?

The Water Cycle Through Your School

California Science Standard:
6th Grade, Ecology (5e)
Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.
6th Grade, Ecology (6b)
Resources: Sources of energy and materials differ in amounts, distribution, usefulness, and time required for their formation.
9th-12th Grade, Ecology (6d)
Stability in an ecosystem is a balance between competing effects.

Time: One 50-minute class period

Objective:
Students will recognize the massive weight of rainfall that enters the watershed by calculating the volume of rain that falls on the school in a year.
Students will understand the different pathways that water travels in the watershed by discussing ground absorption of water, runoff and investigating municipal pathways of storm drains to transport rain water.

Background Information:

Students may understand rainfall, but runoff is sometimes an unfamiliar concept. We often watch rain or snow attentively, but seldom consider the volume of water falling. The volume and mass of precipitation from a single rainstorm is astounding when you calculate the values.

Understanding the amount of water that flows through the watershed and the many processes that transport water is important to understanding the water cycle. Lateral movement of water across the land is called “runoff.” Runoff may flow naturally into streams or rivers, or through man-made structures like storm drains and flood control channels. Water may move vertically into the earth, being absorbed by soil or recharging deep aquifers.

Urban development, like parking lots, streets and buildings, may impede absorption of water into soil and aquifers, thus adversely affecting vegetation and groundwater recharge. Water that is not absorbed vertically will move horizontally as increased runoff. Increased volumes of runoff result is more rapid erosion and sediment plumes in water bodies.

Runoff is the primary way that water travels through the watershed. Many pollutants, like motor oil, plastic debris, and waste from industrial sites, are transported by runoff into streams and rivers into outlying natural places.

Materials:

Meter stick and 100 meters of string
Local rainfall data (search internet sources)
Writing materials and calculator
Local map.

Local street map that includes your school, city, and drainage systems, like flood control channels, streams, rivers, lakes or oceans. For a great urban map that includes these watershed features, contact your local Department of Public Works for free maps.

Worksheet: Determine School Area

Worksheet: Weight of Rain on my School

Procedure:

1. Discuss background information with students, and divide the class into groups of 3-4 students.
2. Determine the dimensions of your school.
    a. Take the 100 meters of string and tie a knot at every yard.
    b. Using the map of your school, draw the shape of the perimeter.
    c. Using the 100 meters of knotted string, measure the length of each segment of the perimeter, from corner to corner.
3. Determine area of the school grounds.
    a. Give student groups the "Determine School Area Worksheet."

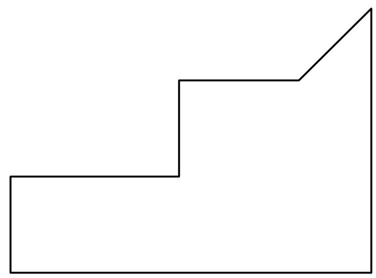
4. Determine the weight of precipitation on the school annually.
    a. Give each student a copy of "Worksheet: Weight of Rain on My School"
    b. Explain to students how to find the rate of annual rainfall for your region. Try to obtain local data if possible.
        i. Search online for rates of rainfall. National Weather Service has online regional rates of rainfall. City or county public works departments usually publish rainfall data.
        ii. Rainfall data will be measured as feet or inches per year, (e.g. 9 in./yr., or .75ft./yr.) Convert to centimeters per year, (2.54 cm = 1 inch).

Questions:

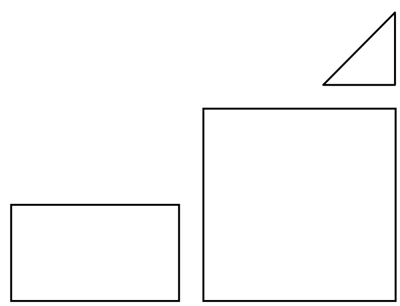
1. Using the city map, answer the following questions about the flow of runoff from your school.
    a. Locate the storm drains near your school.
    b. Locate the nearest stream, river or flood control channel on the map.
    c. Locate the river, lake, ocean or other body of water that flood channels flow into.
    d. Using a pencil and a piece of white paper, trace the path of water from your school.
2. What are some of the positive and negative effects runoff may have as it travels across the surface of the land?
3. At what points along the watershed can water be absorbed into the ground?
4. What kinds of pollutants does the water come in contact with as it travels across the surface of the land?
5. In what ways is the water used by people, plants and animals along the way?
6. Where does the water finally travel? What living things live there? How are they affected by the pollutants contained in the runoff?

Worksheet: Determine School Area

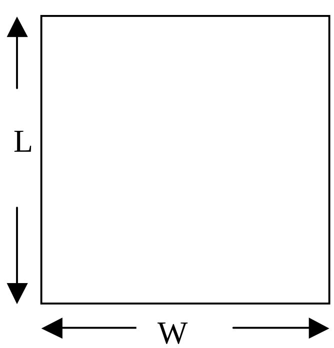
1. Using the map of the school, divide the school grounds into squares and right triangles using your best estimations. For example, a school that has a perimeter that looks like this:



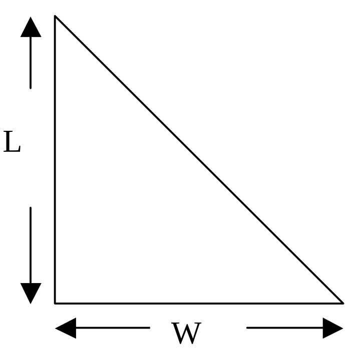
should be redrawn like this:



2. Determine the area of each square, rectangle and right triangle.



L x W = area (A)
of a square or rectangle



L x W x 1/2 = area (A)
of a right triangle

3. Add all of the area calculations together. This is the total area of your school. The area of your school will be measured in square meters. Your answer should be written in square meters($m.^2$).

Worksheet: Weight of Rain on my School		
Area of school	Written in square meters (m.^{2})	(__________ m.^{2})
Annual rate of rainfall for region	Written in meters per year (m./yr.) Remember: 2.54cm = 1 inch 100cm = 1 meter	(__________ m./yr.)
Volume of rainfall for school	Multiply the area of your school by the annual rainfall to get square feet per year. Make sure that area and annual rainfall are both measured in feet.	(_______m.^{2}) x (___ m./yr.) = (_____ m.^{3}/yr.)
Calculate the weight of annual rainfall	Water weighs 1002 kilograms per cubic meter (1002 kg./ m.^{3}). Multiply volume of rainfall by 1002 kilograms to calculate the weight of annual rainfall.	(_____ m.^{3}/yr.) x (1002 kg./ m.^{3})= (_______ kg./ yr.)
Calculate the number of metric tons of rainfall per year.	1000 kilograms equal one metric ton, therefore divide the number of kilograms per year by 1000 to determine the number of metric tons per year. MT = metric ton	(______ kg./ yr.) x .001 MT/kg.) = (______ MT/yr.)

Chapter 2

Human Impact on the Watershed: Problems and Solutions

Deadly Waters

California Science Standard:
<u>6th Grade, Ecology (5e)</u>
Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.
<u>6th Grade, Ecology (6b)</u>
Resources: Sources of energy and materials differ in amounts, distribution, usefulness, and time required for their formation.
<u>9th-12th Grade, Ecology (6b,c)</u>
Stability in an ecosystem is a balance between competing effects.
<u>9th-12th Grade, California Geology (9a,b,c)</u>
The geology of California underlies the state's wealth of natural resources as well as its natural hazards.

Time: One 50-minute class period

Objectives:
Students will identify major sources of aquatic pollution, by dividing into research teams and evaluating pollutants in a hypothetical river.
Students will make inferences about the potential effects of a variety of aquatic pollutants on wildlife and wildlife habitats.

Background Information:
What are the effects that large quantities of pollutants might have on an aquatic environment? Students know about water pollution, but may not understand the effects that these pollutants have on the environment. Most pollutants can be divided into five categories.

Chemical Pollution - The introduction of toxic substances into an ecosystem, e.g., acid rain, contamination of water supplies by pesticides, toxins released from degraded plastics. Clearly human caused.
Mechanical Pollution – Water courses carry human made debris, like plastic food containers and car tires, and natural debris, like sediment and plant material. This debris is transported through the watershed. Plastic trash can break apart as is travels or can photodegrade, sometimes resulting in chemical pollution as other toxins are released.
Thermal Pollution - Varying temperatures above or below the normal condition, e.g., power plant turbine heated water. Dominantly human caused through nuclear power plants, fuel-based electrical power production, and many industries. Some dams also produce unnaturally cooled water with bottom discharges of water.
Organic Pollution - Oversupplying an ecosystem with nutrients. Dominantly human caused, organic pollution in lakes and rivers typically results when organisms living there are enhanced by chemical fertilizers used in agriculture.
Ecological Pollution - Stresses ordinarily created by natural processes, i.e., adding a substance that is not a naturally occurring substance in the ecosystem (adding something that is not usually there), e.g., extreme tides pour saltwater into habitats

ordinarily protected from sea water; increasing the amount or intensity of a naturally occurring substance, e.g., abnormal increase in sediments in runoff water to produce silt; altering the level or concentration of biological or physical components of an ecosystem (changing the amount of something that is already there), e.g., introduction of aquatic plants via bird droppings, etc.

Most of us view pollution dominantly as human caused. When pollution takes place without human intervention, it is most often ecological pollution. Whether beneficial or harmful or neither, ecological pollution - which is dominantly derived from natural processes - does affect wildlife and wildlife habitat. Some acid rain results from volcanic eruptions. Landslides and avalanches alter runoff patterns as well as sometimes killing plant and animal life. Shifts in oceanic currents affect water temperature as well as weather patterns. Sometimes hot springs and geysers can heat water above normal temperatures in lakes and streams.

Yet all that is known points to humans as the greatest source of damage to habitats. Documentation of human illness and death due to pollutants is overwhelming. Research shows that pollution also causes illness and death in wildlife.

The way we feel about pollution has to do with the attitudes and values we hold regarding the quality of life. Issues of economic importance often affect human reaction to pollution. One researcher called pollution the "chosen disease". For the most part, pollution is invisible. It often takes years to display its toxic destructiveness. In the case of DDT, it took years before we could see the effects. Since the effects of most pollution are long-term, we must develop long-term views about its effects on wildlife.

Groundwater is continually being affected by toxins we cannot see. Some pollutants enter water from a localized source, like a chemical discharge from a factory. This is called 'point source' pollution. Other pollutants enter from a variety of less easily identified sources; for example, when rain washes motor oil left from dripping cars in store parking lots into city drains to re-enter the water supply. This is called 'non-point source' pollution.

In its many journeys, water may be contaminated by thousands of different substances and conditions. For the most part, these substances and conditions alter water in such ways that it becomes a hazard to wildlife and humans as well.

Materials:

10 different colors of construction paper (cut or punched into small tokens)
Writing paper or graph paper
Glue, tape
Hole punch (to make 100 tokens of each of the 10 colors of paper)
Tablespoon
Copies of 'Pollution Fact Sheet' for each student.

Procedure:

Before the class begins, make 100 tokens from the 10 colors of construction paper
DISCUSSION

1. Write the five categories of pollution on the board and discuss them with the class. They are: chemical, mechanical, thermal, organic, and ecological. Refer to the background information for a description of each.
2. Distribute the 'Pollution Fact Sheet' to students.

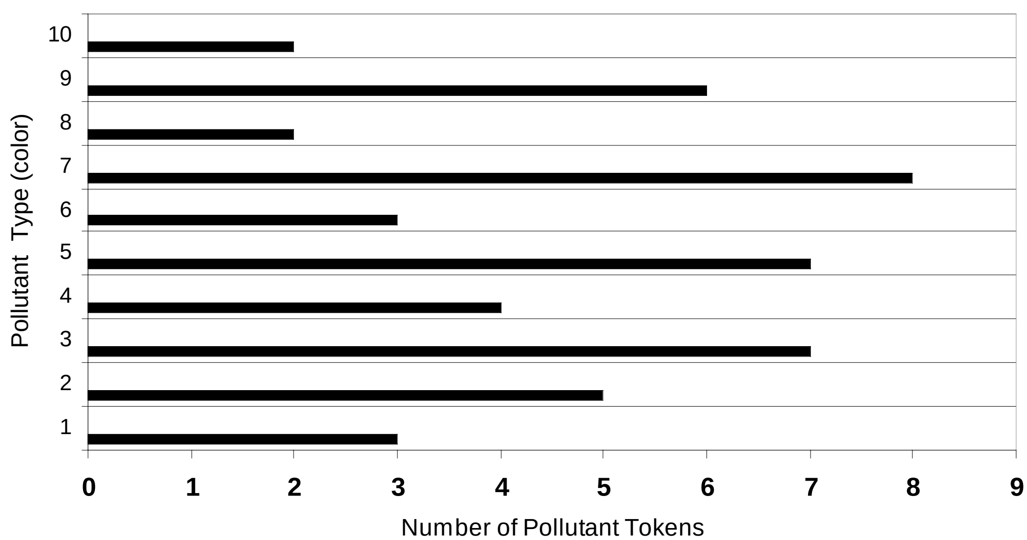
3. The class as a whole will choose 10 different pollutants from the fact sheet. Discuss which category, or categories, each pollutant belongs to. Talk about how some of these can fit into more than one of the five categories of pollution.
4. Distribute 'Color Key of 10 Pollutants' to each student.
5. Each student will write the 10 pollutants chosen by the class on their own color key.
6. The whole class will decide how to color code each of the 10 pollutants with a different color from the construction paper.
7. Each student will write a short description of each pollutant on the color key.

ACTIVITY

Each student should have the same color key, with the same colors for pollutants

1. Put all of the colored paper tokens in a large bag or bowl. Mix them thoroughly. These tokens represent pollutants that were found in a water sample from a hypothetical river.
2. Divide the class into groups of 3-4 students. These will be research teams; each team will analyze the pollution content in a sample of water from a hypothetical river.
3. Distribute the colored paper tokens that have been cut or punched from the construction paper. Pass the container with the colored paper tokens so that each research team can measure out a tablespoon of the colored paper-punched tokens.
4. The teams must separate the colored tokens into piles; using the 'Color Key of 10 Pollutants' they developed.
5. The teams should count the number of each kind of pollutant they have identified and then use graph paper to construct a simple bar graph showing the whole array of pollutants.

Sample Pollutant Bar Graph



6. The class will compare their graphs and discuss results using the questions below to guide the discussion.

Questions:

1. Compare the bar graphs from each team. Their results are not likely to be the same. Explain this result.
2. Consider any pollutant that is represented by two tokens or more to be considered damaging to wildlife habitat. In your hypothetical river, what pollutants would be likely to cause the most damage to wildlife and wildlife habitat? Describe the kinds of damage that could be caused.
3. List five things you can do - starting today –in your own life to reduce the number of pollutants you add to the environment.
4. Is DDT still being used, and where? How are PCB’s entering our marine ecosystems and how are they affecting people? What does ‘nutrient overload’ mean and what are its effects on marine ecosystems?

Color Key of 10 Pollutants		
Color	Pollutant	Description
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Pollution Fact Sheet

	Nutrients	Sediment	Metals	Oxygen-demanding Substances	Plastics, Oil, and other hydrocarbons	Pathogens
Definition	A nutritive substance that fosters growth, especially compounds that contain nitrogen, phosphorus and potassium. Examples of these types of compounds are fertilizers and detergents.	Particles of soil, which often settle to the bottom of liquids.	Fusible, ductile and typically lustrous substances that are good conductors of electricity and heat. Problematic metals in local waterways include chromium, copper, lead and zinc.	Organic compounds that are decomposed by microorganisms, which in turn require oxygen for their work.	Organic compounds that are not easily degraded by organisms.	Disease-causing organisms that affect human health.
Source	Fertilizers; greenwaste; detergents from such practices as car washing, dumping of janitorial wastewater, or failing septic/sewer systems.	Land erosion, mostly during rain on exposed soil, like construction sites or clear-cut forests. Also exposed gardens and channeled storm drains can transport sediment.	Mostly associated with motor vehicles, including direct atmospheric deposition from exhaust emissions, dripping oil and lubricants, tire wear, and brake lining wear. Some may occur naturally from the parent soil material.	Greenwaste, litter and garbage, leaking garbage bins, improperly discarded wash water and improperly disposed of food waste.	Often found in components of oils and greases from vehicles and other motor equipment as well as gasoline and synthetic detergents, pesticides, and herbicides. Large plastic debris release PCB's and DDE's when they photodegrade. Plastic debris also accumulates hydrophobic compounds like DDT.	The primary source is fecal matter from infected humans, often from failing sewer or septic systems. Some less common pathogens are transmitted through the feces of other animals including, birds, rodents, dogs, deer, etc…
Effects	Eutrophication: enrichment of a body of water in dissolved nutrients that stimulate growth of aquatic life. These "blooms" of algae eventually die and decompose. The bacteria consume the available oxygen and create toxic aquatic conditions. Massive fish kills are sometimes caused by this.	Covers and clogs feeding and spawning areas for aquatic animals, interferes with aquatic organisms respiratory functions, increases water temperature, decreases the amount of transmitted light thus decreasing the primary productivity of aquatic plants and phytoplankton, and increases the flooding risk.	Found in bottom sediments, they accumulate in benthic organisms. They can also bioaccumulaate in animal tissue and result in chronic toxic effects for aquatic species and animals, like humans. In high concentrations, dissolved metals can be immediately toxic to aquatic organisms.	If too many of these compounds are present, available oxygen will be consumed and anaerobic (oxygen deficient) conditions will occur. Anaerobic conditions can produce bad odors and choke organisms that require the oxygen. Effect can be worsened with increased temperatures and excessive nutrients.	Many are toxic to fish and aquatic organisms, causing both acute and chronic toxic effects. They may inhibit reproduction, respiration and development of tissue. Additionally, many are mutagenic (causing relatively permanent change in hereditary materials), carcinogenic and can persist and bioaccumulate.	Can cause many sorts of illnesses and discomfort, ranging from minor skin infections, to ear aches, pink-eye and gastrointestinal infections.
Alternatives	Minimize the use of pesticides, herbicides and fertilizers. Compost your yard waste. Keep your septic system working. Wash cars on the lawn where the run-off will soak into the ground instead on going down the drain.	To decrease risk of erosion, keep soil areas properly vegetated. Also, be sure not to sweep soil into storm drains.	Walk, don't drive. Take the bus. Ride your bike. If you own a car, maintain it. Fix oil leaks. Dispose of fluids responsibly. There are hazardous waste facilities that will take oils, paints and other household chemicals that you may wish to discard.	Always properly dispose of yard waste, compost if possible. Pick up and recycle or properly dispose of all waste.	Reduce use of all chemicals, including pesticides and detergents. Utilize public transportation. If you must drive, ensure that your car is not leaking any hazardous fluids and always properly dispose of hazardous materials from cars at the Community Hazardous Waste Collection Center. Recycle and reduce consumption of plastic.	Be sure to always use toilet facilities or properly bury waste. Ensure that septic or sewer systems are functioning correctly. Pick up after your pets.

Oil in Aquatic Systems

California Science Standard:
<u>6^{th} Grade, Ecology (5bc)</u>
Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.
<u>9^{th}-12^{th} Grade, Ecology (6b,e)</u>
Stability in an ecosystem is a balance between competing effects.
<u>9^{th}-12^{th} Grade, California Geology (9a,b,c)</u>
The geology of California underlies the state's wealth of natural resources as well as its natural hazards.

Time: Two 50-minute class periods

Objective:
Students will discover the effect of motor oil on water and organic surfaces by observing oil in water and oil on bird feathers and eggs.

Background Information:
Oil from offshore spills, urban runoff or illegal dumping into storm drains, can affect aquatic ecosystems in many ways. Oil is less dense than water, therefore it floats, and does not dissolve either. Water has a natural surface tension that is important to many insects and biological functions of animals. Oil decreases the surface tension of water.

Birds and marine life can become soaked with oil after an oil spill. Oil soaked feathers no longer insulate the bird's body. Bird eggs are permeable so that gases can be exchanged during the chick's development. Oil clogs the pores in egg shells and permeates the inner membrane. Animals also become sick from oil ingestion. Oil sheens on a water surface can even impede photosynthesis!

Used motor oil that is discarded on the ground or into storm drains pollutes the watershed and travels directly to rivers, lakes or oceans. Oil dumped on the ground may stay in the soil for years affecting the respiration of plant roots, and possibly leeching into groundwater aquifers. Used motor oil also carry pollutants like heavy metals that can affect wildlife.

Materials:
- One copy of "Worksheet: Oil in the Watershed" for each student
- For each group:
  - Two 1000ml beaker or equal size jar
  - 500ml of motor oil (preferably used)
  - Small bowl of water
  - Teaspoon of ground black pepper
  - Hand lenses (2 per group)
  - Three hard-boiled eggs and one feather

Procedure:
DAY ONE
1. Discuss the background information with the class using the guide topics below.

   a. List places where you have seen oil on the ground in your neighborhood?
      i. Oil can or filter in storm drain.
      ii. Oil "slick" on surface of a puddle or in a stream.
      iii. Oil dripping from a car.
   b. List ways that animals or plants are affected by oil?

DAY TWO

2. Divide students into groups of 3-4.
3. Give each student a copy of "Worksheet: Oil in the Watershed" and discuss the activity.
4. Distribute materials to each group.
5. After completing the activity, discuss the results with the class.
6. Dispose of used oil into a sealed container for recycling. Have students find the local hazardous waste recycling center.

Questions:

1. How can you explain the reaction the pepper had when the drop of oil was dropped into the bowl of water?
2. What do you think oil affects the development of birds within eggs? How do you think oil affects the eggs of fish, amphibians and insects?
3. What are some ways that oil can get into the watershed?
4. What organisms do you think might be affected by oil in the water? Why?
5. Why is it important to keep oil out of aquatic ecosystems?
6. What are some solutions to keep oil out of the watershed?

Web resources:

To learn more about the effect of oil on wildlife and to find a location to recycle used motor oil, call 1-800-CLEAN-UP or visit www.cleanup.org.

Extensions:

Adopt a Watershed

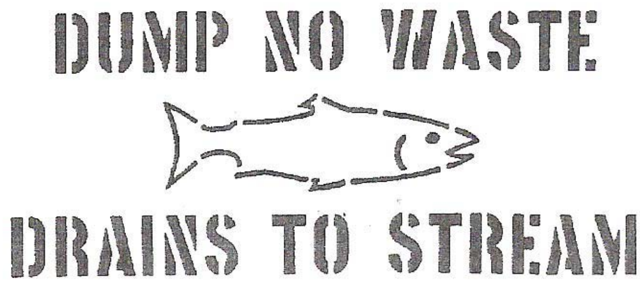
Your class can become active stewards of a local watershed. Materials and resources are available by calling 530-628-5334 or visit www.adopt-a-watershed.org.

Global Water Sampling Project

An online resource helping students to collect local water samples, measure the water quality and post local water quality data online about your local watershed. This provides a connection to the community while learning watershed concepts.

Worksheet: Oil in the Watershed		
1. Fill the small bowl with water and sprinkle the ground black pepper on the surface.	Drop a drop of motor oil into the bowl.	Describe your observations.
2. Fill a 1000ml beaker with 500ml of used motor oil. Carefully drop three hard-boiled eggs into the oil. *(This may be done as a teacher demonstration if time and resources are scarce.)*	Remove one egg after five minutes, peel it and examine the shell and egg white.	Describe and sketch your observations.
	Remove the second egg after it has been in the oil for a total of 10 minutes. Peel and examine it.	Describe and sketch your observations.
	Remove the third egg after it has been in the oil for a total of 20 minutes. Peel and examine it.	Describe and sketch your observations.
3. Using the hand lens, examine a feather dry, wet and oily.	Examine the feather when it is dry using the hand lens.	Describe and sketch your observations.
	Dip the feather in water. Examine it using the hand lens.	Describe and sketch your observations.
	Dip the feather in oil. Examine it using the hand lens.	Describe and sketch your observations.

Stencil your Storm Drains!



California Science Standard:
5^{th} Grade, Earth Science (3e)
Water on Earth moves between the oceans and land through the processes of evaporation and condensation.
6^{th} Grade, Ecology (6b)
Resources: Sources of energy and materials differ in amounts, distribution, usefulness, and time required for their formation.
9^{th}-12^{th} Grade, Ecology (6b,c)
Stability in an ecosystem is a balance between competing effects.
9^{th}-12^{th} Grade, California Geology (9a,b,c)
The geology of California underlies the state’s wealth of natural resources as well as its natural hazards.

Time: Two homework assignments
One 50-minute class period, or a class field trip after school or on a weekend.

Objective:
Students will participate in a community project that directly affects the quality of the environment.
Students will recognize public attitudes and misconceptions about trash that flows into storm drains by talking with residents in their neighborhood.
Students will recognize that local actions sometimes have a global effect by discussing the path trash in storm drains takes through the watershed and to the ocean.

Background Information:

Stenciling storm drains with reminders of where runoff goes, is an opportunity for students to become active stewards of their local watershed. Storm drains almost always empty into waterbodies; like streams, rivers, lakes and oceans. There are few barriers between your curb and the natural environment. Sometimes booms are installed across rivers or grates placed over outfalls to contain large floating debris, but most trash makes it’s way out to sea.

Misperceptions about the sewer system prompt some people to use storm drains as local dump sites to discard used motor oil and trash collected on the street. Storm drain stencils provide a clear reminder of where the water goes.

Materials:

Obtain a sidewalk stencil by contacting:

Earthwater Stencils
Dept. WT,
4425 140th Avenue
Southwest, Rochester, WA 98579

One can of blue spray paint
Permission from local sewage board to apply stencil
Poster paper to make a map of the school and surrounding neighborhood.

Procedure:

1. Teacher should obtain permission from the local sewage board to apply stencils to the surface of storm drain covers. Explain the precedent across the country for schools conducting this activity. Describe exactly what the stencil looks like and how it will be applied.
2. Canvas the Neighborhood
    a. Discuss the background information with students.
    b. Draw a map of the school and neighborhood within a three-block radius.
    c. In groups of 3-4, assign students areas of this local map to investigate for storm drains.
    d. With a complete map of storm drains within a three-block radius of the school, have student groups prepare a one-paragraph introduction and explanation of the Storm Drain Stencil Project to be given to neighbors.
    e. Student groups will return to the same area of the neighborhood map to distribute information letters door to door.
    f. In class, discuss the response students had with neighbors.
3. Stenciling Storm Drains
    a. Practice the procedure for applying the stencil to the storm drain surface.
    b. With a can of blue spray paint and the stencil, each group will stencil storm drains in their neighborhood area. Each student group will be accompanied by a parent, teacher or teacher assistant.
4. What if the stencil already exists? Many urban storm drains have been stenciled already, but the ink does wear away over time. You may wish to re-stencil an old sign, or add a new stencil.

Questions:

1. Why was it important to communicate with the sewage board as well as local residents about the project?
2. What kinds of concerns did people have regarding the Storm Drain Stencil Project?
3. Think of a much bigger environmental project in your neighborhood that might interest you, like installing catch basin inserts in storm drains, convincing a local business to recycle, or having your school switch from Styrofoam food trays to cardboard ones.
    a. Who would you contact first?
    b. What would your plan look like?

Chapter 3

Plastic Debris Research

"Like diamonds, plastics are forever."

Captain Charles Moore
Founder of the Algalita Marine Research Foundation

Discover Plastic Debris on Streets and Beaches

California Science Standard:
9^{th}-12^{th} Grade, Ecology (6b,e)
Stability in an ecosystem is a balance between competing effects.
9^{th} –12^{th} Grade, Investigation and Experimentation (1a,b,c,d,f,I,j,k,l,m)
Scientific progress is made by asking meaningful questions and conducting careful investigations.
9^{th}-12^{th} Grade, California Geology (9a,b,c)
The geology of California underlies the state's wealth of natural resources as well as its natural hazards.
9^{th}–12^{th} Grade, Social Science
Students analyze the major social problems and domestic policy issues in contemporary American society.

Time:
4 50-minute class periods.

Day 1 - Practice Collecting Sample – 1 50-minute class period
Homework reading assignment:

Appendix E: Comparison of Plastic and Plankton in the North Pacific Central Gyre
Appendix F: A comparison of neustonic plastic and zooplankton at different depths near the southern California shore
Appendix G – Guide to Writing a Student Research Manuscript

Day 2 - Collect Sample – 1 50-minute class period (teacher may collect material instead)
Day 3,4 - Sort Sample – 2 50-minute class periods

Objectives:
Students will understand the process of scientific research by conducting their own research project.
Students will carefully sample plastic debris from a sand surface using a research protocol provided. This activity will show students how to apply established methods of collecting data to a new research project.
Students will understand that using multiple samples creates a richer data set that is more representative of the subject described.

Background Information:

Our storm drains carry plastic debris and less "visible" pollution, such as bacteria, viruses, and toxins to the ocean. Most beach warning signs are posted after the ocean has tested high in bacterial levels. While bacterial levels are what we measure quantitatively as pollution that closes beaches, there are many other types of pollutants that are found in the ocean that make the water unhealthy.

This pollution is harmful to the environment and the creatures that live there. The amount of debris is astounding. Every year, millions of our taxpayer dollars are spent on beach cleaning. Even so, there is always more trash to clean up.

People do not realize that the one cigarette butt tossed to the ground contributes to polluting the marine environment. Many think that their litter is small and will not have a large impact. While this may be true, the problem is that there are over six billion people on earth, and if everyone thinks in this way there will be an incredible amount of pollution. When everyone contributes a little it adds up to a lot.

Plastics, like diamonds, are forever, in that they don't biodegrade. Biodegradable materials, like paper products or food scraps, are eaten by bacteria and other organisms, therefore they are recycled into the environment. Less than 4% of plastics are recycled in any way. In the Central North Pacific, broken, degraded pieces of plastic outweigh surface zooplankton by 6 to 1. Read Appendix E "A Comparison of Plastic and Plankton in the North Pacific Central Gyre" and Appendix F " A comparison of neustonic plastic and zooplankton at different depths near the southern California shore." An estimated 63 pounds of plastics for each American enters landfills each year. Roughly half of all plastics that reach the ocean are negatively buoyant. They sink. Photodegradation, break down due to exposure to heat and UV light, doesn't work on plastics that have sunk or are buried. Pre-production plastic pellets manufactured in the United States exceed 100 billion pounds annually. Each pound can contain between 10,000 and 20,000 nurdles! We are a culture immortalized by plastic.

The Dirty Dozen

Marine debris collected by volunteers in Los Angeles County on Coastal Cleanup Day, 1997

	Type of debris collected	Total number reported	Percent of total debris collected
1	Cigarette buts	15,738	25.21
2	Foamed pieces	5,719	9.16
3	Plastic pieces	4,171	6.68
4	Straws	3,992	6.39
5	Paper pieces	,869	6.20
6	Plastic bags/wrappers	3,036	4.94
7	Plastic caps/lids	2,875	4.61
8	Glass pieces	1,426	2.28
9	Metal bottle caps	1,332	2.13
10	Other plastic	1,296	2.08
11	Cups	1,062	1.70
12	Cups/utensils	971	1.56

Note: This data is a portion of the complete data set from the California Coastal Commission and the Center for Marine Conservation.

Marine ecosystems are harmed by plastic debris. 90% of Laysan Albatross chick carcasses and regurgitated boluses contain plastics. Fish and other seabirds mistake plastics for food. Plastic debris release harmful plasticizers and additives. Plastic debris become carriers for other hydrophobic pollutants, like PCBs, DDT and create dioxin when burned. These pollutants are transported into the food chain when consumed. These pollutants bioaccumulate and biomagnify up the food chain. Indigenous cultures that thrive on hunting marine mammals for sustenance have been shown to carry the highest levels of toxins in their bodies when compared to people living in urban centers in Europe and North America, mostly due to "Global Distillation."

Students will have an opportunity to participate in the ongoing research of the Algalita Marine Research Foundation (AMRF). AMRF is dedicated to the preservation of the marine environment. Their mission is to restore and preserve coastal, near-shore and off-shore marine environments through ecological stewardship. Research projects include kelp reforestation and documentation of plastic debris in the Pacific Ocean and California watersheds.

Students will participate in current research by carefully collecting, analyzing, and reporting data on plastic debris. Their data will add to a school database, which in the future will be compiled with other schools in order to report to the public and scientific community on the status of plastic debris in our watersheds. Students will have the opportunity to make significant contributions to environmental science while increasing their awareness and appreciation of the nature of science.

Procedure:

Day One – Preparation and background information

1. Distribute the Appendix E, F and G to students for background reading.
2. Divide class into groups of three or four students in order to practice the "Collecting Plastic Debris Sample" protocol.
3. Write RESEARCH QUESTIONS AND HYPOTHESES. Have students think of questions and make predictions about what they might discover.

Day Two – Collecting Plastic Debris Sample

*** The teacher may choose to collect the sample to save class time.***

1. Discuss background information with students.
2. Organize a field trip to COLLECT SAMPLE according to Collecting Plastic Debris Sample protocol.
3. Bring sample back to the classroom for sorting.

Day Three – Sorting the Sample

1. SORT SAMPLE according to Sorting Plastic Debris Sample protocol.
2. PREPARE RESEARCH REPORT. Review Appendix G: "Guide to Writing a Student Research Manuscript" with students.

Questions for Students to Think About:

1. Where did the debris in your collected sample come from?
2. Which types of debris were the most abundant? Why?
3. Can you think of a public campaign to raise awareness of plastic debris?
4. How is your data similar or different from other student groups?
5. Would combining your data with data collect from other classmates be a good thing?

Collecting Plastic Debris Sample

Materials:

1. Copy of protocol for each student
2. Materials for field trip to collect plastic debris sample
    a. Non-allergenic gloves for each student
    b. 4 meters of string to make the grid (Tie ends to make a loop with a 4-meter perimeter. Tie a knot at every meter.)
    c. Screen sieve (1.4mm diameter holes)
    d. Piece of chalk
    e. One five-gallon bucket
    f. Two large brushes (or two garden shovels for beach collection)
    g. Small pail and cup for rinsing sample if wet
    h. Large bowl
    i. Large bag (cloth or paper)

Procedure:

1. In student groups of 3-4 students, collect all materials and travel to beach.
2. Select a site.
    a. If collecting a street sample, choose a location away from traffic where debris has accumulated, like a parking lot or gutter.
    b. If collecting a beach sample, choose a site at the high tide line, where the debris washes highest on the beach.
    c. Draw a map of the location so that you can return later if needed.
    d. Put on non-allergenic gloves.
    e. Take the 4-meter rope grid and stretch the loop to make a perfect square 1m x 1m over the collection site.
    f. If collecting a street sample, use the brushes to sweep the 1m x 1m collection site completely. Fill the 5-gallon bucket no more than half. Less than half is okay. Record the size of your sample.
    g. If collecting a beach sample, use the two garden shovels to fill half of the 5-gallon bucket with sand from the 1m x 1m collection site. Scrape the surface evenly!
    h. Hold the screen sieve over the large bowl. Using the cup, scoop the sample into the sieve.
    i. Shake the screen sieve vigorously, being careful not to toss any of the sample out of the sieve.
    j. Transfer sieved sample to the large bag.
    k. Put label with sample.

Collected Plastic Debris Sample	
Date: ______________________	Sample collected by: ______________________
Location: ______________________	______________________

Sorting Plastic Debris Sample

Materials:

1. Copy of "Data Sheet: Sample Sort for Type of Plastic" and "Labels for Each Type of Plastic"
2. Materials needed by each group to sort sample.
    a. Collected sample
    b. One aluminum pan or large food tray
    c. Two pairs of forceps
    d. Seven petri dishes
    e. Seven paper envelopes to store the different classes of debris
    f. Large envelope to store entire sample when done
    g. Non-allergenic gloves for each student

Procedure:

1. Gather all materials, including collected sample.
2. Put on vinyl gloves.
3. Empty the collected sample into the aluminum sorting pan or food tray.
4. Sort the different types of plastic and other debris into the seven categories listed on the data sheet titled, "Data Sheet: Sample Sort for Type of Plastic."
5. Count the quantities of each type of plastic and list the description and quantity of the plastic items on the data sheet.
6. Place each type of debris into a separate envelope labeled with the sample size, type of plastic, date, location and count.
    a. Use the labels provided from the list titled, "Labels for Each Type of Plastic"
    b. Write the same information on the outside of each envelope.
    c. You should have 7 separate envelopes for the sorted debris.
    d. The remaining inorganic debris in the aluminum pan can be discarded.
7. Once the research report is completed, put all 7 paper envelopes into the large envelope for safe keeping and possible future research. Refer to Appendix G "Guide to writing a student research manuscript" for a format for your report.

Data Sheet: Sample Sort for Type of Plastic

	Description	Quantity
Pellet Pre-production plastic pellets, also called "nurdles."		
Fragment Pieces of hard plastic debris that is unrecognizable.		
Film Plastic debris, such as pieces of bags or wrappers, are called "films."		
Foam Foamed plastic is often used to insulate and serve foods or in packaging.		
Filament Examples of filament include: fishing line, rope, or synthetic cloth.		
Cigarette parts Synthetic materials can be found in cigarette butts and filters.		
Other Glass, rubber, metal.		

Labels For Each Type of Plastic

Pellet Date: __________
Location: ____________________
Count ______________________
Collected by: __________________

Fragment Date: __________
Location: ____________________
Count ______________________
Collected by: __________________

Film Date: __________
Location: ____________________
Count ______________________
Collected by: __________________

Foam Date: __________
Location: ____________________
Count ______________________
Collected by: __________________

Filament Date: __________
Location: ____________________
Count ______________________
Collected by: __________________

Cigarette Parts Date: ______
Location: ____________________
Count ______________________
Collected by: __________________

Other Date: __________
Location: ____________________
Count ______________________
Collected by: __________________

The Number in the Triangle: Classifying Plastic

California Science Standard:
6th Grade, Resources (6a,c)
Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their consumption.
8th Grade, Density and Buoyancy (8a,b,c)
All objects experience a buoyant force when immersed in a fluid.
9th –12th Grade, Investigation and Experimentation (1a,b,c,d,f,I,j,k,l,m)
Scientific progress is made by asking meaningful questions and conducting careful investigations.

Time:
Two 50-minute class periods

Objectives:
Students will recognize that materials are classified by their composition rather than external characteristics.

Background Information:
The EPA (Environmental Protection Agency) has set a national goal to recycle 25 percent of our national waste. Some plastics can be recycled through curbside recycling, grocery store drop bins or drop-off centers. A raised number (1 through 7) in a triangle on the bottom of most plastic containers tells you what type of plastic it is. The triangle of arrows around a number doesn't automatically signify that the plastic product can be recycled! Only types 1 and 2 can be recycled.

Here is a brief look at each number that appears on the plastic.

1. **Plastic #1 (recyclable)** Polyethylene terephthalate. Pete: Soda bottles, water bottles, vinegar bottles, medicine containers, backing for photography film, clear plastic ketchup bottles, plastic egg cartons, clear mustard bottles and microwave trays.
2. **Plastic #2 (recyclable)** High-density Polyethylene. HDPE: Plastic bottles that often contain laundry/Dish detergent, fabric softeners, Milk, bleach, conditioners, motor oil, some toys, vitamin containers, and shampoo.
3. **Plastic #3 (currently not recyclable)** Polyvinyl Chloride. Commonly called PVC: Pipes, Shower curtains, meat wraps, cooking oil bottles, baby bottle nipples, shrink wrap, clear medical tubing, vinyl dashboards and seat covers, coffee containers.
4. **Plastic #4 (currently not recyclable)** Low-Density Polyethylene. LDPE: Wrapping Film, grocery bags, sandwich bags, mustard container.
5. **Plastic #5 (currently not recyclable)** Polypropylene. PP: food storage containers, syrup bottles, yogurt tubs, diapers, outdoor carpet.
6. **Plastic #6 (currently not recyclable)** Polystyrene. PS: Coffee cups, disposable cutlery and cups, bakery shells, meat trays, packing peanuts, Styrofoam insulation. Recycled post consumer polystyrene beads can be found in our hemp and natural cotton bean bag chairs.

7. **Plastic #7 (currently not recyclable)** Other: Not much use for this. It is usually made from a combination of the other plastics and is less commonly used.

How should you begin to sort and recycle plastic trash?

1. Call your county's Department of Public Works or recycling center to determine what type of plastic to recycle and where to take it. Also call 1-800-CLEANUP for state recycling information. Call the American Plastics Council, 1-800-2-HELP-90, for more information about plastics.
2. Rinse and sort your plastic containers by number. Recyclable plastic often must be separated by number in order to avoid contamination as it begins the recycling process.
3. Take caps and pump spray tops off of plastic containers unless they are marked with a number. They are often made from a type of plastic that is different from the main part of the container and generally are not recyclable at this time.
4. Find out if your community requires you to remove labels from plastic containers before you recycle them.
5. Crush plastic containers to save space in your recycling bin.
6. Type 1 (PETE) and type 2 (HDPE) plastics are the easiest to recycle. Plastic type 1 (PETE) can be recycled into items like carpet, auto parts, paint brushes and industrial paints. Plastic type 2 (HDPE) is recycled into products like detergent and engine oil bottles, trash cans and recycling bins.
7. Drop off plastic grocery bags - usually type 4 (LDPE), sometimes type 2, though not always marked - at your grocery store to be recycled. Most large chain grocery stores will have bins located in the store. Clean out bags before recycling.
8. Contact your city or state Department of Public Works or recycling center to find out how to recycle other types of plastics, like foam packaging and other foamed plastic materials (type 6, Expanded Polystyrene or EPS), type 3 (plastic food wrap and vegetable oil bottles), 5 (yogurt containers, syrup bottles, diapers, some bags, most bottle tops and some food wrap) and 7 (layered or mixed plastic). While some of these are recyclable, the plastics industry is still in the early stages of recycling and does not recycle these in most cities unless it is through a test program.

Density Table	
Substance	Density (>1.0 = floats) (<1.0 = sinks)
Water	1.00
(1) PET - Polyethylene terephthalate	1.38 – 1.39
(2) HDPE - High-density Polyethylene	0.95 – 0.97
(3) PVC - Polyvinyl Chloride	1.16 – 1.35
(4) LDPE - Low-Density Polyethylene	0.92 – 0.94
(5) PP - Polypropylene	0.90 – 0.91
(6) PS – Polystyrene	1.05 – 1.07

Materials:

Copy of “Plastic Analysis Flow Chart” worksheet for each group
Large assortment of plastic containers that represent the 6 classifications of plastic
Several sets of plastic fragments of each classification (Type known only to teacher)
Bunsen burner, stand and heat-resistant pad
Three 500 ml beakers
Two test tubes
One liter of isopropyl alcohol
One liter of vegetable oil (Mazola works well)
One liter of acetone
Water source
Copper wire

Procedure:

Day One

1. Assign students to groups of 3-4.
2. Give each group a collection of plastic trash to classify according to any criteria the group chooses. Students should write down their classification scheme.
3. Each group will briefly describe their classification scheme to the group.
4. Distribute “Plastic Identification by the Number”. Teacher can now begin discussing the industrial classification standard according to chemical composition.

Day Two

1. Distribute a set of materials to each group and explain safety procedures.
2. Distribute a copy of the Plastic Analysis Protocol and discuss it with students.
3. Distribute a copy of the Plastic Analysis Flow Chart and discuss it with students.
4. Have students summarize their findings in a lab report or oral presentation.

Questions:

1. Did your classification scheme differ from the numbered classification standard?
2. Are the plastics different because of the chemical composition of the plastic, chemicals added to change the properties of the plastic, or both?
3. What type of plastics are most harmful to the bodies of marine organisms?
4. Why are some plastics more difficult to recycle than others?

Web Resources:

For information about plastic debris and recycling, visit:

www.plasticdebris.org
www.earthresource.org

Plastic Analysis Protocol

1. Water Test
    a. Fill one 500ml beaker to the halfway mark with room temperature water.
    b. Submerge all pieces of plastic, being careful to brush away any bubbles of air that adhere to the plastic.
    c. Separate all pieces into two separate piles, those that sink and those that float.
    d. Those pieces that float will be subject to the Isopropyl Alcohol Test.
    e. Those pieces that sink will be subject to the Copper Wire Test.

2. Isopropyl Alcohol Test
    a. Fill one 500ml beaker to the halfway mark with isopropyl alcohol.
    b. Submerge all pieces of plastic that previously floated in the water test
        i. Be careful to brush away any bubbles of air that adhere to the plastic.
    c. All pieces that sink in alcohol will be placed in a separate pile labeled: HDPE # 2.
    d. All pieces that float in alcohol will be subject to the Oil Test.

3. Oil Test
    a. Fill one 500ml beaker to the halfway mark with vegetable oil.
    b. Submerge all pieces of plastic that previously floated in the alcohol test.
        i. Be careful to brush away any bubbles of air that adhere to the plastic.
    c. All pieces that sink in the oil will be placed in a separate pile labeled: LDPE #4.
    d. All pieces that float in the oil will be placed in a separate pile labeled: PP #5.

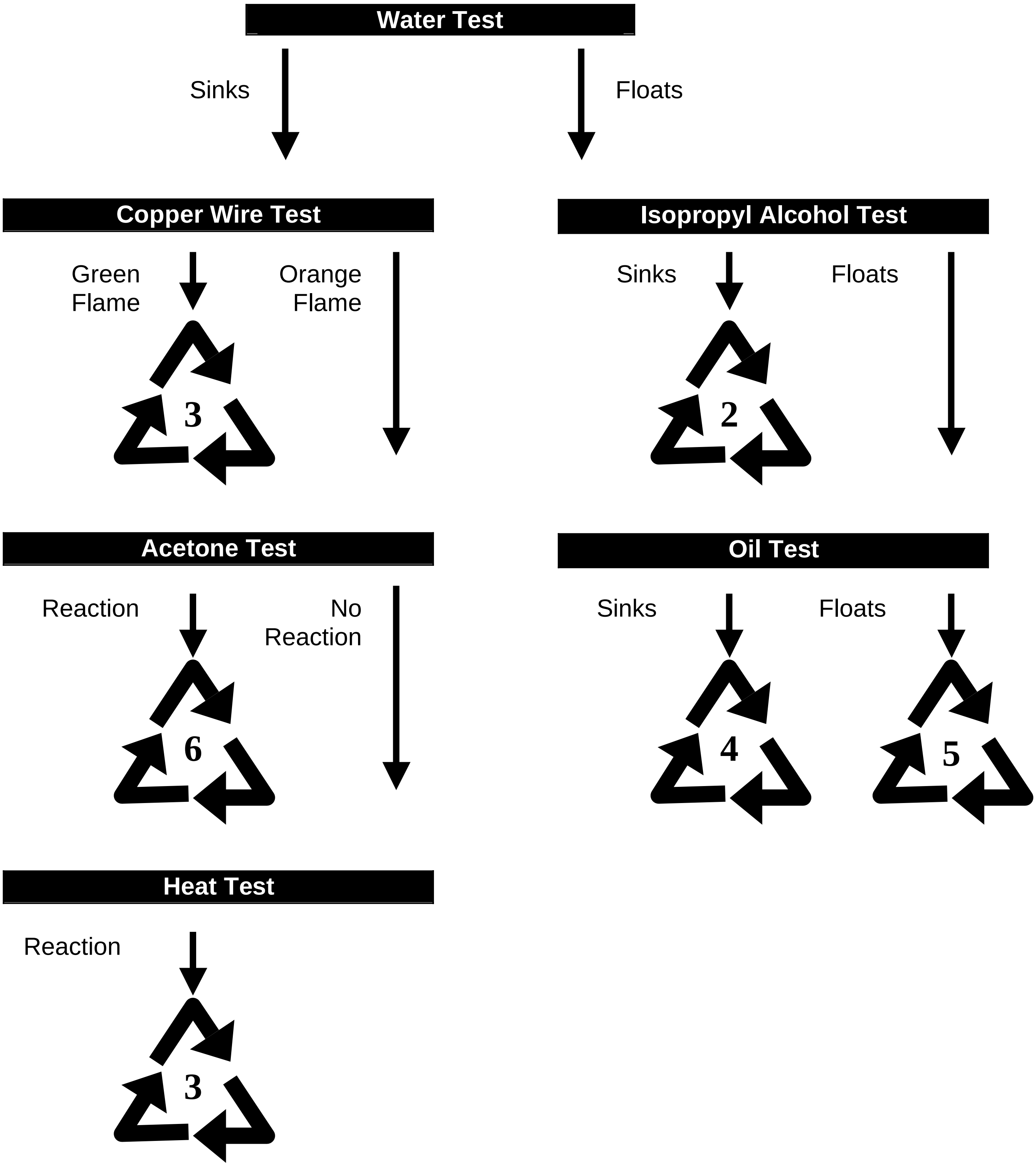
4. Copper Wire Test (conduct in ventilated area)
    a. Pieces of plastic that sank during the initial water test will be subject to the copper wire test.
    b. Prepare a piece of copper wire that is six inches long with a 1cm diameter loop on the end. This will be used to hold pieces of plastic while the copper and plastic are heated together.
    c. Prepare the Bunsen burner.
    d. Cut a small piece of plastic and place it on the copper wire loop and carefully hold it over the flame.
    e. If the flame is green, then the unburned plastic will be placed in a separate pile labeled: PVC #3.
    f. If the flame is orange, then the unburned plastic will be subject to the acetone test.
    g. TURN OFF THE FLAME.

5. Acetone Test (conduct away from any source of flame)
    a. Fill a clean test tube with acetone.
    b. Pieces of plastic that produced an orange flame in the copper wire test will be subject to the acetone test.
    c. Cut a small piece from each sample of plastic and submerge them in the acetone.

d. In approximately 30 seconds the plastic may start to dissolve. If the plastic dissolves, then place the plastic in a separate pile labeled: PS #6.
e. If the plastic does not dissolve, then it will be subject to the heat test.

6. Heat Test
    a. Fill a clean 500ml beaker with water and heat until boiling.
    b. Pieces of plastic that did not dissolve in the acetone test will be submerged in the heated water for one minute.
    c. These pieces should all become flexible in heated water. Those pieces that become flexible will be placed into a separate pile labeled: PET #1.
    d. All pieces that do not become flexible should be retested.

Plastic Analysis Flow Chart



Plastic Identification by the Number

Plastic #1 Polyethylene terephthalate. PET: Soda bottles, water bottles, vinegar bottles, medicine containers, backing for photography film, clear plastic ketchup bottles, plastic egg cartons, clear mustard bottles and microwave trays.

Plastic #2 High-density Polyethylene. HDPE: Plastic bottles that often contain laundry/Dish detergent, fabric softeners, milk, bleach, conditioners, motor oil, some toys, vitamin containers, and shampoo.

Plastic #3 Polyvinyl Chloride. Commonly called PVC: Pipes, shower curtains, meat wraps, cooking oil bottles, baby bottle nipples, shrink wrap, clear medical tubing, vinyl dashboards and seat covers, coffee containers.

Plastic #4 Low-Density Polyethylene. LDPE: Wrapping Film, grocery bags, sandwich bags, mustard container.

Plastic #5 Polypropylene. PP: Food storage containers, syrup bottles, yogurt tubs, diapers, outdoor carpet.

Plastic #6 Polystyrene. PS: Coffee cups, disposable cutlery and cups, bakery shells, meat trays, packing peanuts, Styrofoam insulation.

Plastic #7 Other: Not much use for this. It is usually made from a combination of the other plastics and is less commonly used.

Chapter 4

Age of Sustainability

In the Age of Sustainability our civilization is discovering that in order to survive on this planet, healthy and indefinitely, we must create ways of living that give and take equally.

Worms in the Watershed

> "It may be doubted whether there are many other animals in the world which have played so important a part in the history of the world as the earthworm."
>
> Charles Darwin referring to worms

California Science Standard:
6th Grade, Ecology (5b,c,d)
Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.
7th Grade, Structure and Function in Living Systems (5c)
The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function.
9th-12th Grade, Ecology (6a,b,c,e,f)
Stability in an ecosystem is a balance between competing effects.

Time: Two 50-minute class periods

Objective:
Students will discover ecological factors that contribute to a healthy, biologically diverse environment by carefully extracting earthworms from topsoil in different habitat settings on the school grounds.

Background Information:

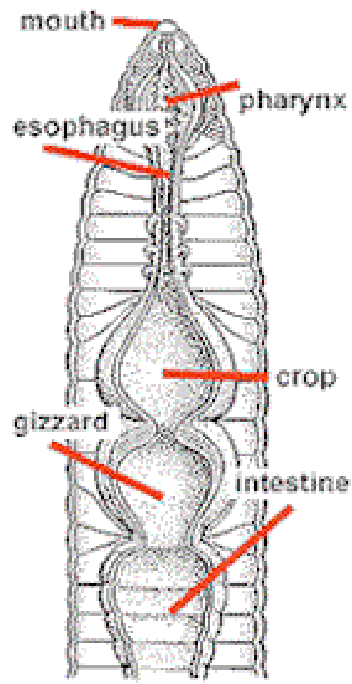
What environmental factors determine how many earthworms are found in different habitats? Some factors that may influence earthworms are the density and moisture level of the soil, the kind and type of organic matter the soil contains, and the presence of animals that eat worms. Also, the presence of pesticides, herbicides, and chemical fertilizers in the soil can reduce earthworm populations.

To study earthworms and their habitats, you must find them. You can dig them up, but that destroys their habitat. Instead, you can force them to come to the surface. By soaking the topsoil with a slurry made from dry mustard—an irritant that bothers worms a little but doesn't harm them— earthworms will come up. Teams count all the worms they find (both adults and juveniles) to get an idea of what might be good or bad worm habitat.

What do WORMS have to do with WATERSHEDS or ECOSYSTEM HEALTH? What is "good" earthworm habitat and how might we improve an area for these humble creatures? Despite their small size and inconspicuous colors, earthworms in large numbers can be a major force below ground. Scientists estimate that a healthy population of 50-200 worms per square meter of ground can "move" nearly 30 pounds of soil each year! In one acre there can be a million or more worms, eating 10 tons of leaves, stems, and dead roots a year and turning over 40 tons of soil. Worms are so effective because of their squirmy movement and unique digestion.

Worms chew up leaves, stems, dead roots, and dead animals in the soil. In doing so, they "turn" the soil over. Their tunnels add air to the soil, which is called aeration. Their constant eating helps trees, leaves, animals, and roots "break down" faster in the soil. Not only does the soil break down with the help of worms, but it becomes even more fertile because of worms. Their poop is a treasured fertilizer, called "worm castings". If we look closely at worm anatomy we discover that they share some of the same body parts that we have.

Mouth: Earthworms have mouths that they can open wide to fit leaves and other good things to eat. But they don't have teeth!
Pharynx: The throat (pharynx) comes out of a worm's mouth to grab leaves and to pull them back into its mouth. Then the worm's saliva moistens the food.
Esophagus: The food gets pushed down the esophagus next.
Crop: Worms store this food in their crop before it gets passed down to the gizzard.
Gizzard: The gizzard is where the work happens. The gizzard muscles are so strong they can grind up leaves-- it's almost like teeth!
Intestine: The intestinal juices break down the ground up leaves even more.
Bloodstream: After the leaf is all digested, some of it will pass into the bloodstream.
Anus: Whatever is leftover comes out the anus as castings (worm poop).



Materials:

For each group of 2-3 students

- Quarter Square Meter (0.25m2) made from sticks or a meter of string tied in a loop.
- Mustard Slurry Jugs with 1 sprinkler head
  - Use gallon milk jugs or watering cans
- Shovel (as a last result to dig up worms in case the mustard slurry doesn't work)
- Bowl or pan (for holding worms)
  - Spray bottle to keep bowl wet and worms moist
- Scissors or clippers (for clipping grass to see worms better)
- Pencil, data sheet, and clipboard

Procedure:

Day One

1. Discuss with students the background information and then tour the school grounds.
   a. Have the students look around the area and imagine what the environment is like below ground in different places.
   b. List the different places that could be good habitat for worms. Determine 3-4 sampling sites. One site per group. Select at least one area with good hydrated topsoil.
   c. Find out what herbicides, pesticides and chemical fertilizers have been used on campus. Choose a location that is as unaltered as possible.

2. Prepare the Mustard Slurry.
    a. Mustard Slurry Recipe: 2 T dry mustard powder per gallon of water. Shake vigorously. (Try Colman's or bulk mustard from organic grocer—it must be fresh). This makes a 0.33% solution of mustard by weight. Higher concentrations might harm the worms.

Day Two

1. Divide the students into groups of 2-3.
2. Distribute materials to student groups.
3. Show students how to set up their quadrant in order to sample a quarter square meter.
4. Use the scissors to cut away grass or weeds that might get in the way of seeing the surface of the ground. Remove leaf litter also.
5. Pour the slurry into the quadrant area.
    a. Pour slurry slowly. Make sure all the slurry stays in the quadrant so they sample all the worms there.
    b. Be extremely careful not to injure worms. Do not pull on them!
7. Put worms into the moistened bowl. Mist the worms with the spray water bottle.
8. If students find no worms, this is still important information about the sampled habitat.
9. Complete Data Sheet.
    a. Number of worms found
    b. Environmental factors above ground and below ground.
        i. Moisture.
        ii. Plant life
        iii. Nutrient level of soil (sand or organic rich)

10. Quickly return worms to the quadrant site or an adjacent site.
11. Rinse mustard jugs and clean all materials.

Questions:

1. Which habitat had the most worms? The most juvenile worms? Why do you think this was so?
2. In what ways did the environmental factors in the two habitats differ?
3. What environmental factors determine how many earthworms are found in different habitats?
4. Can you think of other soil or worm characteristics that should be considered in the Worm Collecting Data Sheet?

Web Extension:

Worm World http://yucky.kids.discovery.com/noflash/worm/
Worm FAQs http://www.ordgrowth.org/compost/wormfaq.html
Worm Words Glossary http://www.cityfarmer.org/wormgloss82.html

Worm Collecting Data Sheet	
Site Description	Surface description (frequency of rain or watering, sunlight, plant material)
	Soil description (sand content, quantity of organic matter, moisture)
Worm Data	(number of worms, species, condition, male/female, juvenile/adult, evidence of worm predators)

Classroom Composting With Worms

California Science Standard:
6th grade Ecology (5a,b,c,d,e)
Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.
7th grade Structure and Function of Living Systems (5b)
The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function.
Grades 9-12 Ecology (6a,b,c,e,f)
Stability in an ecosystem is a balance between competing effects.

Time: Requires out of class assignments and teacher preparation.

Objective:
Students will observe organic recycling in the classroom and understand the role of decomposers in any ecosystem by maintaining a worm bin in the classroom

Background Information:
Refer to the pervious activity "Worms in the Watershed" for background information about worms and vermiculture.

Materials:
If you don't have access to, or permission to use, a backyard or side yard, you can compost indoors with a worm bin. Like any urban composting option, worm bins do require some time and attention; they're not trouble-free—nor is worm-bin composting for everyone. Ready-made worm bins are available from many on-line suppliers, but it's quite easy for you and your students to make your own. The materials are available in any department or hardware store. They include:

One water-sealed storage bin
Drill with ¼ drill bit
Shredded newspaper
Food scraps
Water

Procedure:

1. **Construct the Worm Bin**

Before you buy or build your bin, first decide how much food you plan to compost and how much space to have to spare. Keep in mind that two pounds of worms (approx. 2000 worms) can process up to a pound of food scraps each day. You'll also need one square foot of space for each pound of worms. Now you can figure out the size bin you need.

An old plastic storage container can be recycled into a worm bin, or you can easily make one from wood. If you build a wooden box, make sure it's shallow (8-10 inches) and that there's a tight lid to keep the inside dark and moist.

Drill at least 10 quarter-inch holes in the top and around the top of the sides of the bin for air circulation.

Drill at least 10 holes in the bottom for drainage. Accumulated moisture can kill the worm population.

2. **Make the bedding material**

Your worms will require about 8 inches of bedding material, such as leaves, potting soil, or one-inch strips of newspaper. Shred the newspaper length-wise into long, one-inch strips and then soak the strips in a bucket of water to make them damp. Bedding should be at a moisture level equivalent to a wrung-out sponge.

3. **Wash and add kitchen scraps**

Before you add any fruit or vegetable waste, take the time to scrub the skins before placing them in the bin. This will wash off any fruit fly eggs that already might be present and will greatly reduce your risk of fruit fly infestations.

The best materials to add to a worm bin are washed fruit and vegetable scraps, coffee grounds and filters, tea bags (remove the staples—they harm the worms' stomachs!), egg shells, paper napkins and towels, and dead plants and flowers. Remember to feed worms a varied diet and don't overload the bin with fruit, or you'll attract fruit flies.

Do not feed your worms meat, fish, or dairy products. These items will produce odors and attract flies as they decompose. It is generally not a good idea to feed your worms leftovers, even if they do not include fish or meat, since they also tend to produce odors and attract fruit flies. In general, try experimenting with what works in your bin and what doesn't—but be advised that once your bin has a fruit fly problem, it's hard to get rid of!

4. **Add worms**

You will want to add red worms (*Eisenia fetida* or *Lumbricus rubellus)* to your bin. Don't use nightcrawlers or other garden worms, which are usually brown or gray in color. See the "Database of Suppliers" at the end of this activity for a list of companies that sell worms.

5. **Bury the food scraps and moisten the material**

Bury the food scraps well underneath the newspaper or other bedding material you are using. Do not leave food scraps exposed on top of the bin.

Worms need a dark, moist environment in order to thrive. Especially if you are using a naturally dry bedding material such as shredded newspaper or fall leaves, be sure to keep the bedding material moist. You can use a plant mister to moisten the bedding material.

6. **Harvest your worm bin**

When the bedding starts to resemble dark, crumbly soil (usually in one to four months), it's time to harvest your compost.

   a. Move all the bedding over to one side of the worm bin.
   b. Add new, dampened bedding to the empty side, and start placing food scraps on that side.
   c. Wait approximately a month for most of the worms to move over to the new bedding, allowing you to scoop out the relatively worm-free compost.
   d. Finished worm compost (vermicompost) starts becoming toxic to the worms if it's left in the worm bin for too long.

Questions:

1. Are there more worms after four months than when you started?
2. What kinds of materials are still recognizable in the finished compost?
3. What do you think would happen if a piece of plastic were left in the worm bin for a year or more?

Web Extension:

Information about this activity can be found by visiting http://www.nyccompost.org/how/wormbin.html

DATABASE OF SUPPLIERS

Dave’s Garden
http://davesgarden.com/qwd/

Acme Worm Farm
www.acmewormfarm.com
5726 E 29 St.
Tucson, AZ 85711
phone: 520-750-8056
ARBICO
www.arbico-organics.com
18701 N. Lago Del Oro Parkway
P.O. Box 8910
Tucson, AZ 85738-0910
phone: (800) 827-2847 toll free

Bountiful Gardens
www.bountifulgardens.org
18001 Shafer Ranch Road
Willits, CA 95490-9626
phone: (707) 459-6410

Cape Cod Worm Farm
www.capecodwormfarm.com
30 Center Avenue
Buzzards Bay, MA 02532
phone: (508) 759-8664

Flowerfield Enterprises
www.wormwoman.com
10332 Shaver Road
Kalamazoo, MI 49024
phone: (269) 327-0108

Magic Worm Ranch
www.magicworms.com
3163 Roadrunner Rd
San Marcos, CA 92069
phone: 877-WORM-BOYS

Worm World
www.wormwrld.com
worm farms for homes and students
26 Ihnat Lane
Avella, PA 15312
phone: (724) 356-2397

Unco Industries, Inc.
www.vermiculture.com
7802 Old Spring Street
Racine, WI 53406
phone: (800) 728-2415

Uncle Jim’s Worm Farm
www.unclejim.com
2046 Henry Lane
Spring Grove, PA 17362
phone: (800) 373-0555

Vermi-Technology Unlimited
www.vermitechnology.com
P.O. Box 130
Orange Lake, FL 32681
phone: (352) 591-1111

Worm Ladies of Charleston
www.angoraandworms.com
161 A East Beach Road
Charlestown, RI 02813
phone: (888) 917-9593 toll free

Worm Man’s Worm Farm
www.wormman.com
P.O. Box 6947
Monroe Township, NJ 08831
phone: (732) 656-0369

Worm's Way
www.wormsway.com
7850 North Highway
37 Bloomington, IN 47404
phone: (800) 274-9676

Worms Wrangler
www.wormswrangler.com
large-scale vermiculture operation
P.O. Box 215
Littlerock, WA 98556
phone: (360) 534-3644

Don't Let Your Pollution Leave Home

California Science Standard:
6th Grade, Ecology (6b)
Resources: Sources of energy and materials differ in amounts, distribution, usefulness, and time required for their formation.
9th-12th Grade, Ecology (b)
Stability in an ecosystem is a balance between competing effects.
9th-12th Grade, California Geology (9a,b,c)
The geology of California underlies the state's wealth of natural resources as well as its natural hazards.
9th–12th Grade, Social Science
Students analyze the major social problems and domestic policy issues in contemporary American society.

Time: One 50-minute class period

Objective:
Students will understand the difference between point-source pollution and nonpoint-source pollution.
Students will also be able to identify sources of pollution and their effects on the environment.
Students will understand how consumer choices can reduce nonpoint source pollution.

Background Information:

Land-based marine pollution can either be from a "point source" or a "nonpoint source." Point source pollution originates from a specific place such as an oil refinery or a paper mill. Nonpoint source pollution, on the other hand, is contaminated runoff originating from an indefinite or undefined place, often a variety of places (e.g., farms, city streets and parking lots, yards and landscaping, construction sites, and logging operations). The soot, dust, oil, animal wastes, litter, sand, salt, pesticides and other chemicals that constitute nonpoint source pollution often come from everyday activities are washed from lawns and streets into stormdrains that often lead directly to nearby bodies of water such as streams, rivers and oceans.

Nonpoint source pollution, contributed potentially by all of us in small quantities and from many different locations, is very difficult to track and stop. These small quantities add up to become the largest contributor to water pollution in our local environment. Education and awareness are the key for long term solutions to the water pollution problem. As students learn at a young age about the concept of pollution and become aware of their natural surroundings, their day-to-day actions will reflect their knowledge.

Water from urban areas travels two different pathways. (1) Water used inside our homes, schools and buildings is carried through pipes to wastewater (sewage) treatment plants. Once it arrives there, the wastewater is treated and ultimately ends up in the ocean or is recycled for irrigation. (2) Water that runs off of streets and buildings flows into the storm drains. Storm drains are a large part of the watershed in urban areas. Anything on the street – including trash, fertilizer, pesticides, motor oil, and pet waste -can enter a storm drain. All storm drains flow directly to creeks and to the ocean. This nonpoint-source pollution contributes to the elevation of bacterial levels in creeks and the ocean. Pollution from contaminated runoff can affect aquatic ecosystems and cause the ocean to be unsafe for people to swim in.

Understanding how the storm drain system works is necessary in keeping a watershed healthy. With the knowledge of how these systems work, people can understand the connection between solid and liquid pollutants and the storm drains, creeks and the ocean. It is only with this understanding that we can begin to prevent pollution problems in our watershed.

Materials:
Copies of neighborhood illustration for every student.

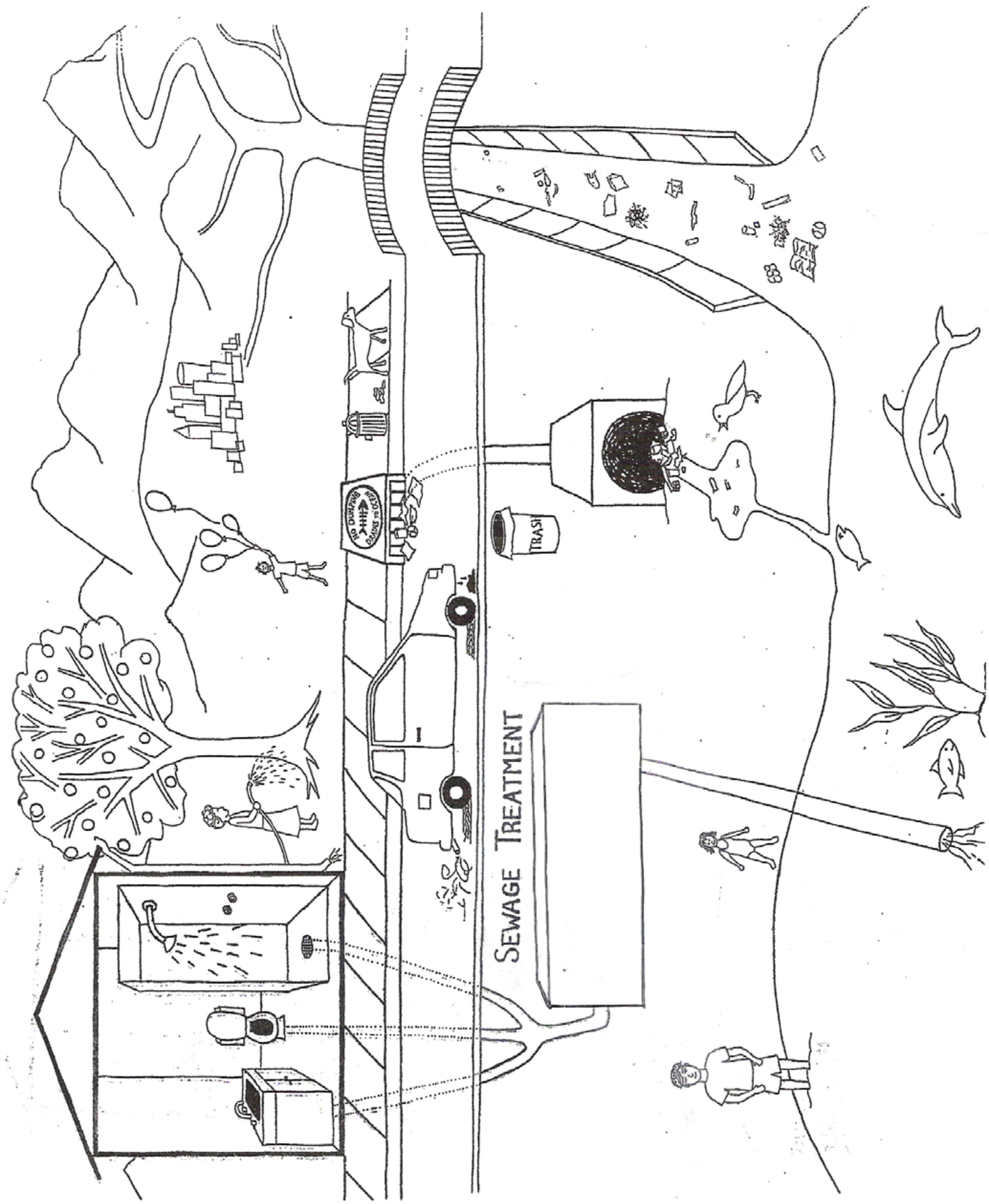
Procedure:
1. Define and discuss with students “point source” and “nonpoint source” pollution, and how substances we use at home can travel through the storm drain system and end up polluting lakes, streams, rivers, marshland, bays and the ocean.
2. Distribute to each student a copy of the neighborhood illustration.
3. Challenge each student to come up with at least 5 causes and 5 solutions to nonpoint-source pollution. Direct students to draw a line from the source of pollution to the storm drain.
4. Using the answer key, discuss with students the causes and solutions to pollution. Remind students that the cumulative effect of nonpoint-source pollution is the largest source of pollution in the natural environment.

Questions:
1. Can you identify places in your home where nonpoint source pollution is generated?
2. Identify 5 other sources of nonpoint-source pollution not identified on the neighborhood illustration. How can those other forms of nonpoint source pollution be stopped?

Web Extension:
Stencil a stormdrain in your neighborhood! Do the storm drains in your neighborhood or near your school say “Don’t Dump Here”? Earthwater stencils (http://www.earthwater-stencils.com/) is an excellent educational , interactive tool to engage people of all ages in community involvement for watershed pollution prevention. It is an action project for students and community involvement for adults.

Answer Key			
Cause of nonpoint-source pollution		Prevention of nonpoint-source pollution	
1	Pouring oil down the storm drain	1	Recycle or take it to a hazardous waste disposal site.
2	Littering near a stream (or anywhere)	2	Throw trash in garbage cans. Do your own trash pick up day. Don't be afraid to pick up and discard someone else's trash.
3	Car leaking oil or radiator fluid into driveway	3	Keep cars in good condition. Clean up leaks with absorbent material such as sawdust or hay.
4	Cleaning paint brushes on lawn	4	Clean brushes in a container, taking care not to spill solvent. Reuse solvent or take it to hazardous waste disposal.
5	Paint can spilling onto lawn	5	Take care not to spill paint on the lawn. It could soak into ground and water below.
6	Cleaning porch with chemical cleaners	6	Use only non-toxic cleansers out of doors, such as baking powder, borax or commercial cleansers labeled as environmentally safe.
7	Sprinkling water and pesticides on flowers	7	Use natural pesticides such as planting marigolds nearby, or introducing ladybugs or eggs of praying mantids.
8	Car cleanser spilling into street	8	Wash car with safe cleansers and take care not to spill undiluted product onto the ground.
9	Gasoline spilling on driveway	9	Take extra precautions not to spill hazardous products. If spills occur, clean up with absorbent materials such as sawdust or hay.
10	Littering on sidewalk	10	Throw litter in trashcans. Pick up litter that others may have carelessly discarded on the ground.
11	Hosing driveways and sidewalks	11	Sweep driveways and sidewalks instead.

Neighborhood Illustration



Reduce, Reuse, and a 100% Recyclable Grocery List

California Science Standard:
6th Grade, Ecology (6b)
Resources: Sources of energy and materials differ in amounts, distribution, usefulness, and time required for their formation.
9th-12th Grade, Ecology (b)
Stability in an ecosystem is a balance between competing effects.
9th-12th Grade, California Geology (9a,b,c)
The geology of California underlies the state's wealth of natural resources as well as its natural hazards.
9th–12th Grade, Social Science
Students analyze the major social problems and domestic policy issues in contemporary American society.

Time: Two homework assignments and one 50-minute class period for discussion.

Objective:
Students will recognize that their consumer choices have end use consequences that produce non-recyclable materials that are difficult to dispose of.
Students will recognize the ease in which to choose recyclable materials over non-recyclable ones.

Background Information:

Reduce, Reuse and Recycle is counter to the consumer culture that most Americans live in today. Manufacturers appeal to consumer desire for convenience, with products packaged in single-serving sizes and with throw-away materials. In order to ensure that customers continue to replace old parts or buy new products, manufactures will purposefully decrease the quality of their merchandise. Manufactures often withhold new technology, like for cars and computers, until old technology has exhausted its profitability. This results in excessive material waste as consumers scramble for the latest model or upgrade. The result of this consumer culture includes rapidly filling landfills and pollution in our watershed.

What can you do? "Reduce, reuse and recycle" is a common statement many conservationist proclaim, but what does it mean?

"Reduce" means that we avoid, or "Refuse", products that are packed with excessive materials, or are designed to require rapid/unnecessary replacement in the near future. Materialism in our culture encourages consumers to measure ourselves by the fashionability of our possessions. They say, "You are what you have." If we think like true "Reducers" we're not lured by fancy packaging, we buy what we need, and we buy quality merchandise that lasts.

"Reuse" means that we use products beyond their initial purpose. Like old clothing can become dishrags or dust cloths. Glass bottles bought for the food inside, can be reused to store other food.

"Recycle" means that products and merchandise can be remanufactured into their original function to be used again. Recycling is the last resort after we reuse and reduce our consumption. Returning a plastic bottle to a manufacturer to be reproduced as a plastic product again, is recycling.

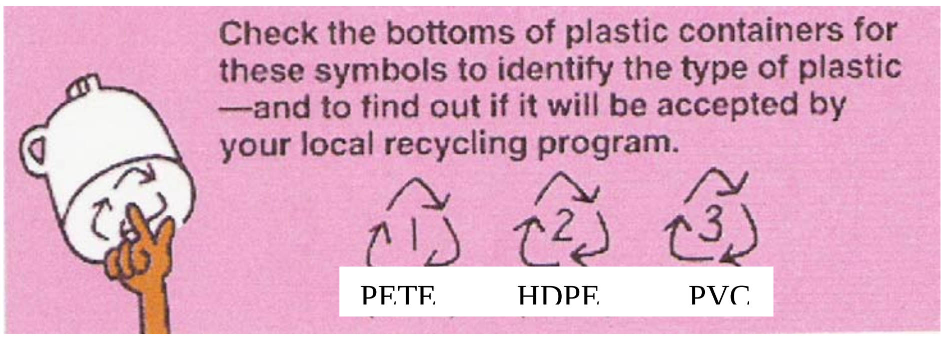
How can you tell if it's recyclable?

Glass – All glass is recyclable! It doesn't matter what color or shape the bottle is in. It is important that containers are cleaned before put into recycling bins.

Paper – Paper is perhaps the easiest material to recycle. It's important to remove staples and plastic tape from boxes before recycling.

Metal – Aluminum cans from soft drinks and steel cans, like the ones that hold vegetables or soup, are completely recyclable.

Plastic – Most consumer plastics are recyclable, but you must know what the number in the triangle means.



Some materials are very difficult to recycle, like old batteries, containers with compressed liquids, like spray paint or hairspray, and hazardous materials, like bathroom cleaners, paint or used motor oil. Take these materials to a hazardous materials recycling center in your area. This is also an area where we can practice REDUCING. Simply try not to use these materials as much. Use rechargeable batteries or a solar radio. Use fewer cleansers by trying to do more with less. Every little bit helps.

To discard hazardous waste contact your local department of sanitation for a nearby collection center. Call 1-800-CLEAN-UP to find a collection center for used oil.

Materials:

Give each student a copy of the worksheet "What Does That Number Mean?"
Each student should bring five clean pieces of trash from home to the classroom.
Paper and pencil to make recyclable/non-recyclable list.

Procedure:

1. Homework Assignment One - Assign students the homework task to bring a typical grocery list from home, and five cleaned objects that they would have usually thrown away. Encourage students to select a diversity of trash from home (Students tend to bring only plastic bottles to this activity.)
2. Activity: Separating trash from home
    a. Discuss the background information with students. Have students form groups of 3-4.
    b. Each group will put their trash in a single pile of 15-20 pieces.
    c. Each students will make a list with four columns.

i. Column One – Items packages with excessive materials.
ii. Column Two – Items that could be reused for another purpose.
iii. Column Three – Items that are not recyclable.
iv. Column Four – Items that are recyclable

d. Each student will separate the pile of trash into one of the four columns.

3. Homework Assignment Two – Make a new grocery list
   a. Have students review their grocery lists in class or at home.
   b. Begin a new list with the same four columns. Divide the family grocery list among the four categories.
   c. For each item that is packed with excessive materials, or is not recyclable, suggest an alternative product.
   d. Create a 100% recyclable grocery list.
4. Discuss with students the ease of altering our consumer choices to become environmentally responsible.

Questions:

1. What are some examples of excessive packaging that you identified? Why do manufactures spend money on excessive packaging?
2. What are common non-recyclable items your class identified? Should manufactures be responsible for the end use of the products they sell? How could this kind of policy be put into action?

Extensions:

Making Environmentally Friendly Products

This activity, created by Roots and Shoots, invites classrooms to create alternative household products out of environmentally friendly materials.
Visit: http://www.rootsandshoots.org/pdfs/lesson-plans/02-Ecocleaning.pdf.

APPENDIX

Appendix A

Evaluate Us:
Feedback for the Writers of this Curriculum

Teachers, please take a moment to answer a few questions about this curriculum.

1. Which section of this curriculum did you find most useful? The least? Please tell us why.

2. If you could change anything in this curriculum, what would it be?

3. Which activities did you use, and for what grade level?

4. Did you modify any activities? If so, how?

5. Which activities worked best? Why?

6. Which activities did not work for you? How would you change it to make it useful for your program?

7. Please give us any other comments or suggestions that you think will improve this curriculum.

Vocabulary

Aquifer – water bearing layer found beneath the Earth's surface.

Age of Sustainability – In the Age of Sustainability our civilization is discovering that in order to survive on this planet, healthy and indefinitely, we must create ways of living that give and take equally.

Biodiversity – The sum total of different organisms within an ecosystem.

Catch Basin – Any place or drain that receives run off from natural or man-made surfaces.

Chemical Pollution - The introduction of toxic substances into an ecosystem, e.g., acid rain, contamination of water supplies by pesticides.

Coastal Upwelling – An ocean process that occurs most notably on the western coasts of continents when cold nutrient-rich bottom water flows to the surface along the continental coastlines.

Flood Control Channel – Open waterway that is designed to carry large amounts of rain water. These structures are often lined with concrete to help control flood waters.

Thermal Pollution - Varying temperatures above or below the normal condition, e.g., power plant turbine heated water.

Organic Pollution - Oversupplying an ecosystem with nutrients, e.g., fertilizer inflow.

Ecological Pollution - Stresses ordinarily created by natural processes, like extreme tides that pour saltwater into habitats ordinarily protected from sea water, and abnormal increase in sediments in runoff water producing silt. Also, altering the level or concentration of biological or physical components of an ecosystem, like invasive species that inhabit a new ecosystem.

Groundwater – Water that is stored in open spaces underground and within sediment.

Hydrology – The scientific study of the properties, distribution and effects of water in the atmosphere, on the Earth's surface and in soil and rocks.

Invasive Species – Non-native plants and animal species that have been introduced to an area where they do not occur naturally.

Marine Debris – Any trash, natural or man-made, that is found in the marine environment.

Native Species – Plants and animal species that have evolved in a specific area over a period of time; naturally occurring species; indigenous.

Nonpoint Source Pollution - Nonpoint source pollution is contaminated runoff originating from an indefinite or undefined place, often a variety of places (e.g., farms, city streets and parking lots, yards and landscaping, construction sites, and logging operations).

Outfall – Opening at the end of a storm drain system that allows water to flow into a channel, lake, river, bay or ocean.

Phytoplankton – Microscopic marine algae that are the primary producers in the marine food web.

Plankton – A general term for the entire community of microscopic free-floating organisms, including phytoplankton, zooplankton, and a host of other marine organisms. Plankton serves as the primary food source for most marine ecosystems. Many animals feed entirely on planktonic organisms and are important stops in the food chain.

Point source pollution – Point source pollution originates from a specific place such as an oil refinery or a paper mill.

Pollutants – Any substance, biological or chemical, in which an identified excess is known to be harmful to desirable organisms (both plants and animals). Some pollutants are toxic or poisonous. Others are dangerous because they stick to feathers (oil and tar) making it impossible for birds to fly or find food, or clog throats and stomachs, and entangle necks (plastic bags and plastic 6-pack rings) of marine creatures.

Pollution – A human or naturally caused change in physical, chemical, or biological conditions that results in an undesirable effect on the environment; contamination of air, soil, or water by the discharge of harmful substances.

Precipitation – The fall of condensed moisture as rain, snow, hail or sleet.

Runoff – Water that flows over land surfaces and does not percolate, or sink, into the ground.

Storm Water – Runoff in the storm drain system.

Wastewater – Water that comes from showers, toilets and kitchen basins, that contain high levels of bacteria, requiring processing at sewage treatment facilities before being returned to the natural environment or used for irrigation.

Water Table – The level below the ground where ground water is closest to the surface.

Watershed - An area that is drained by rivers and streams and includes geographical structures like mountains, valleys, and man-made structures like buildings, parking lots and highways, but it also includes a rich biodiversity that is supported by the ecosystems within.

Zooplankton – Small, free-floating marine organisms that live in the world’s oceans and drift with the currents. These small creatures usually feed on phytoplankton.

Resources on Water and Watersheds

Algalita Marine Research Foundation
www.algalita.org

148 Marina Drive
Long Beach, CA 90803
Phone (562) 598-4889, Fax (562) 598-0712
Algalita Marine Research Foundation (AMRF) is a Long Beach, California based 501 (c)(3) non-profit environmental organization. AMRF is dedicated to the preservation of the marine environment. With the help of its chartered research vessel, The Oceanographic Research Vessel (ORV) Alguita, AMRF is actively engaged in innovative research, education and restoration of the marine environment.

Audubon Center at Debs Park
http://www.audubon-ca.org/debs_park.htm

4700 North Griffin Ave.
Los Angeles, CA 90031
Phone (323) 221-2255, Fax (323) 221-2444
The Audubon Center at Debs Park is a cutting-edge environmental education center and ecological monitoring program within the nearly 300-acre city park, located on the border of Highland Park and Montecito Heights between Dodger Stadium and South Pasadena in Los Angeles.

Cabrillo Marine Aquarium
www.cabrilloaq.org

3720 Stephen White Drive
San Pedro, California 90731
(310) 548-7562

California Coastal Commission
www.coastforyou.org

Established in 1972, the CCC's mission is to protect and enhance the resources of the California coast and ocean for current and future generations. Projects include the annual California Coastal Clean-up Day; the Adopt-A-Beach Program; the Boating Clean and green Campaign; the Waves, Wetlands, and Watersheds school program; and the Whale Tail License Plate Program.

Community Environmental Council
www.communityenvironmentalcouncil.org

An excellent resource for all educators in California, especially in Santa Barbara County! For classroom materials or to plan a free field trip to study watersheds, visit the South Coast Watershed Resource Center located in Arroyo Burro Beach County Park at 2981 Cliff Drive in Santa Barbara, CA, or call 805-682-6113.

California Regional Environmental Education Community (CREEC)
www.creec.org

The CREEC network is an educational project whose mission is: To develop a communication network which provides educators with access to high quality environmental education resources to enhance the environmental literacy of California students.
3350 Education Drive in San Luis Obispo, CA 93405. Call 805-782-7224.

Earthwater Stencils
http://www.earthwater-stencils.com/

Storm drain stenciling is an educational, interactive tool to engage people of all ages in community involvement for watershed pollution prevention. It is an action project for students and community involvement for adults.

Heal the Bay
www.healthebay.org

3220 Nebraska Ave
Santa Monica, California 90404
(800) HEAL-BAY

Long Beach Organic
www.longbeachorganic.org

The vision of Long Beach Organic extends to the creation of school gardens and educational programs, a thriving organic nursery, as well as a community resource center for those interested in pursuing organic gardening and supporting local organic farms.
1336 Gladys Avenue
Long Beach, CA 90804
(562) 438-9000

Marine, Coastal and Watershed Resource Directory
www.coastforyou.org

The Resource Directory details educational resources, volunteer opportunities and internship possibilities statewide that address marine, coastal and watershed topics. It is designed for educators and students, as well as the general public.

Marine, Coastal and Watershed Resource Directory
www.coastal.ca.gov/publiced/directory/resdirectory/c_orgs/californiawaterfowl.html

This website is an excellent resource to find out what watershed conservation organizations exist in each county in California.

Orange County Coastkeeper
www.coastkeeper.org

441 Old Newport Boulevard, Suite 103
Newport Beach, California 92663
(949) 723-5424

Permaculture Institute of Southern California
Bill Roley, PhD., Director
1027 Summit Way, Laguna Beach, CA 92651
949-494-5843 – drroley@aol.com

Project WET
http://www.projectwetusa.org/
(Water Education for Teachers) is a nonprofit water education program and publisher for educators and young people ages 5-18. The program facilitates and promotes awareness, appreciation, knowledge, and stewardship of water resources through the dissemination of classroom-ready teaching aids and the establishment of internationally sponsored Project WET programs.

San Diego Bay Keeper
www.sdbaykeeper.org
2924 Emerson Street, Suite 220
San Diego, California 92106 (619) 758-7743

Surfrider Foundation
www.surfrider.org
P.O. Box 6010 San Clemente, CA 92674. For further information call (949) 492-8170

Watershed Student Opportunities
http://www.kn.sbc.com/wired/fil/pages/liststudentja.html
Summer camps and scholarships available to California students interested in watershed conservation.

U.S. Environmental Protection Agency: Adopt Your Watershed
www.epa.gov/adopt/
To encourage stewardship of the nation's water resources, the Environmental Protection Agency (EPA) is leading an "Adopt Your Watershed" campaign. Through this effort, EPA challenges citizens and organizations to join us and others who are working to protect and restore our valuable rivers, streams, wetlands, lakes, ground water, and estuaries. By visiting our on-line database, you can learn about opportunities to get involved in activities in your community, such as monitoring, cleanups, and restoration projects. As of September 2004, the database has nearly 4,000 groups that you might want to join.

Virtual Watershed
www.vanderbilt.edu/VirtualSchool/vwactivities.htm
Virtual Watershed Activities and Lesson Plans – An excellent source of lessons and online quizzes for your students to take.

Internet Resources

Adopt-A-Watershed Leadership Institute
www.adopt-a-watershed.org - Schools can adopt a local watershed
(530) 628-5334

Algalita Marine Research Foundation
www.algalita.org - Education materials reflecting current research on conservation of the marine environment and California's watersheds.
Phone (562) 598-4889, Fax (562) 598-0712

California Regional Environmental Education Community Network
www.creec.org - Environmental Education resources for Santa Barbara, San Luis Obispo, Ventura and Kern Counties.

California Environmental Resources Evaluation System
www.ceres.ca.gov/education - An information system developed by the California Resources Agency to facilitate access to electronic data describing California's rich and diverse environments.

Department of Water Resources California Water Page
www.dwr.water.ca.gov/owe
Provides educational services for schools throughout California.

California Aquatic Science Education Consortium
www.rain.org/casec/index.html - Encouraging, supporting, and enhancing aquatic (fresh and marine) education programs in the State of California.

Earth's 911
www.cleanup.org - Call 1-800-CLEANUP – Information about residential hazardous waste and locations where they can legally be discarded.

Water Education for Teachers Network, Project WET
www.montana.edu/wwwwet - Classroom-ready teaching aids to help promote awareness, appreciation, knowledge, and stewardship of water resources.

Environmental Education on the Internet
www.nceet.snre.umich.edu/index.html - Your link to environmental Education resources.

Water Education Foundation
www.water-ed.org - On-line catalog for educational products which create a better understanding of water issues and help resolve water resource problems.

USGS Water Science for Schools
www.ga.water.usgs.gov - Information about water use, including maps, pictures and an interactive center that tests your knowledge about water.

Appendix E

Pergamon

Marine Pollution Bulletin Vol. 42, No. 12, pp. 1297–1300, 2001
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Printed in Great Britain
0025-326X/01 $ - see front matter

PII: S0025-326X(01)00114-X

A Comparison of Plastic and Plankton in the North Pacific Central Gyre

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The potential for ingestion of plastic particles by open ocean filter feeders was assessed by measuring the relative abundance and mass of neustonic plastic and zooplankton in surface waters under the central atmospheric high-pressure cells of the North Pacific Ocean. Neuston samples were collected at 11 random sites, using a manta trawl lined with 333 u mesh. The abundance and mass of neustonic plastic was the largest recorded anywhere in the Pacific Ocean at 334 271 pieces km^2 and 5114 g km^2, respectively. Plankton abundance was approximately five times higher than that of plastic, but the mass of plastic was approximately six times that of plankton. The most frequently sampled types of identifiable plastic were thin films, polypropylene/monofilament line and unidentified plastic, most of which were miscellaneous fragments. Cumulatively, these three types accounted for 98% of the total number of plastic pieces. **© 2001 Elsevier Science Ltd. All rights reserved.**

Keywords: North Pacific central gyre; neuston; plastics; zooplankton; debris; pollution monitoring.

Marine debris is more than an aesthetic problem, posing a danger to marine organisms through ingestion and entanglement (Day, 1980; Balazs, 1985; Fowler, 1987; Ryan, 1987; Robards, 1993; Bjorndal *et al.*, 1994; Laist, 1997). The number of marine mammals that die each year due to ingestion and entanglement approaches 100 000 in the North Pacific Ocean alone (Wallace, 1985). Worldwide, 82 of 144 bird species examined contained small debris in their stomachs, and in many species the incidence of ingestion exceeds 80% of the individuals (Ryan, 1990). In addition, a recent study has determined that plastic resin pellets accumulate toxic chemicals, such as PCBs, DDE, and nonylphenols, and may serve as a transport medium and source of toxins to marine organisms that ingest them (Mato *et al.*, 2001).

Many studies have focused on the ingestion of small debris by birds because their stomach contents can be regurgitated by researchers in the field without causing harm to the animal. Less well studied are the effects of ingestible debris on fish, and no studies have been conducted on filter-feeding organisms, whose feeding mechanisms do not permit them to distinguish between debris and plankton. Moreover, no studies have compared the amount of neustonic debris to that of plankton to assess the potential effects on filter feeders.

Concerns about the effects of neustonic debris in the marine environment are greatest in oceanographic convergences and eddies, where debris fragments naturally accumulate (Shaw and Mapes, 1979; Day, 1986; Day and Shaw, 1987). The North Pacific central gyre, an area of high atmospheric pressure with a clockwise ocean current, is one such area of convergence that forces debris into a central area where winds and currents diminish. This study compares the abundance and mass of neustonic debris with the amount of zooplankton in this area.

Materials and Methods

Eleven neuston samples were collected between August 23 and 26, 1999, from an area near the central pressure cell of the North Pacific sub tropical high (Fig. 1). Sampling sites were located along two transects: a westerly transect from 35°45.8′N, 138°30.7′W to 36°04.9′N, 142°04.6′W; and a southerly transect from 36°04.9′N, 142°04.6′W to 34°40.0′N. Location along the transect and trawl duration were selected randomly. Samples were collected using a manta trawl with a rectangular opening of 0.9×0.15 m^2, and a 3.5 m long, 333 u net with a 30×10 cm^2 collecting bag. The net was towed at the surface outside of the effects of port wake (from the stern of the vessel) at a nominal speed of 1 m s^{-1}; actual speed varied between 0.5 and 1.5 m s^{-1}, as measured with a B&G paddlewheel sensor. Each trawl was conducted for a random distance, ranging from 5 to 19 km. Sampling was conducted as the ship moved along the transect with an approximately even split of sampling between daylight and night-time hours. Estimates of plastic and plankton per square kilometer were obtained by using the width of the trawl net opening times the length of the trawl.

Samples were fixed in 5% formalin, then soaked in fresh water and transferred to 50% isopropyl alcohol.

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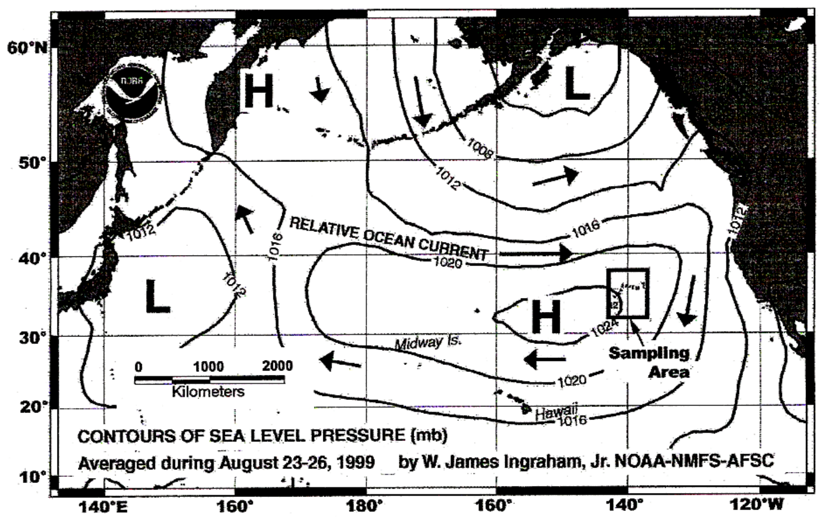

Fig. 1 Location of sampling area in the North Pacific gyre.

To separate the plastic particles from living tissue, the samples were drained and put in seawater, which floated most of the plastic to the surface, leaving the living tissue at the bottom. Top and bottom portions were inspected under a dissecting microscope. Intermixed plastic was removed from the tissue fraction and tissue was removed from the plastic fraction and placed in the appropriate containers. Plankton were counted and identified to class.

Plastic was sorted by rinsing through Tyler sieves of 4.76, 2.80, 1.00, 0.71, 0.50, and 0.35 mm. Plastic and plankton were oven dried at 65°C for 24 h and weighed. Individual pieces of plastic were categorized into standardized categories by type (fragment, Styrofoam fragment, pellet, polypropylene/monofilament line fragment, thin plastic films), and one nonplastic category (tar); then they were counted.

Results

A total of 27 698 small pieces of plastic weighing 424 g were collected from the surface water at stations in the gyre, yielding a mean abundance of 3 34 271 pieces km^2 and a mean mass of 5114 g/km^2. Abundance ranged from 31 982 pieces km^2 to 969 777 pieces/km^2, and mass ranged from 64 to 30 169 g km^2.

A total of 152 244 planktonic organisms weighing approximately 70 g were collected from the surface water, with a mean abundance of 18 37 342 organisms km^2 and mean mass of 841 g/km^2 (dry weight). Abundances ranged from 54 003 organisms km^2 to 50 76 403 organisms km^2, and weights ranged from 74 to 1618 g/km^2.

Plastic fragments accounted for the majority of the material collected in the smaller size categories (Table 1). Thin plastic films, such as those used in sandwich bags, accounted for half of the abundance in the second largest size category, and pieces of line (polypropylene and monofilament) comprised the greatest fraction of the material collected in the largest size category.

Plankton abundance was higher than plastic abundance in 8 out of 11 samples, with the difference being higher at night (Fig. 2). In contrast, the mass of plastic was higher than the plankton mass in 6 out of 11 samples. The ratio of plastic-to-plankton mass was higher

TABLE 1

Abundance (pieces km^2) by type and size of plastic pieces and tar found in the North Pacific gyre.

Mesh-size (mm)	Fragments	Styrofoam pieces	Pellets	Polypropylene/ monofilament	Thin plastic films	Miscellaneous		
						Tar	Unidentified	Total
>4.760	1931	84	36	16 811	5322	217	350	24 764
4.759–2.800	4502	121	471	4839	9631	97	36	19 696
2.799–1.000	61 187	1593	12	9969	40 622	833	72	114 288
0.999–0.710	55 780	591	0	2933	26 273	278	48	85 903
0.709–0.500	45 196	567	12	1460	10 572	121	0	57 928
0.499–0.355	26 888	338	0	845	3222	169	229	31 692
Total	195 484	3295	531	36 857	95 642	1714	736	334 270

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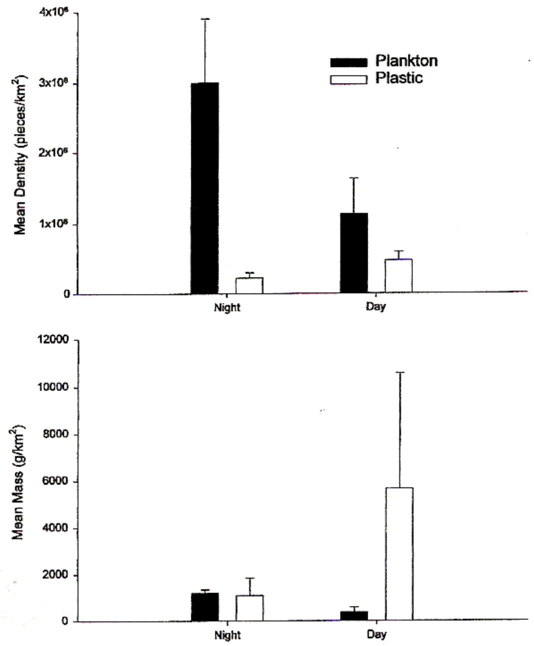

Fig. 2 Abundance and mass of plankton and plastic in night versus day samples.

during the day than at night, although much of the difference during the day was due to a plastic bottle being caught in one daylight sample and 1 m of polypropylene line being caught in the other.

Discussion

The mean abundance and weight of plastic pieces calculated for this study are the largest observed in the North Pacific Ocean. Previous studies have estimated mean abundances of plastic pieces ranging from 3370 to 96 100 pieces km^2 and mean weights ranging from 46 to 1210 g km^2 (Day and Shaw, 1987). The highest previous single sample abundance and weight recorded for the North Pacific Ocean was taken from an area about 500 miles east of Japan. At 316 800 pieces km^2 and 3492 g km^2 (Day *et al.*, 1990), the abundance and weight are three and seven times less than the highest sample recorded in this study, respectively.

Several possible reasons are suggested for the high abundance found in this study. The first is the location of our study area, which was near the central of the North Pacific subtropical high pressure cell. Previous studies in the North Pacific Ocean were conducted without reference to the central pressure cell (Day *et al.*, 1990), which should serve as a natural eddy system to concentrate neustonic material including plastic. However, while previous studies did not focus on the subtropical high, many studies were conducted as transects that passed through the gyre (Day *et al.*, 1986, 1988, 1990). Thus, it is unlikely that location alone was the reason for the higher densities we observed, as Day *et al.* (1990) collected samples from the western part of this same area.

An alternate hypothesis is that the amount of plastic material in the ocean is increasing over time, which Day and Shaw (1987) have previously suggested based upon a review of historical studies. Plastic degrades slowly in the ocean (Andrady, 1990; US EPA, 1992). While some of the larger pieces may accumulate enough fouling organisms to sink them, the smaller pieces are usually free of fouling organisms and remain afloat. Thus, new plastics added to the ocean may not exit the system once introduced unless they are washed ashore. Although numerous studies have shown that islands are repositories of marine debris (Lucas, 1992;.Corbin and Singh, 1993; Walker *et al.*, 1997), the North Pacific Ocean has few islands except near coastal boundaries. The dominant clockwise gyral currents also serve as a retention mechanism that inhibits plastics from moving toward mainland coasts. A recent surface current modeling study simulated that most of the particles from our sampling area should be retained there for at least 12 years (Ingraham *et al.*, in press).

The large ratio of plastic to plankton found in this study has the potential to affect many types of biota. Most susceptible are the birds and filter feeders that focus their feeding activities on the photic portion of the water column. Many birds have been examined and found to contain small debris in their stomachs, a result of their mistaking plastic for food (Day *et al.*, 1985; Fry *et al.*, 1987; Ainley *et al.*, 1990; Ogi, 1990; Ryan, 1990; Laist, 1997). While no record was kept of the presence or absence of fouling organisms on plastic particles during sorting, a subsequent random sampling of each size class found 91.5% of the particles to be free of fouling organisms. As the size class decreased, there were fewer particles that showed evidence of fouling. Hence ingestion of plastic for its attached food seems unlikely, especially for organisms feeding on the surface. However, organisms such as the two filter-feeding salps (*Thetys vagina*) collected in this study which were found to have plastic fragments and polypropylene/monofilament line firmly embedded in their tissues, may have ingested the line at depth and utilized fouling organisms for food.

Although our study focused on the neuston, samples also were collected from two oblique tows to a depth of 10 m. We found that the density of plastic in these areas was less than half of that in the surface waters and was primarily limited to monofilament line that had been fouled by diatoms and microalgae, thereby reducing its buoyancy. The smaller particles that have the greatest potential to affect filter feeders were even more reduced with depth, as should be expected because of their positive buoyancy and lack of fouling organisms, noted above.

Several limitations restrict our ability to extrapolate our findings of high plastic-to-plankton ratios in the

North Pacific central gyre to other areas of the ocean. The North Pacific Ocean is an area of low biological standing stock; plankton populations are many times higher in nearshore areas of the eastern Pacific, where upwelling fuels productivity (McGowan *et al.*, 1996). Moreover, the gyre beneath the subtropic high probably serves to retain plastics, whereas plastics may wash up on shore in greater numbers in other areas. Conversely, areas closer to the shore are more likely to receive inputs from land-based runoff and ship loading and unloading activities, whereas a large fraction of the materials observed in this study appear to be remnants of offshore fishing-related activity and shipping traffic.

The authors wish to thank the Algalita Marine Research Foundation for the use of its charter of the Oceanographic Research Vessel, ALGUITA. We thank Dr Curtis Ebbesmeyer (the Beachcombers' and Oceanographers' International Association), W. James Ingraham, Jr. (US National Oceanic and Atmospheric Administration), and Chuck Mitchell (MBC Applied Environmental Sciences) for their advice in the design and interpretation of the study. We thank the following individuals for their assistance in data collection: Mike Baker, John Barth, Robb Hamilton, and Steve McLeod. We also thank Ann Zellers for her help with sample processing.

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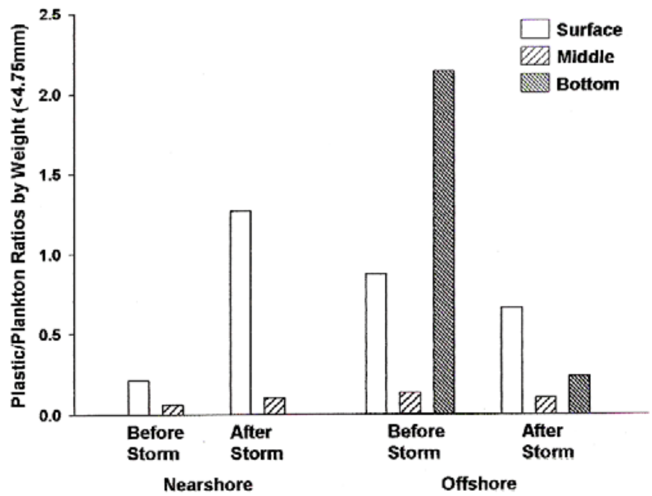

Fig. 3. Plastic/plankton ratios (pieces less than 4.75 mm) before and after a storm at different depths and proximities to shore.

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Acknowledgements

We thank Kevin Herbinson of Southern California Edison and Giancarlo Cetrulo of Los Angeles Conservation Corps for the use of the S.E.A. Lab in Redondo Beach, California.

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Appendix F

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Marine Pollution Bulletin xxx (2004) xxx–xxx
MARINE POLLUTION BULLETIN
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A comparison of neustonic plastic and zooplankton at different depths near the southern California shore

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Abstract

Previous studies of neustonic debris have been limited to surface sampling. Here we conducted two trawl surveys, one before and one shortly after a rain event, in which debris and zooplankton density were measured at three depths in Santa Monica Bay, California. Surface samples were collected using a manta trawl, mid-depth samples with a bongo net and bottom samples with an epibenthic sled, all having 333 micron nets. Density of debris was greatest near the bottom, least in midwater. Debris density increased after the storm, particularly at the sampling site closest to shore, reflecting inputs from land-based runoff and resuspended matter. The mass of plastic collected exceeded that of zooplankton, though when the comparison was limited to plastic debris similar to the size of most zooplankton, zooplankton mass was three times that of debris.
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Keywords: Southern California; Neuston; Plastics; Zooplankton; Debris; Pollution monitoring

1. Introduction

Most studies of marine debris have focused on large, visible material found on beaches, with only a few studies describing abundances of small material in the water column (Derraik, 2002). The earliest of these was Shaw and Mapes (1979) who found a high density of plastics near the surface. More recent studies have shown that the mass of neustonic plastic can be comparable to that of zooplankton in both the mid-Pacific gyre (Moore et al., 2001) and along the California coast (Moore et al., 2002).

Studies of neustonic debris have been limited so far to sampling of surface waters. While some birds feed on plankton near the surface and could potentially consume surface debris, most filter feeding occurs below the surface. Plastics make up a high percentage of neustonic debris and many plastics are positively buoyant. Therefore, studies limited to collection in surface waters have the potential to overestimate prevalence of debris in the water column.

Our study extends previous work by comparing the density of neustonic debris and zooplankton at several depths along the California coast. The study also addresses how distribution in the water column changes following a storm event, when higher wind conditions and urban runoff have the potential to enhance vertical mixing.

2. Materials and methods

Sampling was conducted at two Santa Monica Bay sites offshore from Ballona Creek, which drains downtown Los Angeles. The first site was located approximately 0.8 km offshore and the second about 4.5 km offshore. Sampling took place on March 21, 2001 following six weeks without rain, and on March 25, 2001, following a 20 mm rain event.

The sampling site closest to shore was 15 m deep and was sampled near the surface and at 5 m depth. The second site was 30 m deep and samples were collected at three depths: surface, 5 m and near the bottom. Surface samples were collected using a 0.9×0.15 m^2 rectangular opening manta trawl with a 3.5 m long, 333 micron net and a 30×10 cm^2 collecting bag. Mid-depth samples were collected using paired 61 cm diameter bongo nets with 3 m long, 333 micron nets and 30×10 cm^2 collecting bags. Bottom samples were collected using a 31

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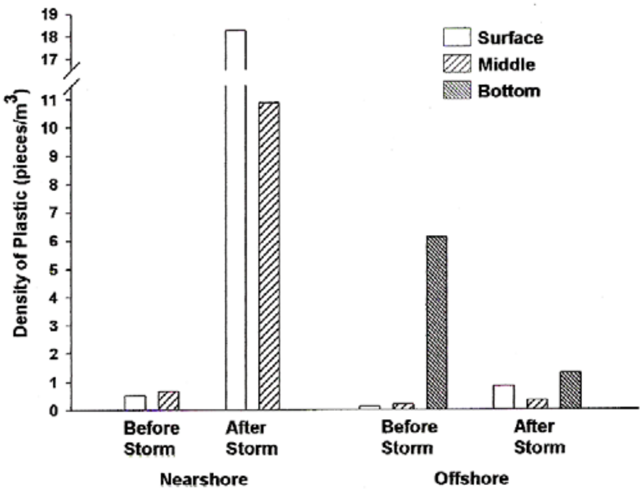

Fig. 1. Amount of plastic (pieces/m^3) before and after a storm at different depths and proximities to shore.

cm^2 rectangular opening epibenthic sled with a 1 m long, 333 micron net and a 30×10 cm^2 collecting bag. The net on the epibenthic sample was located 20 cm from the bottom. Visual inspection by scuba divers showed no sediment stirred from the bottom and entering the net. All samples were fixed in 5% formalin in the field, and later soaked in fresh water and transferred to 70% isopropyl alcohol.

Trawls were done parallel to shore for 10 min. Trawl speed varied between 1.0 to 2.3 m/s as measured with a B&G paddlewheel sensor, resulting in a trawl distance of between 0.5 and 1.0 km. A General Oceanics flowmeter was mounted across the net mouth during all deployments to measure the volume filtered.

In the laboratory, samples were placed in fresh water and floating plastic removed. A dissecting microscope was then used to remove remaining debris and plankton. Debris was sorted by category (plastics, tar, rust, paint chips, carbon fragments, and feathers) and plastics were further categorized (fragments, styrofoam, pellets, polypropylene/monofilament line, thin plastic films, and resin). Each category was sorted through Tyler sieves of 4.75, 2.80, 1.00, 0.71, 0.50 and 0.35 mm and counted. Plastics were oven dried at 65 °C for 1 h and plankton and plant material oven dried at 65 °C for 24 h, then weighed.

3. Results

Plastics were present throughout the water column on both sampling dates, but relative concentrations within the water column varied between dates and sites. The site closest to shore had nearly equal density at the two sampling depths before the storm (Fig. 1), but density on the surface was considerably higher after the storm.

Debris densities at surface and midwater depths of the offshore station were similar to that at the nearshore station; the increase in density after the storm was not nearly as large as at the inshore site. Debris density near bottom at the offshore station was considerably greater than at both the surface and midwater depths. Unlike surface samples, there was reduced debris density at bottom following the storm.

The spatial patterns for mass were similar to that of density, though the differences between dates were exaggerated (Fig. 2). For example, the weight of plastic increased by more than two hundred times on the surface after the storm. Much of this increase was attributable to the presence of larger items at surface after the storm (Table 1).

The average mass of plastic was 1.4 times that of plankton in this study, but much of the plastic mass was large material that is unlikely to be confused for planktonic prey (Table 2). When the comparison was limited to smaller particles (less than 4.75 mm), the mass of plankton was approximately three times that of plastics. This ratio was consistently higher near the surface and on the bottom than it was at mid-depth (Fig. 3).

4. Discussion

The plastic to plankton ratio that we observed near surface was similar to that found in previous studies (Table 2); ours was the first study, however, to measure it at other depths. While we found that there was more debris near the surface than in midwater, we also found

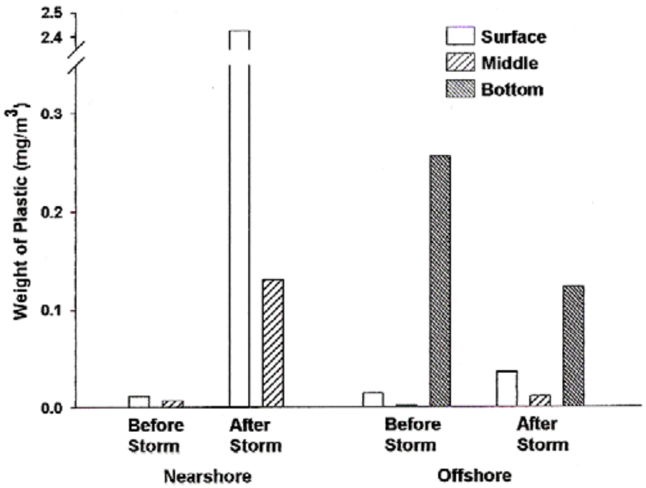

Fig. 2. Mass of plastic (mg/m^3) before and after a storm at different depths and proximities to shore.

Table 1
Percent weight and density of plastic by size and depth category

Size class	Category	Depth		
		Surface	Middle	Bottom
0.355–0.499	Weight	0.5	10.6	6.1
	Density	3.2	5.7	0.3
0.500–0.709	Weight	0.8	19.7	36.5
	Density	2.9	2.3	9.1
0.710–0.999	Weight	1.9	12.5	23.0
	Density	33.4	10.6	22.7
1.000–2.799	Weight	7.0	27.6	17.9
	Density	24.4	21.2	17.8
2.800–4.749	Weight	2.5	4.6	12.6
	Density	23.5	31.8	36.1
>4.750	Weight	87.2	25.0	3.9
	Density	12.6	28.4	14.0

that there was more on the bottom than on the surface. When only small size classes were considered, there was little difference between surface and midwater densities.

It is commonly perceived that plastics are positively buoyant, but only 46% of manufactured plastics actually are (USEPA, 1992). Many buoyant items are products such as Styrofoam, in which air is injected. Even those plastics that are lighter than water at the time of manufacture can become negatively buoyant as they are fouled by biota or accumulate debris. We observed sand embedded in many items, such as plastic bags, that might otherwise float.

Few plastics are neutrally buoyant, which in the absence of turbulence would lead to a natural separation of debris top to bottom in the water column. The

Table 2
Comparison between this study, San Gabriel River study (Moore et al., 2002), and North Pacific Gyre study (Moore et al., 2001)

	Average debris		Ratio of plastic to plankton for mass	
	(g/m^3)	(pieces/m^3)	All debris	Debris <4.75 mm
This study	0.003	3.92	1.4:1	0.3:1
San Gabriel River study	0.002	7.25	2.5:1	0.6:1
Gyre study	0.034	2.23	6.1:1	0.3:1

amount of turbulence necessary for resuspension of debris into midwater appears to be small. We observed that density near the bottom declined and midwater density was elevated after a storm, suggesting that storm or wind-related turbulence may be adequate for resuspension. This is consistent with the density of most plastics differing from that of seawater by a small amount (USEPA, 1992).

While mixing occurred in the shelf waters we sampled, the influence of resuspension in deeper waters is less clear. The distance from bottom to the middle of the water column is greater in deeper waters, meaning that more turbulent energy is required to resuspend bottom material to the middle of the water column and the influence of wind on mixing decreases with depth. Still, our study suggests that there is sufficient routine turbulence that potential biological effects of plastics in the water column are not limited to surface waters.

Many marine fauna are known to ingest debris (Fowler, 1987; Bjorndal et al., 1994; Robards et al., 1995; Blight and Burger, 1997), but few studies have

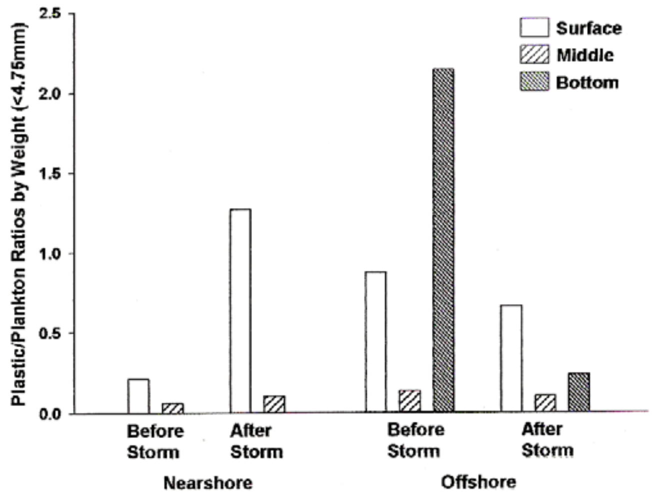

Fig. 3. Plastic/plankton ratios (pieces less than 4.75 mm) before and after a storm at different depths and proximities to shore.

examined whether they become artificially sated on this non-nutritive material (Ryan, 1987). Mato et al. (2001) found that contaminants adsorb to plastics, creating a potential for indirect effects of debris consumption; however, no study has considered whether this is a viable pathway for contaminant uptake by biota. These kinds of studies need to be conducted before we can fully assess the importance of debris in the water column.

Acknowledgements

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Appendix G

Guide to Writing a Student Research Manuscript

TITLE PAGE

This section includes the title of your report, your name and date of project completion.

- **Write your name, date and project title.**

ABSTRACT

Some readers will only look at the first paragraph of a research paper to know if the findings are relevant to the reader's interest. The abstract is the first paragraph that tells everything in a nutshell. The abstract is a summary of your entire project that allows the casual reader to know what questions you asked, the data you collected, and your results, in one 300 word paragraph or less.

- **Write an abstract so the casual reader can summarize your study.**

INTRODUCTION AND STATEMENT OF THE PROBLEM

This section will look almost like an essay, with a five or six paragraph, thorough summary of previous research relevant to your current study. In the case of plastic debris collection on a beach, you should briefly describe all other studies of plastic debris on that beach. The research questions you choose to ask will be your guide as to what kind of previous research you should include.

Each previous study you include should be referenced appropriately. For example, if Mr. Smith published a study in 1999 about plastic floating in the ocean, then you would follow any mention of his study in your paper with his name and year at the end of the sentence, (Smith, 1999). And don't forget to put all of your references at the end of the paper in a list, called the bibliography.

- **Write the five paragraph introduction with cited references.**

In the last paragraph you state the problem you have identified from having read all of the previous research. Discuss the current issues or observations that lead you to identify the problem you wish to investigate. You need to tell the reader why your study is an important issue. Why should the reader care? Then state the problem in a clear and concise manner.

- **State the problem clearly in the last paragraph.**

RESEARCH QUESTIONS AND HYPOTHESES

What are the precise questions you wish to address? The two or three research questions you choose to ask are the foundation of your study. The research questions will determine what experiments and methods you use. The research questions also determine what kinds of references you should include in your introduction.

Research questions should be written clearly and to the point. For example, you might want to document the different kinds of plastic debris that is washed up on the beach, so the research question might be written as, "What types of plastic debris are found on Southern California beaches?"

- **Write two or three research questions.**

The hypotheses for these questions will be written in the last paragraph of this section. You will state what you think the outcome will be based on what you know from reading earlier studies and investigating the problem.

- **Write hypotheses for each research question.**

METHODS

In this section you will describe the details of what you are going to do and how it will be done. You've already established the research questions you want to ask, now you must provide a detailed description of how you plan to address each research question. Provide enough details so that another researcher could repeat your study exactly as you've done it. If you've used a standard procedure, like written protocols, include them in your report.

- **Describe exactly what you've done and how you did it.**

RESULTS

The results section is where you present the details of your data. Using tables or graphs, show the reader the exact numbers and descriptions of what you found. Tables and graphs should include a title and axes should be labeled. A sentence or two in the results section should refer to the table. Remember to write results in past tense, since the experiment has been done. Also, use the narrative form instead of "we" or "I".

- **Write a detailed description of the data you've collected.**

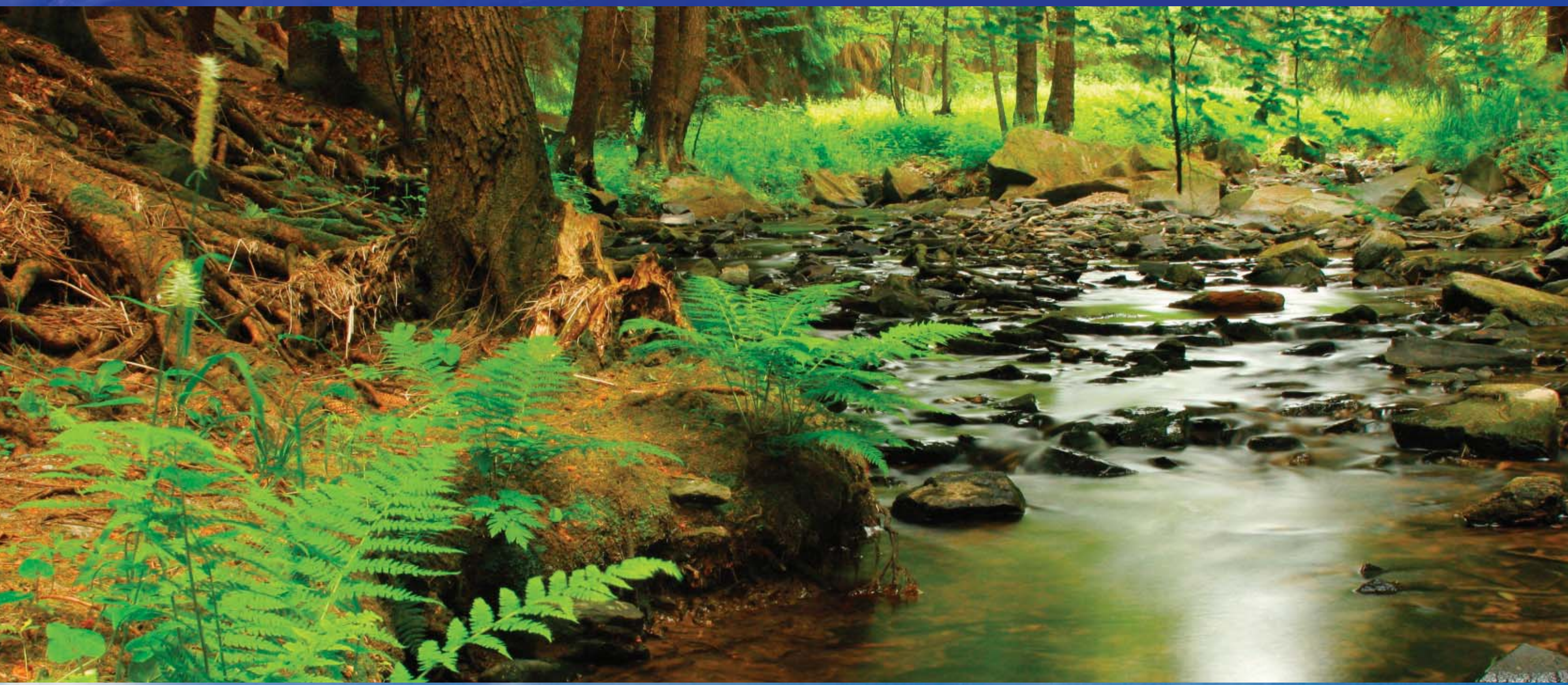
DISCUSSION and CONCLUSION

In the discussion section you will compare your data to your hypotheses and research questions. You will tell the reader what you asked, expected, and eventually found out. Explain what the data implies to the reader. Are the results meaningful?

- **Discuss how the data answered the research questions.**

The conclusion is a brief summary of what the research project uncovered. It is this section where you make recommendations for future research.

- **Write suggestions for further study.**



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