Birds, Bioaccumulation, and the Bay Overview for Instructors

Grade Level: 9th-12th
Approximately 2 hours in length, can be broken into sections
Objectives: At the end of this activity, students will:

*be able to write an algebraic formula to answer a question
*be able to translate numerical data into a graph format
*compare data and draw conclusions based on the comparisons
*define bio-accumulation and bio-magnification
*describe one way the individual can impact the process of bio-accumulation/bio-magnification

Overview: Students act as biologists, analyzing pollution and survival data from Forster's and Caspian Tern colonies in the San Francisco Bay Area. They will learn to manipulate data into formats, allowing them to draw conclusions from it. Students will make educated guesses based on the data, as well as design further experiments that might support the data. This can be carried out as an in class group project or a homework assignment.

Background Information for the Educator

This activity is based on an actual on-going study. The San Francisco Bay Bird Observatory (SFBBO) in cooperation with the U.S. Fish and Wildlife Service (FWS) has monitored tern populations throughout the San Francisco Bay Area for population health and the effects of pollutants like mercury, PCB's and other chemicals. The study is on-going as of 2004.

See Species Overview sheet and Teacher Data Sheet.

The study was carried out by monitoring tern nests during May and June, the peak of nesting season in the Bay Area. Tern colonies were marked with stakes at the beginning of the season, and then monitored sometimes by scope observation, and also by walk-throughs of the colonies. Eggs were also collected from each site, and sent to a laboratory for pollutant analysis.

Biologists and volunteers participated in this study, watching for many hours with scopes and kayaking out to islands where the terns nested. Hazards of the job include being dive-bombed by the birds, mobbed by many birds at once, and having the occasional whitewash land on your head (hats are recommended).

Other Resources

http://www.abag.ca.gov/bayarea/sfep/reports/fact/pollute.html
History and trends of pollution in the SF Bay Area
http://www.abag.ca.gov/bayarea/sfep/reports/fact/aquaorg.html
History and trends of aquatic life in the SF Bay Area
http://www.wildeducation.org/programs/ocean_ed2001/lessons/Lesson6.asp
Bio-accumulation/bio-magnification activity
http://www.sfbbo.org
San Francisco Bay Bird Observatory's home page; gives examples of on-going avian research in the Bay Area, including the Tern contaminant study in this activity

Part 1: Introduction (10 minutes)

Today we are looking at the San Francisco Bay, a key part of our community. Can you name some reasons the SF Bay is important for our communities? Write suggestions down in a place where the class can refer back to them later.

Examples: recreation (fishing, boating, bicycling, boating), economic (commercial fishing, water quality, flood control), aesthetic (beauty)

Review any values the class has missed.
Today you're going to take a look at some of the human actions that affect the health of the San Francisco Bay. Later, we will look back this list and decide if these human actions are significantly impacting any of the values listed.

Before we move on, I want to make a second list. Name some factors that you think might impact the value of the SF Bay, things that could damage its health.

Examples: mercury runoff from south Bay mines (i.e. Almaden Quicksilver), storm drain runoff, overfishing, agricultural runoff, smog, oil spills, litter, leaves, shopping carts, illegal dumping

Part 2: Deciding what to study (15 minutes)

Scientists have a choice to study many different species in the San Francisco Bay, from algae to seals. If a scientist wants to look at long term effects of human actions in the Bay, she must often choose what species might be the most accurate in predicting those effects; which species will show the biggest picture. Read the Species Overview Sheet. As a scientist, you have a choice to study one of these three species: a polychaete, Jacksmelt, or a tern. You have 5 minutes in your group to decide which species you would pick, and explain why.

Pick two or three groups to present their chosen species and explain why they were chosen.

Each of these species can tell us something about the San Francisco Bay's health. However, a tern would probably be the most effective in giving us the big picture of the Bay's health. Can anyone guess why?

Terns are high up on the food chain. This means they are on a similar ***trophic level*** *as people. A tern eats fish, that eat water insects, that eat algae. People also eat fish, that eat water insects, that eat algae. Examining a tern will give us an idea of how much pollution is in the watershed AND the effects of accumulating the pollution over time.*

Part 3: Data Analysis (1 hour)

Scientists at the San Francisco Bay Bird Observatory right here in the South Bay designed and conducted a study on Terns and pollutants. The study was carried out by monitoring Tern nests during May and June, the peak of nesting season in the Bay Area. Tern colonies (groupings of nests) were flagged at the beginning of the season, and then monitored sometimes by scope observation, and also by walk-throughs of the colonies. Scientists kept track of egg hatching, chick mortality from predators or other causes, as well as eggs that were discarded. Eggs were also collected from each site, and sent to a laboratory for pollutant analysis.

Your worksheet contains data from the study. Your job as a biologist is to arrange the data in a different format so that you can answer some questions about pollution and its effects on Terns. The worksheet has specific questions and tasks for you to complete. The process is similar to what biologists do in their studies. Your group will work together to complete each of the tasks. When the worksheets are completed, we'll come back together and discuss your findings based on the data.

Part 4 (20 minutes)

Review the answers for Questions 8, 9, and 10 (see answer sheet).

Let's go back to those lists we made at the beginning of the activity (why the SF Bay is valuable to communities). Are bio-accumulation and bio-magnification having an impact on any of these values? What about an impact on the economy, now and in the future? The mercury contamination comes from various historic mines in the Bay Area. Cities and other agencies are working to find ways to reduce the runoff from leftover mercury. For this particular pollutant, it is something that the individual cannot easily impact. However, there are other pollutants we do have direct control over. One way to prevent further bioaccumulation is to ensure that chemicals such as garden fertilizers and pesticides do not flow into storm drains during heavy rains.

What about the science involved in this study? Were there very clear answers? There were some potential patterns, but not clear answers to how much of an effect mercury has on breeding Caspian and Forster's Terns. What are some other experiments, or measurements that can be taken by biologists to further this study?

Examples include:

Repeating the study in another season to compare results. For instance, were this year's measurements unusual due to high rainfall?

testing the blood of Tern chicks and closely monitoring chick development in a few nests

monitoring what Terns are eating: what types of fish, and from where

water quality of feeding sources: if Terns can be tracked to feeding areas, taking in depth water quality tests of the areas upstream and downstream, looking for other pollutants besides mercury

The exercise you just went through is very similar to what the biologist actually doing the study had to carry out. That biologist also saw patterns in the data, but is continuing the study with different techniques in order to better support and expand the data. This is fairly common in field research. Often, the initial tests/experiments bring answers to a few questions, and bring up even more questions. This presents a challenge and a fun puzzle for researchers; developing better tests and better experiments to better answer a question they have about the environment around them. Whenever you look at data as a scientist, whether you are a student or a professional, in the field or in the classroom, you should always be asking more questions about what you see. Does the data make sense? Is there some other interesting pattern, outside of the initial question you were asking? If you were to go back and do the experiment again, how would you change the methods? It is easy to think of

science as only learning a string of facts. In actuality science is all about asking questions and finding the answers to these questions.

Birds, Bio-accumulation, and the Bay Worksheet

1. Write a formula that calculates the success rate of a tern colony in the form of a percentage (%). Keep in mind you may not use all of the data elements gathered to develop this formula.

2. Find the success rates (%) of Caspian Terns for the North Bay, Central Bay, and South Bay. Show one sample calculation of a success rate.

North Bay

Central Bay

South Bay

2b. Find the success rates (%) of Forster's Terns for the North Bay, Central Bay, and South bay.

North Bay

Central Bay

South Bay

3. On a separate sheet of paper, graph the success rates (%) to summarize which colony was the most and least successful. Include the Caspian Tern and Forster's Tern rates on the same graph for comparison. Are there any patterns in the graphs?

a. What area had the highest success rate for the Forster's Terns? For the Caspian Terns?

b. What area had the lowest success rate for the Forster's Tern? For the Caspian Terns?

4. Find the average egg mercury (Hg) measurement in the north bay, central bay, and south bay in Forster's Terns. Show one example of your calculations

Sample Calculation

North Bay

Central Bay

South Bay

4b. Repeat the process above for Caspian Terns

North Bay

Central Bay

South Bay

5. On a separate piece of paper, graph the average mercury concentrations for the North, Central, and South Bay areas. Include Caspian Tern and Forster's Tern data on the same graph. Are there any patterns in the graph?

a. What area has the highest mercury concentration in Forster's Tern eggs? In Caspian Tern eggs?

b. What area has the lowest mercury concentration in Forster's Tern eggs? In Caspian Tern eggs?

6.Looking at graphs for success rate and mercury concentration, can you see any patterns? Any relationships between success rate and mercury concentration?

7. Can any strong conclusions be drawn about mercury contamination and its effects on birds in the San Francisco Bay Area? If so, what are the conclusions? If not, what should be done to determine more concrete conclusions?

8. Can any conclusions be drawn about mercury contamination and its potential effects on people in the San Francisco Bay Area?

9. How do the Terns absorb mercury into their bodies i.e where is the mercury coming from? How is the process related to bio-accumulation and bio-magnification?

10. Name some other pollutants that may be entering the watershed directly from our streets and neighborhoods. How are they pollutants reaching the streams/Bay? What can we do to prevent this?

Tern Data Sheet

Data Definitions:

PPM: parts per million meaning that for every million part of liquid, there is one part of mercury.

Above 0.5 ppm of mercury is known to affect whether or not an egg will hatch as well as bird development in general.

Mercury Concentration By Area and Species

-SPECIES	REGION	Mercury PPM
Caspian	South	1.773
Caspian	South	1.367
Caspian	South	1.152
Caspian	South	0.610
Caspian	South	1.012
Caspian	Central	0.677
Caspian	Central	1.046
Caspian	Central	0.713
Caspian	Central	0.723
Caspian	Central	0.419
Caspian	North	1.108
Caspian	North	0.483
Caspian	North	1.114
Caspian	North	0.817
Caspian	North	0.978

SPECIES	REGION	Mercury PPM
Forsters	South	0.375
Forsters	South	0.610
Forsters	South	0.727
Forsters	South	0.408
Forsters	South	0.816
Forsters	South	1.944
Forsters	South	3.334
Forsters	Central	0.699
Forsters	Central	0.463
Forsters	Central	0.537
Forsters	Central	0.435
Forsters	Central	0.379
Forsters	North	0.824
Forsters	North	0.564
Forsters	North	0.788
Forsters	North	0.342
Forsters	North	0.604
Forsters	North	0.707

Data Definitions

Addled eggs: Term refers to eggs where the embryo dies before hatching. In this study, it refers to eggs that are rejected or pushed out of the nest by the parent bird. Some birds can sense when eggs are "bad," and will push them out of the nest.

Total # eggs: total number of eggs in a population that could have hatched. Does not include dead chicks or addled eggs. Remember, dead chicks and addled eggs represent part of the potential for the population in addition to the total # eggs.

Dead Chicks: includes chicks that may have been predated by gulls, or other predators.

Forster's Terns

		total # nests	total # eggs	live chicks	dead chicks	addled eggs
Central Bay	total central bay pop	557	1050	82	76	0
North Bay	total north bay pop	300	707	66	77	297
South Bay	total south bay pop	1545	3404	500	150	185

Caspian Terns

	total # nests	total # eggs	#chicks	dead chicks	addled eggs
south	120	210	27	5	3
central	80	145	36	10	33
north	145	251	95	24	5

Birds, Bioaccumulation, and the Bay Answer Sheet

1. Write a formula that calculates the success rate of a tern colony (in a percentage format). Keep in mind you may not use all of the data elements gathered to develop this formula.

% Success Rate=
[live chicks/(total eggs + dead chicks + addled eggs)]100

2. Find the success rates (%) of Caspian Terns for the North Bay, Central Bay, and South Bay. Show one sample calculation of a success rate.

See formula above and data sheet for figures to plug into formula.

North Bay ***34%***

Central Bay ***19.1%***

South Bay ***12.4%***

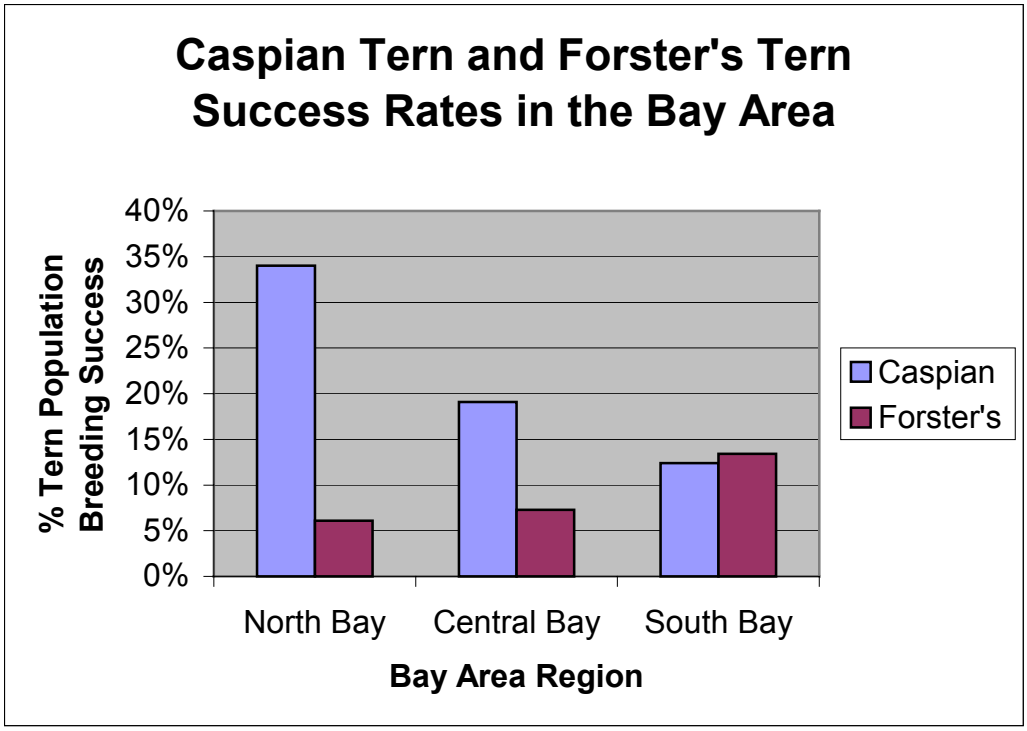
2b. Find the success rates (%) of Forster's Terns for the North Bay, Central Bay, and South bay.

North Bay ***6.1%***

Central Bay ***7.3%***

South Bay ***13.4%***

3. On a separate sheet of paper, graph the success rates to summarize which colony was the most and least successful. Include the Caspian Tern and Forster's Tern rates on the same graph for comparison. Are there any patterns in the graphs?



As Caspian Tern populations progress south in the Bay, the success rates become progressively lower. In Forster's Terns, the success rates increase traveling South in the Bay.

a. What area had the highest success rate for the Forster's Terns? For the Caspian Terns?

Forster's Terns: South Bay Caspian Terns: North Bay

b. What area had the lowest success rate for the Forster's Tern? For the Caspian Terns?

Forster's Terns: North Bay Caspian Terns: South Bay

4. Find the average egg mercury (Hg) measurement in the north bay, central bay, and south bay in Forster's Terns. Show one example of your calculations

Sample Calculation

North Bay ***0.638***

Central Bay ***0.503***

South Bay ***1.173***

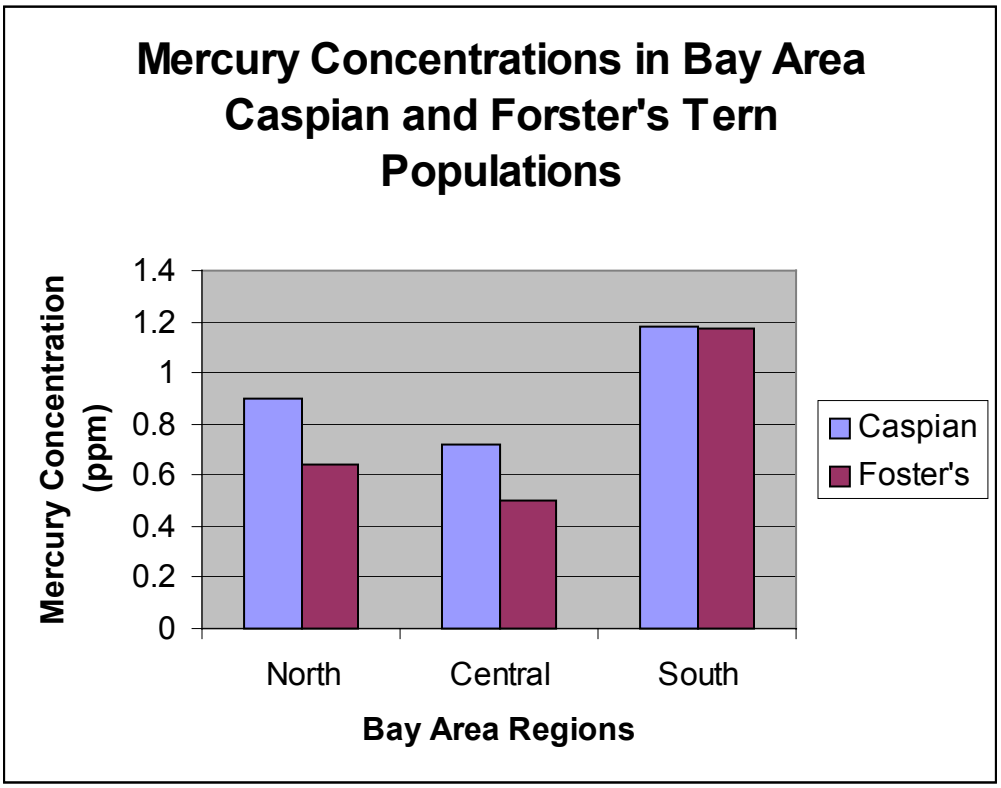
4b. Repeat the process above for Caspian Terns

North Bay ***0.9 ppm Hg***

Central Bay ***0.716 ppm Hg***

South Bay ***1.183 ppm Hg***

5. On a separate piece of paper, graph the average mercury concentrations for the North, Central, and South Bay areas. Include Caspian Tern and Forster's Tern data on the same graph. Are there any patterns in the graph?



Caspian and Forster's Terns both had the highest pollution rates in the South Bay, the second highest in the North Bay, and the lowest in the Central Bay.

a. What area has the highest mercury concentration in Forster's Tern eggs? In Caspian Tern eggs?

Caspian Tern: South Bay
Forster's Tern: South Bay

b. What area has the lowest mercury concentration in Forster's Tern eggs? In Caspian Tern eggs?

Forster's Terns: Central Bay
Caspian Terns: Central Bay

6.Looking at graphs for success rate and mercury concentration, can you see any patterns? Any relationships between success rate and mercury concentration?

Caspian Terns had the lowest success rates in the South Bay, which is also where the highest mercury concentrations in Caspian Terns were found.

All of the populations, Caspian and Forster's, had success rates under 40%. All except one of the six populations had success rates under 20%. This appears low for population success. Consider what would happen if populations continued producing according to these rates.

All of the tern populations have mercury levels higher than 0.5ppm, above which mercury has been shown to impact eggs and bird development.

7. Can any strong conclusions be drawn about mercury contamination and its effects on birds in the San Francisco Bay Area? If so, what are the conclusions? If not, what should be done to determine more concrete conclusions?

Strong conclusions between the level of mercury concentration and the success of a colony cannot be made.

More concrete conclusions could be drawn by tracking the development of chicks more closely, continued monitoring to see how much the success rates and mercury concentrations vary from year to year.

8. Can any conclusions be drawn about mercury contamination and its potential effects on people in the San Francisco Bay Area?

Because Terns feed on fish from the Bay, just as some people might, it is possible that mercury contamination could be effecting people in the San Francisco Bay. If people were to eat too many fish from the Bay, they could suffer from the effects of mercury poisoning or other chemicals.

Note: There are limits on the amount of SF Bay fish people should be eating specifically because of methyl-mercury and other contaminants that have been absorbed by fish.

9. How do the Terns absorb mercury into their bodies i.e where is the mercury coming from? How is the process related to bio-accumulation and bio-magnification?

Terns are absorbing mercury through the food chain. Certain areas of the Bay Area, for instance, Almaden Valley, were once mined for mercury. The tailings, or left overs, of the mining process remain to this day, and as water/rain flow over these tailings, mercury ends up in the streams/rivers. These streams/rivers eventually flow to the SF Bay, carrying the mercury with it. Plankton may absorb, or bioaccumulate, the pollution directly into their bodies or through feeding. Fish may feed on these polluted plankton, absorbing the chemicals into their tissues (also bio-accumulating). Larger fish may eat these contaminated fish, and so-on until the Terns are eating a concentrated amount of mercury in their meals. The effects of the accumulated mercury on the Terns is called BIO-MAGNIFICATION.

10. Name some other pollutants that may be entering the watershed directly from our streets and neighborhoods, and as a result, may be bio-accumulated by Bay Area wildlife. How are they pollutants reaching the streams/Bay? What can we do to prevent this?

One of the on-going and significant sources of Bay pollution is urban runoff from storm drains. It includes any pollution that flows from streets, down storm drains, directly to Bay Area waterways. Pollutants include soap from people washing cars in their driveways, pesticides and fertilizers washed off gardens, leaves and debris that are blown into the street, and motor oil dumped down the storm drain.

Urban runoff is consistently ranked among the top 3 polluters of estuaries. The San Francisco Bay is the largest estuary on the west coast.

Species Overview

Terns

Terns are members of the gull family. However, most terns are much more accurate and skillful in their flight compared to gulls. Terns generally live near bodies of water including lakes and marshes. There are many species of terns, but this study focuses on two that can be seen in the San Francisco Bay Area: the Forster's Tern and Caspian Tern. The Forster's Tern is the smaller of the two, feeding on fish as well as flying insects. The Forster's Tern is about half the size of a Western Gull you might see around your school. The Caspian Tern feeds on fish and crustaceans. Both terns feed by hovering above the water (20-50 feet), diving and grabbing just under the water surface. The Caspian Tern is about ¾ the size of a gull.

Terns can be seen in the San Francisco Bay Area primarily in the spring and summer months. Caspian Terns migrate south to Central and South America in the winter months.

Jacksmelt

These fish are fairly common in the San Francisco Bay and can be found near the surface of the water. Jacksmelt feed on small crustaceans and plankton. They can be up to 17 inches long, but most are smaller. The fish are omnivores, eating algae and crustaceans.

Polychaete

Polychaetes are not a species name, but a class of worms (under the phylum *Annelida*). There are many types of polychaetes, and they can be found in San Francisco Bay water and mud. All polychaetes have many bristles or legs. Polychaetes eat many things, but most filter feed very microscopic particles like plankton.

Sources: *The Birder's Handguide, The Sibley Guide to Birds, www.sfbaymsi.org, http://www.delta.dfg.ca.gov/baydelta/monitoring/jack.asp*

Glossary

Bio-magnification: increase in concentration of a pollutant from one link in a food chain to another

Bio-accumulation: increase in concentration of a pollutant from the environment to the first organism in a food chain

Trophic level: essentially a level in the food chain. Trophic levels define how energy is transferred from each level of the food chain to the next.

http://www.kesgrave.suffolk.sch.uk/Curric/geog/trophic.html
http://www.marietta.edu/~biol/102/2bioma95.html