SECTION 1: The Scientific Method

Lab 1: Scientific Knowledge

Introduction

Science has assumed enormous importance in modern society. Many decisions affecting our future depend upon scientific discoveries. No one person can learn all that is now known about science and its practical applications. As responsible citizens, however, we can follow some of the important studies that bear on public issues, and we can apply scientific reasoning to arrive at our own positions on these issues.

There is nothing mysterious about scientific reasoning or experiments. They are merely logical ways of trying to solve problems that are used by business people, historians, and each of us in our daily lives. We do not need specialized training or knowledge to decide whether conclusions are justified from the data present. We can request further tests of a theory that does not appear to be well-supported by the evidence, and we can agree or disagree with the predictions from a theory. The best way for us to clearly understand a theory, however, is to first understand how a scientist arrives at a conclusion by conducting a similar process ourselves.

Scientific Method

You may never have thought about how you solve problems, test theories, or decide upon a plan of action before, but let us examine how a scientist attacks a problem to understand the main types of thinking involved.

The **scientific method** is a formalized way of answering questions about causation in the natural world. In principle, the scientific method has three main steps. The first step is **observation** of phenomena that can be detected by the senses. Second, the scientist forms a **hypothesis,** or idea about the cause of the phenomena that has been observed. The third step is **experimentation,** performing tests designed to show that one or more of the hypotheses is more or less likely to be correct. These tests often include numerical data so the results can be quantified.

One peculiarity of the scientific method is that a hypothesis can never formally be proven; it can only be disproved. A correct hypothesis will make predictions that are borne out by the experiment, but an incorrect hypothesis may also produce the predicted outcome, meaning the outcome was right, but for a different reason. Therefore, if the results of an experiment agree with the prediction, we are still not sure of the validity of the hypothesis. The more alternative hypotheses we disprove or cast doubt on, however, the more we increase the likelihood that the hypothesis that remains is correct.

Sampling Error

Scientists also hesitate to accept the results of an experiment until they are assured of its repeatability. Repetition guards against two types of errors. First, we may have inadvertently made a mistake in our technique, such as writing the results in the wrong columns. Second, any experiment is subject to **sampling error** due to the number of subjects used. In this case, we would use statistical tests to tell us how "sure" we are of our results with a given sample size. We can also use statistical tests to decide whether our results are so far from our prediction that we should discard our hypothesis.

Theory

A hypothesis supported by many different lines of evidence from repeated experiments is generally regarded as a **theory** and, after even further testing, comes to be accepted as scientific "fact."

It's a Fact

"It's a scientific fact" is often presented as the clincher to an argument. Most scientists, however, would argue that any scientific finding is open to question. The doubts and uncertainties inherent in the scientific method make it impossible to be 100% sure that a scientific discovery is "right."

The Limitations of Science

Scientific discoveries and theories are useful, but they are always open to question; in science there is no such thing as "proof positive." Time and time again in the history of science, widely accepted theories have turned out to be wrong. Even today, scientists are busily discarding or remodeling some of the supposed truths that you may have already learned.

As a science student, you should try to develop a healthy skepticism toward scientific findings, both old and new.

Critical Thinking

To what extent should scientists be held responsible for the social and moral consequences of their discoveries? Scan the science section of a newspaper and find an article that you can critically assess. Are the claims valid, or does the report seem to be biased in any way that you can detect?

References

Haines, L. (1997). Consumer Testing: Applying the Scientific Method to Everyday Life. *Science Scope.* v21 n4 p34-38 September.

King, Ken. (1996). Addressing Superstitious Beliefs through Science Activities. *Science Activities.* v33 n3 p20-22. Fall.

Van den Brul, Caroline. (1995). Perceptions of Science: How Scientists and Others View the Media Reporting of Science. *Studies in Science Education*. v25 p211-37.

http://www.sciam.com/currentissue.html (selections from Scientific American)

http://www.orni.gov/

Sunshine State Standards

MA.E.3.4. The student explains the limitations of using statistical techniques and data in making inferences and valid arguments

S.C.H.1.4. The student uses the scientific processes and habits of mind to solve problems.

S.C.H.3.4. The student understands that science, technology, and society are interwoven and interdependent.

Lab 2: Statistics

Introduction

What is statistics? Statistics is the science of collecting and interpreting numerical data. Scientists need to be sure that their results are not due to random chance.

The best way to answer “what is statistics” is to consider an example of its application. Suppose a research biologist wishes to investigate the food preference of a fish. The fish is placed in a tank with a thread herring and a shrimp. If the fish liked both prey equally, it would have a 50/50 chance of choosing one randomly. However, if the fish had a strong preference for shrimp, you would expect it to choose its favorite food most of the time. If you did the experiment only once, you could not draw any valid conclusions. If the experiment was repeated twice, and the fish chose shrimp each time, this would still not be enough of a case for a preference. After 10 trials, however, if the fish chose the shrimp every time, this would indicate a strong statistical case for shrimp being the fish’s favorite food.

So, let us now look at the characteristics common to the scientific method and its application to inferential statistics. First, we make an observation or measurement that cannot be predicted with any certainty in advance. We cannot say in advance whether the fish will choose the shrimp or the thread herring. Then, we sample by using a group of fish from the main population of fish. Third, we collect the data or measurements with a measurement corresponding to each fish. Finally, our objective is to obtain information that can be used to make an inference about a larger set of measurements called a population.

Putting these four steps together, using random observations, sampling, numerical data and inference about a population, we can then define statistics as the science of collecting and interpreting numbers:

Objective

- Understand basic statistical techniques and their application to scientific research.
- Draw inferences or ask additional questions based on various statistical charts and graphs.

Materials Required

- Graph paper

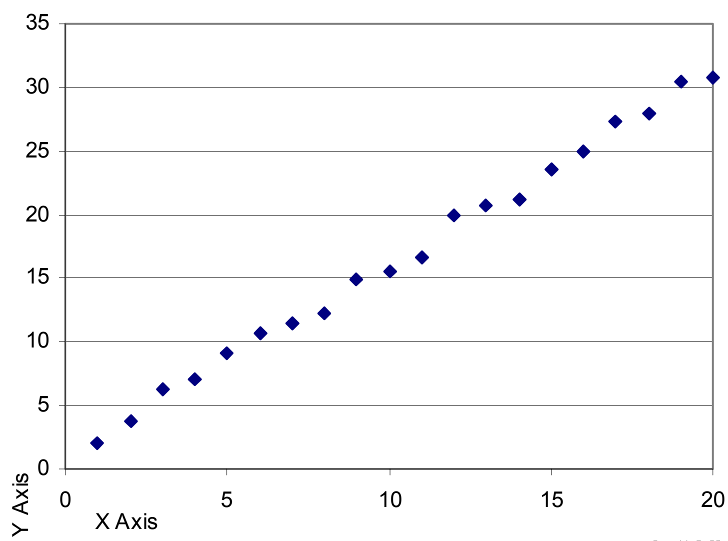
Procedure

Relationships between different variables can be easier to understand when the data are graphed. One type of graph is called a scatter gram. The values from one variable are plotted along the horizontal (x) axis, and the values from the other variable are plotted along the vertical (y) axis. Once you create such a graph, you can often see whether the variables have a relationship to each other.

Try to draw a line through the scattered dots to get an idea of what the trend appears to be. This line is called the regression line.

If the line moves up from left to right, it has a positive slope. This means that an increase in the values along the horizontal axis will also contribute to an increase in the values along the vertical axis. This trend is demonstrated on graph "A":

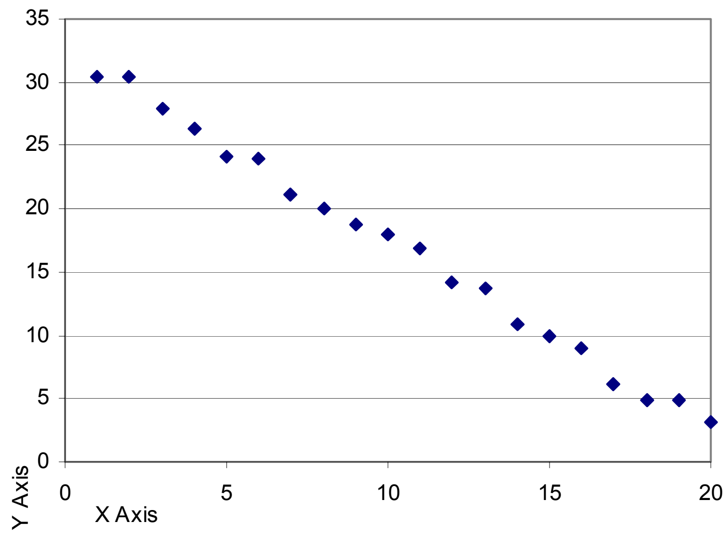
Positive Slope Scatter Graph



graph "A"

If the regression line moves down from left to right, it has a negative slope. This means that an increase in the values along the horizontal axis will contribute to a *decrease* in the values along the vertical axis, as shown on graph "B":

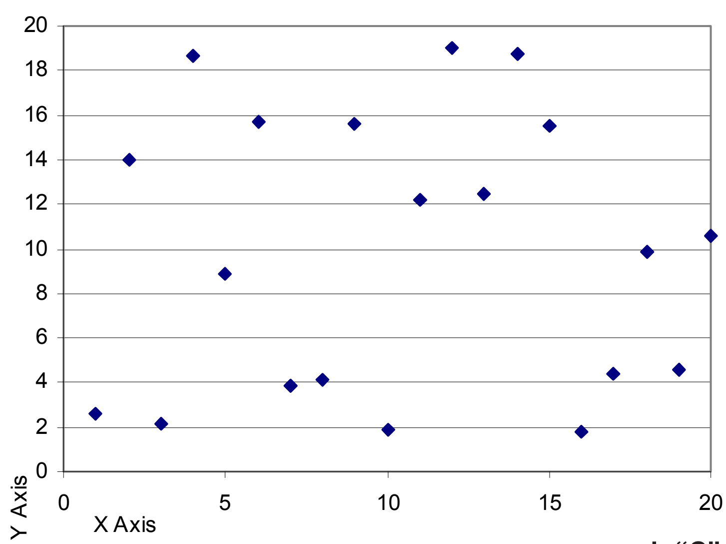
Negative Slope Scatter Graph



graph "B"

If the data points are randomly distributed, the variables have little or no relationship to each other. In this case, the scatter gram would look like graph "C":

Randomly Distributed Scatter Graph



graph "C"

Critical Thinking

Let's look at some data involving manatee mortality from boat collisions and see if there is a relationship between the number of registered boats and manatee mortality from boat collisions.

Manatee Deaths vs. Registered Boats

Boat Collisions	Registered Boats (Times 10,000)
10	45
14	46
21	47
25	49
25	51
17	51
20	52
16	55
32	58
31	61
31	64
32	67
43	71
47	72
48	73
51	73

Plot the number of registered boats along the horizontal (x) axis, and the number of manatee deaths from boat collisions along the vertical (y) axis. Does there appear to be a correlation between the number of boat registrations and manatee mortality? Is it positive or negative? Do you think this is significant, or is it just random chance?

Another way of looking at populations is through finding out what a typical item looks like in a population, and how much variability there is among those items. The four most common tools for accomplishing this are the range, mean, median, and mode.

The **range** is the difference between the largest and the smallest value. The **mean** (or average) is determined by adding all the values and dividing that number by the number of items in the population. The **median** is the value within the population that has an equal number of values higher or lower than its value. The **mode** is the most commonly occurring value.

Let's say we seined along a beach and sampled the lengths of twenty-nine fish of the same species. Their lengths are listed as follows:

Fish Length (cm)		
9	20	44
10	22	44
10	22	45
12	23	46
18	32	46
18	34	47
18	38	58
18	42	62
19	42	76
20	44	

What is the range, mean, median, and mode for this group of fish? Is the mean or mode a better measure of central tendency for this group?

Fish length can often be analyzed to determine the strength of relative year classes of fish (year class refers to the young of the year fish produced in that year's spawning effort). These fish are usually similar in size. Can you identify different possible year classes by size in this sample? Do some year classes seem stronger (higher number of fish)? Why might fish have different reproductive success in successive years?

References

Guillaume, Andrea M.(1997). The Squid Challenge. *Science Activities. v33 n4 p12-17*

Maret, Timothy, Ziemba, Robert. (1997). Statistics and Hypothesis Testing in Biology. *Journal of College Science Teaching. v26 n4 p283-85. February.*

O'Shea, T.J., Ackerman, B.B., Percival, H.F. (1995). *Population Biology of the Florida Manatee*. U.S. Department of the Interior, Washington, DC.

Mendenhall, W., Oh, T. (1980). *Understanding Statistics*. Duxbury Press, North Scituate, Massachusetts.

Smith, G.B. (1996). *Marine Science Lab Activities.* Edison Community College, Fort Myers, Florida.

http://www.statistics.com/June 2000

http://www.statsoft.com/textbook/stathome.html

Sunshine State Standards

MA.E.1.4 The student understands and uses the tools of data analysis for managing information.

M.A.E.2.4 The student identifies patterns and makes predictions from an orderly display of data using concepts of probability and statistics.

Lab 3: Natural Resources

Introduction

The scientific method requires:

- making observations
- developing questions based upon observations
- developing a hypothesis as a tentative answer to the question
- developing an experimental procedure to test the validity of the hypothesis
- collecting and analyzing the results using a statistical method to support or reject the hypothesis
- draw a conclusion from the results

Collier County is one of the fastest growing counties in the country. It has experienced a growth rate of 180% over the last fifteen years. This rapid growth is threatening to degrade local natural resources. Local resource managers need information about how rapid growth can affect these resources. As the local population grows, there will be an increased demand for more public access to estuarine and coastal habitats. Coastal managers will have to balance this need for public access with the protection of critical estuarine habitats. There may also be an increase in conflict between different user groups such as recreational and commercial fishers, campers, birders, jet-skiers, boaters, and kayakers. Managers will have the difficult job of trying to resolve these conflicts as well as protecting the resources. As a result, they will need accurate and up-to-date information on natural resources, recreational and commercial user impacts, and population trends.

Objectives

- To use the scientific method to solve problems.
- To perform investigations in order to explore phenomena and to seek out possible bias.

- To make observations about the habitats and resources of Rookery Bay.
- To design possible research projects that will help provide useful management information.

Materials Required

- Map of Rookery Bay (see Appendix)
- Clipboard
- Colored pencils
- Binoculars

Procedure

On a boat ride through Rookery Bay use the map to locate the different significant natural habitats present. These may include oyster bars, mud flats, sea grass beds, and mangrove forests. Also note the presence of wildlife in any of these areas. Pay special attention to alterations caused by human impact. Such examples may include docks, channels, buildings, camping, boating, trash, and the presence of nonnative plants or animals.

Critical Thinking

Identify the potential human impact on the natural resources of Rookery Bay. How could these impacts be monitored or tested using the scientific method? Devise a hypothesis about a resource management question that can be tested.

Environmental Application

- Be aware of your own personal actions and how they can impact natural resources in parks, refuges, and reserves.
- Help support resource management initiatives and obey rules and regulations posted.
- Always remember that natural resources are not inexhaustible. Be aware that they can run out.

References

Anderson, T., Wentworth, Donald. (1997). Water,Water Everywhere, but Can We Drink It? Solving the Blue Planet's Water Problems of Overuse and Abuse. *Social Education. v61.n6. p337-41. October.*

Dunlap, Thomas. R. (1997). Remaking the Land: The Acclimatization Movement and Anglo Ideas of Nature. *Journal of World History. v8 n2 p303-19. Fall.*

Welch, Mary A. (1996). The Cost of Keeping Up Appearances. *Economic Issues for Food, Agriculture and Natural Resources.* n11 Spring-Summer.

Project Wild Elementary Activity Guide (1983). Westen Regional Environmental Education Council. Boulder, Colorado.

http://www.usl.edu/business/ecology/htm

http://www..america-alfresco.com/-America Alfresco 1999

http://www.envirolink.org/EnviroLink 1999

Sunshine State Standards

S.C.G.2.4. The student understands the consequences of using limited natural resources.

S.C.H.3.4. The student understands that science, technology, and society are interwoven and interdependent.

Lab 4: Biological Sampling

Introduction

Sampling estuarine waters to determine physical and chemical properties provides information on the effects of the water on animal and plant communities. Long-term monitoring of marine animal communities can also detect trends and changes within those communities.

Since no one sampling technique is appropriate for all animals, a variety of sampling techniques are used.

It is very important to measure fishing effort. Often times it is measured by the catch per unit effort (CPUE).

Catch per unit effort:

number of traps used versus number of creatures captured, or

time trawling and seining versus number of creatures captured

Trawls

Trawls are used to sample areas of an estuary that are deeper than 1.5 meters. A trawl is a bag-shaped net that is attached to one or two power boats by ropes or cables. An otter trawl is dragged along the bottom of the water or through the water column. Otter trawls use water pressure against door-shaped boards attached to the entrance of the net to keep the net open. Trawls are conducted on a fairly smooth bottom where the net will not become entangled or torn by underwater obstructions. The net collects animals living on, or just above, the bottom. The animals are collected in the sock-like end of the net, which is called the cod end. Large, fast swimming fish can easily avoid small otter trawls.

Seines

Seines are surrounding or encircling nets. The top edge of the net has floats and the bottom end of the net has weights attached to it. Typically, two people pull this net through the water, therefore this kind of net is only used in relatively shallow water as along a beach. The seine often has a bag into which the animals are funneled and collected. Seines are good for collecting juvenile fish along bay edges, river banks, tidal flats, and seagrass beds where the water depth is less than 1.5 meters.

Traps

Traps or pots are equipment that animals enter into through small openings. They are most effective in the capture of bottom dwelling species seeking food or shelter.

Objectives

To learn biological sampling techniques using trawls, seines, and traps.

Materials Required

- Otter trawl
- Pole
- Minnow traps
- Secchi disk
- Tray
- Water quality probe
- Seine net
- Crab traps
- Pit fall traps
- Buckets
- Dip nets

Procedure

Sampling by Otter Trawl:

Design a data sheet for recording your data and decide the length of each pull and number of trawls you wish to include in your sampling effort (see example data sheets in Appendix). If you trawl for too short of a period of time, you may not catch much. If you trawl for too long, you may not be able to lift your catch into the boat. Most estuarine trawls are between 2 and 10 minutes. How long do you want to trawl? Remember, you can modify the time for the second trawl if necessary.

Place marker buoy over the stern of the mullet skiff. While the boat is proceeding forward at idle speed, two students start feeding the rest of the net out.

Place the doors that are attached to the mouth of the net over the back of the boat while holding onto the ropes. Slowly let the ropes out, applying some tension. Water pressure from the boat moving forward should spread the doors apart.

Clip the end of the line onto the bridle line. Start timing the trawl when the line becomes tight.

Designing a Data Sheet

Here is some information that you may wish to consider when designing a data sheet:

- Water quality conditions.
- Number and species of fish.
- Tide conditions.
- Number and species of crustaceans.
- Type of vegetation.

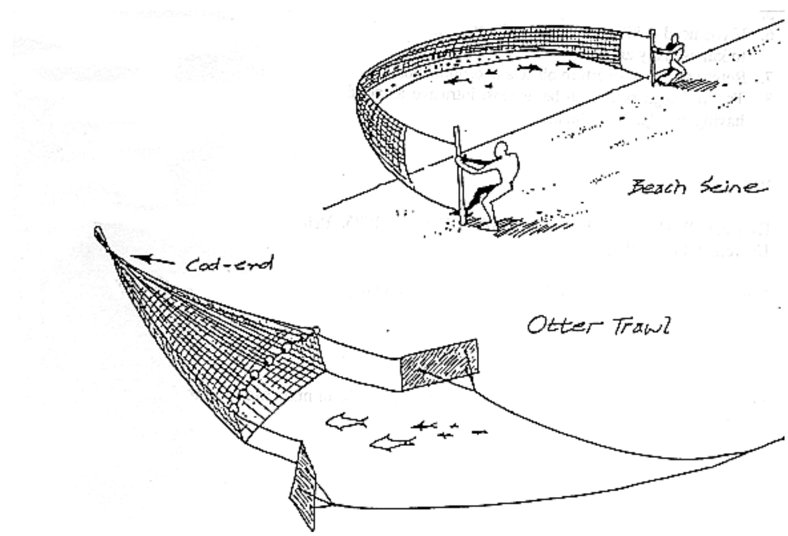
See Appendix for sample data sheets.

Using the bucket, place a few inches of water in the holding tray. When the sample time has passed, stop idling the boat and start to bring the net in. Bring the doors back onto the boat and start shaking the catch back into the cod end of the net. Pick up the cod end and carry the catch back to the holding tray. Open the cod end and empty out the catch onto the observation tray.

Sort the catch according to your data classification sheet. Use jars to temporarily hold individual specimens for up-close examination. Identify and record. Clean the net.

Sampling by Seine Net:

Design a data sheet that illustrates what information you find important. Decide how you will quantify your seining operation. You may wish to use a tape measure so that you can seine a predetermined distance, or you may wish to seine out to a certain depth. You may also choose to use time as a measurement by timing how long you pull the seine.



Unravel the seine and spread it until it is in a U shape. Tie a rope from the top of the two poles so that the distance between them stays the same. To avoid stingrays, shuffle your feet along the bottom when pulling the net.

Have a colleague on the beach ready with a bucket and jar. Pull the seine up onto the beach where the catch will be sorted, identified, and recorded. Put the catch into a bucket of sea water and use jars to examine individual specimens. Clean the net and fold.

Open Water Seine:

Follow procedure as for the beach seine but this time you will use a seine with a pocket or bag. Make sure that the bag is properly deployed into the water, with floats on outside of pocket.

To close the open water seine bring the two poles together, then use a third pole to pull the net along until all the fish are forced into the bag at the end of the net.

Empty the bag end of the net into a bucket or tray and continue with sorting, identifying, and recording.

Traps:

Crab traps are used to collect stone crabs, blue crabs, and juvenile jewfish. Traps are often baited with fish heads and guts and need to be frequently maintained with fresh bait in the warm waters of southwest Florida. Pitfall traps are used to sample animal life in mangrove forests or coastal scrub. This type of trap has to be set at low tide and should be checked only after the next high tide has occurred.

Design two data sheets; one to record data from the crab trap and the other to record data from the pitfall trap.

Decide upon location of the traps. This choice will be influenced by the type of animal you are hoping to collect and the habitat being sampled.

Decide upon length of time that you wish to have the traps set. Are you looking at one hour, one tidal cycle, overnight, or weekly?

Check your traps after the sampling time and record onto your data sheet.

Critical Thinking

On the basis of your catch, how would you change your sampling technique and data sheet for your next catch, seine, or trawl?

Do you think that your catch is a good representation of the underwater fauna of Rookery Bay?

How might you obtain a better representation of local marine life?

How selective are traps as a sampling technique? Which method did you prefer and why?

What techniques do you feel would be most accurate in quantifying your effort?

Environmental Application

- Biological sampling should be designed to have as little impact on the systems being studied as possible. How could you design your study to be as unobtrusive as possible? How might the very act of sampling influence your study?
- Methods for reducing the environmental impacts of biological sampling studies.
- Handle fish gently with hands that are wet so that the protective slime of the fish is not removed.
- Keep all organisms in well oxygenated water. Release them as soon as you have the information required.
- Keep the organisms out of the direct sunlight and heat.
- When observing, do not approach too closely; you may affect their behavior.
- Avoid trampling the sample site or making too many trails to the sample site.
- Return stones and objects to their original positions.

References

Buckland, S., Anderson, D., Burham, K. (1993). *Distance Sampling: Estimating Abundance of Biological Populations.* Chapham and Hall. N.Y. New York.

Skalski, John., Robson, Douglas. (1992). *Techniques for Wildlife Investigations.* Academic Press Incorp. D.C. Washington.

Eyerhart, W.H., A.W. Eipper & W.D. Youngs. 1975. *Principles of Fishery Science.* Cornell University Press, Ithaca, New York.

Nielson, L., D. Johnson, and S. Lampton 1983. *Fisheries Techniques.* American Fisheries Society. Bethesda, MD.

http://inlet.geol.sc.edu/qcp_inter.html

http://www.state.nj.us/dep/watershedmgt/bfbm/March 2000

http://k12science.stevens-tech.edu/curriculum/waterproj/index.html

Sunshine State Standards

S.C.H.1.4. The student uses the scientific process and habits of mind to solve problems.