TITLE: Land to Sea
Subtitle: Searching for the source of pollutants

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Field tested with: Grade 9, Integrated Science, Watsonville High School, Watsonville, CA (Sept.–Oct. 2013)

Module Type: Short lecture and lab activity with a worksheet and discussion

Duration: 1hr 30min class period

Key materials:
- Printed maps (color) in plastic sleeve or laminated
- Dry erase markers
- Photocopied handout
- Projector
- Computer with Microsoft Powerpoint

Concepts: Harmful algal bloom, Land-use, Land-sea interface, Map legend, Map scale, Parasite, Watershed

Skills: Understand water flow in watersheds, Interpret maps, Support conclusions using evidence, Communicate procedure and results

Science Education Standards: Science and Engineering Practices 4,6,7,8; Crosscutting Concepts 2; Disciplinary Core Ideas HS-LS2.C
•**National:** A, C, F
•**California:** Biology/Life Sciences, 6 b; Investigation and Experimentation 1 a, d, h, l

Overview:
Students apply their knowledge of watersheds to identify the most likely sources of pollutants in marine organisms. Knowing that the source is likely on land, students first identify the most likely rivers that may contain pollutants based on their geographic proximity to infected or exposed animals in the marine population. Students then identify the watershed that contains the freshwater source using a map. Finally, students decide whether the source of pollution is likely to be natural or anthropogenic based on the dominance of urbanized, agricultural, and natural areas in the watershed. By the end of the module students should be able to:

- Name two ways that substances and organisms on land affect ocean life
- Identify the watershed that supplies a freshwater source
- Interpret maps of watersheds and land-use (using map legends)
- Combine information from different maps (using map scales)
- Support a conclusion using evidence

Navigate: Background Materials &Time Starting Point Procedures Standards Supplemental

Background for Teachers

Why this matters: Maps can be used to answer spatial questions in science. For example, in 1854 six hundred and sixteen people died in a cholera outbreak in London, England. John Snow, a physician, mapped the locations of cholera deaths (Figure 1). He was able to use this map to identify the contaminated public water pump, located on Broad Street. This study enabled Snow to develop and support his idea that cholera was transmitted through the water supply, rather than through the air.

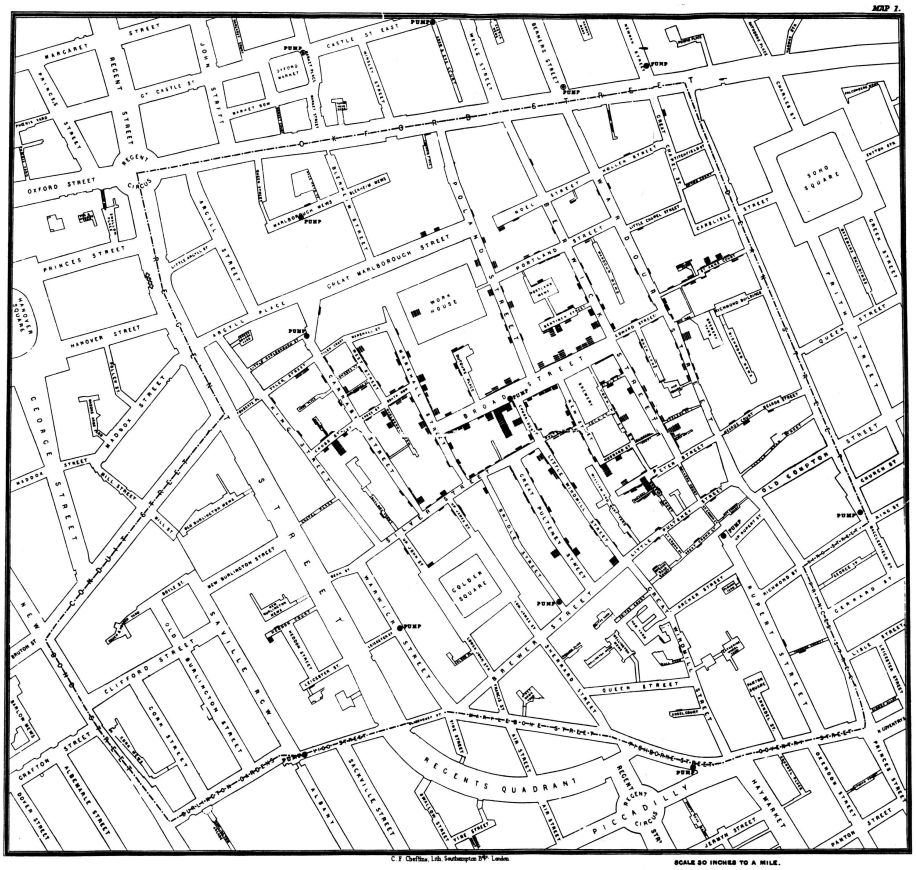

Figure 1. Original map by John Snow showing the cluster of cholera cases in the London epidemic of 1854. The pump is located at the intersection of Broad Street and Cambridge Street (C.F. Cheffins, Lith, Southhampton Buildings, London, England, 1854 in Snow, John. On the Mode of Communication of Cholera, 2nd Ed, John Churchill, New Burington Street, London, England, 1855).

Maps and spatial analyses can be used to locate the source of contaminants for other organisms as well. This module illustrates the use of maps in identifying the source of terrestrial contaminants in two marine species: California sea otters and California sea lions.

Assumed background: This module should follow a discussion of maps and watersheds in an integrated or environmental science class. The module is designed to apply recently gained knowledge of maps and watersheds. Students should understand that all runoff into a watershed flows to a common area. Students should be able to identify and understand the

scale and the legend on a map. Students will learn about parasitic infections and harmful algal blooms in this module.

Special context: *Toxoplasma gondii* is a parasite that infects multiple terrestrial and marine mammals, including California sea otters, Pacific harbor seals, and California sea lions. Prevalence of infection in California sea otters ranges from 52% of dead stranded individuals to 38% of live individuals (Conrad et al. 2005). *T. gondii* is a major contributor to mortality in this threatened population (California sea otters are listed as threatened on the IUCN endangered species list). Sea otter subpopulations with the highest prevalence of *T. gondii* exposure are found in areas near urban centers with freshwater runoff. According to Conrad et al. (2005), the most likely source of infection is by "environmentally resistant oocysts that are shed in the feces of felids and transported via freshwater runoff into the marine ecosystem." Possible sources of infection include domestic felids and wild felids, such as mountain lions and bobcats. The importance of domestic felids to infection has been contentious within the scientific community.

Domoic acid toxicity causes brain damage, seizures, and death in California sea lions. Domoic acid is a toxin produced by harmful algal blooms (HABs). These blooms are stimulated by nutrient runoff from agriculture. (More information can be found at http://www.marinemammalcenter.org/science/top-research-projects/domoic-acid-toxicity.html).

Scaffolding supplements: This module could be preceded by the "Contour What?" module (http://scwibles.ucsc.edu/Products/Norris_ContourWhat.html).

Module Description

Materials:

- Photocopied maps (color) in plastic sleeve or laminated
- Dry erase markers
- Photocopied handout
- Projector
- Computer with Microsoft Powerpoint

Preparation:

The maps and handouts must be printed. We suggest having one set of maps per pair of students and one handout per student. Instructors may want to assign student groups for parts 2 and 5 before beginning the activity.

Timeline:

1. Lecture to introduce species and their contaminants, the mystery, and the use of maps in answering spatial questions (20 minutes)
2. Students form groups and receive materials (5 minutes)
3. Students use the maps and handout to identify the river, the watershed, and the probable source of pollution (30 minutes)
4. Pairs decide how to present their evidence (10 minutes)
5. Student groups share their conclusion and evidence (15 minutes)
6. Lecture to synthesize (10 minutes)

Starting Point For Inquiry:

Use the introductory lecture to introduce the use of maps in answering spatial questions. Students can fill out the background information on their worksheets. Give students a chance to identify the pattern in John Snow's map during the presentation (as described in the "Why This Matters" section above). This will get students engaged in using maps and allow them to practice noticing spatial patterns. It will also allow students to see an example where spatial patterns are used to answer an ecological question—in this case, what is the source of cholera?

Tell students that they will conduct their own investigations to identify the source of a marine pollutant. Use the introductory lecture to introduce *T. gondii* and domoic acid (as described in the "Special context" section above). For domoic acid, discuss with students how nutrients cause algal blooms, which lead to the production of domoic acid. Do not emphasize that agricultural run-off is often the source of these nutrients, as this is a fact they will discover in their own investigation.

Give students an overview of the tools they will have to conduct their investigation. Briefly review the maps and tell students that they will need to look at the titles and legends of the maps to decide which map will be useful in answering each question. Point out the differences in map scales. From here, split students into groups and assign (or allow students to choose) their pollutant to investigate.

Detailed Procedure:

1. The instructor presents the introductory lecture to students. The instructor begins by introducing sea otters and sea lions and the health consequences of the pollutants. The instructor explains the mystery of the source of the pollutants. The instructor then suggests tools that students could use to solve the mystery by describing J. Snow's use of a map to identify the source of cholera. Students fill out the beginning of the handout during the introductory lecture.
2. Students form groups of two or three based on their interest in sea otters/parasites or sea lions/harmful algal blooms. Instructors may decide on these groups in advance, but this will allow less student ownership of the investigation. Having an equal number of groups investigating each topic is preferred for the discussion section (see step 5). Instructors give students the appropriate materials (maps). The handout can be used as a scaffold for problem solving with less independent students, but can be eliminated for students that are able to meet a greater challenge. This decision should be made by the instructor for the whole class before beginning the lesson.
3. Instructors allow students to engage with the materials to identify the source of pollution. Facilitation should be used where appropriate if students are having difficulty identifying the appropriate maps to use in each stage. Students should: a) use the infection/exposure rates in sea otters/sea lions to identify the river; b) identify the watershed that contains that river; and c) identify the most likely source of the pollutant based on land-use within the watershed. Students visually estimate the percent of the watershed that is composed of each type of land-use to aid them with part c. Students with the sea otter challenge should conclude that *Toxoplasma gondii* is more likely to be from wild cats (mountain lions or bobcats found in natural areas) rather than domestic cats (house cats which are found in urban areas) because the Pajaro River Watershed does not have much urban cover. This conclusion is also supported by the lack of *T. gondii* infection downstream of the Carmel River Watershed, which has the most urbanization and domestic felids. Students with the sea lion challenge should conclude that harmful algal blooms are caused by runoff from agricultural areas because land-use in the Bolsa Neuva Watershed is primarily agriculture.
4. After student groups decide on their answers, the instructor prompts students to decide how they will share their conclusion with other students. Students are told to support their conclusion using evidence, both verbally and with the maps as useful figures. Students decide in their groups how they will support their conclusion using evidence.
5. Student groups break apart and form new discussion groups. No students from the same investigation group should remain together in a discussion group. This ensures that each student is solely responsible for sharing the information from their group. Ideally, discussion groups should include two students that worked on sea otters, and two that worked on sea lions. Students take turns stating their conclusions and supporting them using evidence. Students discuss any differences in their conclusions or approaches.
6. The instructor presents the synthesis lecture. The instructor should be sure to acknowledge student contributions, and to emphasize that the synthesis lecture reflects the conclusions of scientists that used similar processes to the students. Although research in these areas is ongoing, the synthesis lecture provides the current understanding of the sources of *Toxoplasma gondii* and domoic acid. The instructor

should tell students that there is not one source of pollutants on land. *T. gondii* enters the environment through both domestic and wild felids. Harmful algal blooms are caused by both natural and anthropogenic nutrient input (e.g. sewage or fertilizers). The instructor should emphasize that the goal of the module is to learn about tools used to investigate the source of pollutants in particular instances. The primary source may vary over time and across space. The instructor should remind students that maps can be useful in noticing spatial patterns, and that all maps should have a scale and a legend to help convey information. Finally, the instructor can conclude the lesson by sharing ways that students can make a difference by minimizing pollution that is transported from the land to the ocean (outlined in the Synthesis Powerpoint).

Assessment Methods:

Assessment of how students use maps can be accomplished during student group discussions. Students need to justify their conclusions using the maps as evidence. Encourage the group that is listening to pose questions to the presenting group, such as, “How did you know you had identified the correct river?” Assessment of student performance can also be accomplished by collecting student worksheets to review that the correct maps were used to answer each question. The instructor can also circulate as students move through the investigation to check that students circle the correct river and identify the correct watershed.

Possible pitfalls:

Students may have difficulty identifying their watershed on the land-use map because the scale of the map is different from the watershed map. Discuss map scales with the class before they embark on this step.

The goal of the activity is for students to learn the process of investigating the source of a pollutant. Although *Toxoplasma gondii* does originate from wild felids and domoic acid is an indirect product of agricultural run-off, these are not the only sources of these pollutants. Discuss the other sources of the pollutants with the class, so they don’t leave the activity with the misconception that domestic felids and natural sources of nutrients do not contribute to pollution.

Glossary:

Toxoplasma gondii – a parasite that infects multiple terrestrial and marine mammals, including California sea otters, Pacific harbor seals, and California sea lions

Harmful algal blooms (HABs) – large increases in the local abundance of species of algae that produce toxins, which are often caused by an influx of natural or anthropogenic nutrients

Domoic acid – a toxin produced by some harmful algal blooms which causes seizures and mortality in some animals

Watershed – a geographic area that acts as a single drainage basin, where all runoff water is contained in the area

Pollutant – nutrients, debris, silt, toxic chemicals, pathogens

Science Education Standards Addressed

National Science Standards (NSES)
A. Science As Inquiry (p.173-176)
C. Life Science (p.181-187)
F. Science in Personal and Social Perspectives (p.193-199)

Next Generation Science Standards
Science and Engineering Practices
- 4. Analyzing and Interpreting Data.
- 6. Constructing Explanations and Designing Solutions: Construct and revise and explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- 7. Engaging in Argument from Evidence: Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.
- 8. Obtaining, Evaluating, and Communicating Information.

Crosscutting concepts
- 2. Cause and effect: Mechanism and explanation.

Disciplinary Core Ideas
- **HS-LS2.C,** Ecosystem Dynamics, Functioning, and Resilience: Anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

California Public Schools Standards (SCSCPS)
Biology/Life Sciences**,** 6. Ecology: Stability in an ecosystem is a balance between competing effects.
- **b.** Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size (p. 54).

Investigation and Experimentation, 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing content in the other four strands, students should develop their own questions and perform investigations. Students will:
- **a**. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
- **d.** Formulate explanations by using logic and evidence.
- **h.** Read and interpret topographic and geologic maps.
- **l.** Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

NSES (http://www.nap.edu/catalog/4962.html)
SCSCPS (http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf);

Guide to supplemental materials

Lectures
The module should be introduced with the introductory Powerpoint presentation. The presentation includes an example of how to use maps for scientific investigations (John Snow's investigation of the source of cholera) and background information about the two marine pollutants. The module should by synthesized using the concluding lecture. The concluding lecture reiterates the sources of *Toxoplasma gondii* and domoic acid. The lecture reviews the use of maps in scientific investigations and why each component of a map is useful. The lecture suggests how students and the community can change practices to minimize the harm of marine organisms by terrestrial pollutants.

File names: LandtoSea_intro.ppt, LandtoSea_synthesis.ppt

Graphics
Each group will receive three maps for their investigation. All groups will receive a map of Central California watersheds and a map of land use in those watersheds. Half of the groups will receive a map of the distribution of sea otters affected by *Toxoplasma gondii*, and the other half of the class will receive a map of the distribution of sea lions affected by domoic acid. These maps are used in the investigation in conjunction with the worksheet.

File names: LandUse.jpg, Watersheds.jpg, SeaOttersTg.jpg, SeaLionsDA.jpg.

Worksheets
Each group member will receive a worksheet that aids in the investigation. The questions on the worksheet suggest the order in which the maps should be used and the conclusions that can be drawn from each map. For independent students who are familiar with inquiry-based learning, the worksheet can be simplified or eliminated and only provided if students need additional scaffolding. The use of the worksheet is suggested, but advanced classes may benefit from initial independent thinking.

File name: LandtoSea_handout.pdf

Works Cited

Conrad, P. A., M. A. Miller, C. Kreuder, E. R. James, J. Mazet, H. Dabritz, D. A. Jessup, F. Gulland, and M. E. Grigg. 2005. Transmission of *Toxoplasma*: clues from the study of sea otters as sentinels of *Toxoplasma gondii* flow into the marine environment. International journal for parasitology 35:1155–68.