A Research Guide for Students and Teachers

State University of New York
College of Environmental Science and Forestry

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To the outstanding teachers who, by opening their classrooms to us, have changed the way we view the world.

Contents

Part III. Presenting your Research, continued

Appendices

Preface

As NSF GK12 Fellows, we have had the opportunity to work with many high school students conducting scientific research for the first time, and we realize that for many students this is a challenging experience. To help guide you through the process, we have written this research guide for you, the student, and for your teachers.

Through our work with high school students, we noticed that many students have misperceptions about how and why we do science. So why should you do research? The process of conducting research is the foundation of science and it provides the evidence that is needed to formulate and support the answers to many vital questions. By carrying out your own research you will develop the analytical skills that are helpful for interpreting the results from other studies that you may see in books, presentations, movies, etc.

This document is a step-by-step guide for someone who is conducting research for the first time. We will show you how to get started with your project by providing an overview of the research process, presenting different types of research, and sharing previous student projects. We will then show you how to determine what type of data you will need and how to collect and analyze the data. Finally, we will guide you through the process of presenting your research in a scientific journal-style paper and a conference-style oral presentation. You will be expected to complete milestones throughout your research process to assist you in staying on task, such as developing a research question, a hypothesis, a proposal, and an outline for your final paper,. It is our goal in writing this research guide to provide you with the tools that you will need for each step in the research process.

The process of research that you will learn by following this guide is not limited to the context of "science". You can apply this process when trying to answer questions in any discipline. The skills that you will accumulate as you develop and carry out your own research project can be used in your future studies and professional life. Our goal is for you to acquire useful, transferable skills such as critical thinking, data collection and analysis, technical writing, and oral communication. Additionally, we want you to be scientifically literate citizens, so that you can understand and critique scientific issues that you will encounter in the media, in policy, and in your future education and work.

The NSF GK12 project at SUNY-ESF:

Environmental Science to Promote Sustainable Urban, Rural, and Indigenous Communities

The goals of National Science Foundation Graduates in K12 (NSF GK12) project are to enrich high school student science learning and engagement and to enhance teacher and graduate student professional development. We seek to increase the environmental knowledge and science literacy of today's high school students to produce citizens who will be able to make informed decisions regarding the environment. Through the graduate education program and service research we aim to produce environmental science leaders who will be able to meet the extraordinary environmental challenges of the 21st century. Within the theme of Sustainable Communities, our activities focus on experiential and inquiry-based classroom and field-based activities and graduate teaching fellow-facilitated student research projects. The activities culminate in the Environmental Summit, a student science symposium.

This NSF funded project builds upon two well-established college/school partnerships: the *ESF in the High School* dual enrollment program and the ESF *Science Corps*. The *Science Corps* embodies ESF's Vision 2020: A Better World through Environmental Discovery. The Science Corps supports campus-based, in-school, workplace and field-based STEM (science, technology, engineering and mathematics) learning and professional development experiences for middle and high school students and teachers.

We are currently collaborating with 26 high schools in urban, rural, and indigenous communities in New York, with the aim of engaging traditionally underrepresented and financially disadvantaged students.

For information about the NSF GK12 project, *ESF in the High School*, the ESF *Science Corps*, and other programs please contact:

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Part I. Beginning a Research Project

In this first part of the *Research Guide*, we will provide you with the tools you will need to get started on your research project. You will first learn about the general steps in the research process and different ways to conduct research. To help you brainstorm ideas for your own research, you will find examples of previous studies that have been done by high school students just like you. Once you have chosen a topic that you would like to pursue, you will have to do a background search to identify your research question(s). To help with this step, we have provided tips on how to find and read scientific literature. The remainder of this section will help you to move beyond your research question to develop your hypothesis and a project proposal.

Overview of the Research Project

The goal of this research project is to teach you how to apply a scientific approach to thinking about the world around you. This project is an opportunity for you to immerse yourself in a topic that you are passionate about. You will conduct independent research that will require creativity, critical thinking, brainstorming, collaboration and organization.

Here is an overview of the research process:

1. Choose an environmental topic. Be creative! A broad range of topics have been researched in the past. See the list of previous research projects (pg. 7) to get some ideas.

2. Identify the major issues, problems, or questions surrounding the topic. This process will require that you do background research on the topic using internet and library resources such as books and scientific journal articles.

3. Formulate a research question and a hypothesis about your topic based on your background research. The goal of your research will be to test this hypothesis.

4. If your research will require secondary data sources (e.g., information from databases), conduct a preliminary data search to determine what data are readily available for your research.

5. Develop the research methods that you will use to test your hypothesis. Your methods could include some combination field measurements, surveys, questionnaires, online database analysis, and a review of primary literature publications.

6. Gather the data to test your hypothesis.

7. Conduct an analysis to determine if your data support your hypothesis.

8. Explain/interpret your results. What does it all mean?

Your final research project report will be written in the format of a scientific journal article. It will include the following sections: abstract, introduction, methods, results (with tables and figures), discussion, conclusion, acknowledgements, and literature cited.

General research topics include, but are not limited to, alternative energy, biodiversity, natural history, ecological economics, sustainable food systems, ecology and climate change, pollution and remediation, ecological footprint, and globalization.

Types of Research Projects

As you begin the challenging process of developing your research project, you will have to decide on the type of research that you would like to conduct. Would you prefer to sample invertebrates in a stream, conduct interviews in a shopping mall, or study plant growth in a laboratory? The type of research that you select will depend on your research question; however, it is possible that you will use multiple types of research to investigate your research question.

I. Primary research

Investigate your research question by collecting new data from the field or the laboratory.

Local Field Research: Collect primary data to answer your research question by conducting fieldwork outside of the classroom. This type of research requires that you go to the location you are researching and collect data by recording observations, collecting samples, distributing surveys, or conducting interviews.

Examples

Observational

- What species of soil invertebrates do you find in different types of soil?
- How does the water chemistry of a stream vary along a rural to urban gradient?
- What birds over-winter in this area and what types of food do these birds prefer?

Survey/Interview

- Examine local farm land use practices. Work closely with a farmer to analyze his/her practices and devise a plan to implement more sustainable practices.
- Survey 100 people in town/city of various age ranges. Calculate an average "ecological footprint" for a certain group of people (www.myfootprint.org).

Resource Analysis

- Do an energy audit of your school/home and identify ways to reduce energy consumption.
- Analyze the composition and quantity of the high school waste stream. Identify ways to reduce the quantity of garbage.

Laboratory Research: Collect primary data to answer your research question by conducting experimental research in the classroom laboratory. This type of research is considered a true experiment if subjects are randomly assigned to treatment and control groups to investigate a cause and effect relationship.

Examples

Observational (behavior)

- Record the preferences of a species toward different environmental conditions.

Experimental

- Assess the effect of environmental factors (temperature, pH, moisture, light, direction, etc.) on above and belowground grass growth over time by sub-sampling plant biomass from grass samples grown indoors.
- Identify the impact of allelopathic plants on the growth of other plants.

II. Secondary research

Investigate your research question using data that was previously collected by an outside source. For this type of research, also known as data mining, you gather secondary data from online databases, publications, or experts. This allows you to examine changes in space and time over a larger scale than if you were to collect the data yourself. You can also download digital maps to use in geographical information systems (GIS).

Examples

Database Research

- Identify whether there is a relation between sea surface temperatures in the Gulf of Mexico and hurricane frequency and intensity.
- Examine trends over time and correlations between economic development indicators and deforestation in Indonesia
- Determine if there is a relation between cereal production and fertilizer consumption over time in the U.S.

GIS Research

- Conduct a spatial analysis of a town to identify the areas suitable for wind mills.
- Use soil maps to identify areas suitable for a specific plant species.
- Examine the changes in land use in a watershed over time.

III. Environmental Action Plans

Analyze a previously developed environmental action plan or develop a new plan. Collect data on the outcomes of the current program, or similar programs, on potential financial/material limitations, on stakeholder concerns, and on other factors that limit the implementation of an environmental action plan.

<u>**Examples**</u>

Assess and improve upon a previously developed plan

- Assess a recycling initiative in the High School or throughout the district. Measuring the success of the plan by the amount of materials recycled.
- Examine the types of chemicals/cleaning supplies used by the school district, and work with school employees to research the availability and use of environmentally-friendly "green" chemicals. Analyze the cost efficiency of the newer products.

Develop a new environmental action plan

- Initiate a town-wide campaign to promote/stop the use of/make people aware of some environmental issue.
- Implement a "Green Schools" plan for your school with the goal of reducing energy consumption (www.greenschools.org).
- Research and implement a community garden by working with community members to determine the best location, researching the types of plants required, applying for necessary permits, and then begin planting the garden.
- Develop an interpretative nature trail for the school and surrounding areas, including posters and pamphlets for your trail.

Examples of Student Projects

Alternative Energy

- Do we have enough land area to replace the entire world's current and future oil consumption using corn ethanol?
- Assessment of solar energy potential for high schools in New York State
- Ways to reduce carbon footprints through alternative energy production
- Analysis of the potential to use biodiesel in the high school bus fleet
- Energy analysis of the ethanol for NYS: corn, willow, or switch grass?
- Assessment of costs and energy savings of green homes

Biodiversity and Natural History

- Developing a nature trail for environmental education at a rural high school
- A survey of the level of environmental awareness in urban areas
- Populations of zooplankton from Onondaga Lake and Oneida Lake
- Seasonal acclimatization of non-migratory songbirds in Memphis, New York
- Changes in crow behavior in response to negative interaction
- An identification guide to the winter bird community near Fabius, New York
- Bird reactions to changes in food offerings and different noise treatments
- Allelopathy in buckthorn: germination experiments to assess the allelopathic affect of buckthorn on other invasive plants

Ecology and Climate Change

- The effects of CO_2 and temperature on native plant germination and growth
- Primary productivity as a function of temperature in the Cook Forest Pond, Union, New York
- Hurricane frequency and intensity in relation to rising sea surface temperatures in the Gulf of Mexico

Ecological Economics

- Deforestation and economic development in Indonesia
- An analysis of clothing production to assess correlations between poverty and production of goods in the global economy
- International genetically modified food policies: contrasting the reasons for different policies on GMO's

- Has the loss of honeybees resulted in a decline in the production of apples in Lafayette, New York?
- Ecosystem services: Bee pollination and almond production in California

Ecological Footprint & Energy Audits

- Ecological footprint and environmental education at a local high school
- Energy audit of high school classrooms
- Ecological Footprint of high school students and the surrounding community

Pollution and Remediation

- Characterizing the spatial extent of pollution in Onondaga Lake
- E85 vs. regular fuels: a comparison of NO_X emissions
- Macroinvertebrate population diversity in Meadowbrook Stream as a gauge of water pollution
- Does soil chemistry differ along a rural to urban gradient in Syracuse?
- Measuring the acidity of snowfall along a rural-urban gradient: correlation with location and storm origins
- Water quality of Fabius Brook along an agricultural to forested gradient
- How well do oil-digesting bacteria clean-up an oil spill?
- Decreasing greenhouse gas emissions by composting: Feasibility study for Central New York

Sustainable Food Production

- Sustainable agriculture: cereal production and fertilizer consumption in the U.S.
- Is eating local produce the answer? A tracking of apples in the Syracuse area
- Are community gardens a viable source of food production?: The benefits and challenges of community gardens of past and present
- What is the role of food production in the energy crisis? An energy analysis of ethanol
- The ecological footprint of high school food services. How to reduce waste?
- Food miles analysis of several typical lunch offerings at a local high school
- Waste stream analysis of a high school cafeteria and the potential for waste reduction via vermicomposting
- Does a schoolyard garden influence the nutrition of the students involved?
- A comparison between the health value and energy of ethnic versus modern diets

How to Find Primary Scientific Literature

Locating primary, peer-reviewed literature is a critical step in the research process; however, searching for useful articles can take some practice. Here are several ways you can locate and download primary literature:

Google Scholar (http://scholar.google.com)

- Enter key words related to your topic. The search engine will find relevant primary literature references.
- **IMPORTANT**: Google Scholar will provide you with a link to the article reference but NOT a link to the actual article, because many journals require a subscription to view and download their articles.

NovelNY (http://novelnewyork.org)

- Access to research and reference sources as well as books, magazines, and newspapers.
- Available to NY residents with Driver License, Non-driver ID, or Public Library Card.

Open Source Journals

- Open source journals do not charge readers to access its content. You may search, view, print and save articles for no cost or subscription.
- Examples include: Applied Ecology and Environmental Research, Ecology and Society, Urban Habitats, Atmospheric Chemistry and Physics, American Journal of Environmental Sciences, and many more (over 2000 peer-reviewed journals available).
- *Beware*, some journals may not be peer-reviewed.

Websites to Locate Open Source Journals:

Open J-Gate	http://www.openj-gate.com
Directory of Open Access Journals	http://www.doaj.org
High Wire Press, Stanford University	http://highwire.stanford.edu/
BioMed Central	http://www.biomedcentral.com
Scitopia	http://www.scitopia.org/scitopia
Scirus	http://scirus.com
Public Library of Science	http://www.plos.org

Search Tips:

- Search for the article in Google. Click on advanced search, select file format PDF.
- If you can't find any articles immediately, try different combinations of key words.
- Skim the abstract of an article first to decide whether it is relevant to your research.
- Find one really good paper and then look for more articles in the works cited page – these papers are more likely to be well written and well reviewed.

Developing an Effective Search Strategy

Step 1: THINK about your search before you begin.

Ask yourself, what do I want to do?

1. Browse?
2. Locate a specific piece of information?
3. Retrieve everything I can on the subject?

Your answer will determine how you conduct your search and what tools you will use.

Step 2: CREATE your search statement.

Tips for creating a search statement:

1. Be specific.
2. Whenever possible, use nouns and objects as keywords.
3. The most important terms should be first in your keyword list.
4. Use at least three keywords in your query.
5. Combine keywords, whenever possible into phrases.
6. Avoid common words, e.g., the, an, and, water (unless they are part of a phrase).
7. Think about words you'd expect to find in the body of the page, and use them as keywords.
8. Write down your search statement and revise it before you type it into a search engine.

Step 3: APPLY basic search strategies or Boolean Logic to your search statement

Searching with Boolean Logic

Boolean logic takes its name from British mathematician George Boole (1815-1864), who wrote about a system of logic designed to produce more accurate search results through the formation of precise queries. The operators of this logic are: **AND**, **OR**, and **NOT**, which are used to link words and phrases for more precise queries.

Boolean Logical Operators

- **AND** – Narrows your search by retrieving only documents that contain every one of the keywords you enter. Be careful; the more terms you enter, the narrower your search becomes.
- **OR** – expands your search by returning documents in which either or both keywords appear. Since the **OR** operator is usually used for keywords that are similar or synonymous, the more keywords you enter, the more documents you will retrieve.

- **NOT** / **AND NOT** – limits your search by returning only your first keyword but not the second, even if the first word appears in that document, too. Note that **AND NOT** sometimes can be typed as **ANDNOT** (without space).

Nesting Operators:

- Using parentheses is an effective way to combine several search statements into one search statement. Parentheses separate keywords when you are using more than one operator and three or more keywords.

Other Search Strategies:

- (+) and (-): Use in front of words to force their inclusion (+) and/or exclusion (-) in searches. Do not use a space between the sign and the keyword. Example; +lake –fish

- (" "): Use around phrases to ensure they are searched exactly as is, with the words side by side in the same order. Example; "Onondaga Lake Partnership"

- (*) wildcards: Use to look for variations in spelling and word form. Example; librar* returns library, libraries, librarian, etc. colo*r returns color (American spelling) and colour (British spelling)

- Type keywords and phrases in lower case to find both lower and upper case versions. Typing capital letters will usually return only an exact match.

- Remember you can combine phrases with keywords using the double quotes and the plus (+) and minus (-) signs. Example; +buffalo +animal -"New York" –chicken

How to Read a Scientific Paper

"Primary literature" refers to scientific articles that report research results and are written by the scientists who conducted the research. Primary literature is always "peer-reviewed", meaning that other scientists reviewed, edited, and approved of the quality of the article before it was published. These articles are published in scientific journals, rather than in magazines or books. Primary literature keeps researchers up to date in the new developments in their field. Reading this technical literature is also an excellent way to learn how to write scientific reports of your own, and re-reading is always necessary, as scientific articles are dense with information.

In primary literature, the same general format is used so that readers can quickly get the information they need. The format includes the following sections in the following order: Title, Abstract, Introduction, Methods, Results, Discussion, Acknowledgements, and Literature Cited. Each section always includes the same type of information, but, depending on the journal, the sections might be organized slightly differently.

Here are some questions to guide your reading:

1. **Who wrote the article? With which institution(s) are the authors affiliated?** It is important to identify the affiliations of the authors, because their affiliations will give you clues as to the possible perspectives of the authors. For example, researchers at independent universities may have a different perspective than researchers affiliated with government or industry,. Look for other papers published by the same authors to provide insight into the background and experience of the authors.

2. **What is the publication date?** In rapidly changing fields of science, it is important to know how this paper fits into the development of ideas over time.

3. **In what scientific journal is the paper published?** Is a peer-reviewed scientific journal, conference proceedings, a government research report? Does the journal have a general focus (e.g., *Science*) or a specific focus (e.g., *Plant Ecology*)?

4. **What is the goal of the paper?** Scientific papers are written with a variety of goals, most often to report the findings of a particular investigation and therefore advance our knowledge of the natural world. Papers may try to summarize our current knowledge and formulate new generalizations; such papers are termed "review papers." A paper may also try to resolve a controversy by proposing a new theory. The goal of a scientific paper is frequently found in the Introduction.

5. **What are the specific objectives of the paper?** The research objectives are usually stated in the Introduction, and they may be listed as hypotheses or predictions.

6. **What is the conceptual framework into which this research fits?** The authors should describe the current level of understanding of the research topic and explain how his/her study fits into this topic by reviewing the past works of other scientists and then identifying the need for the current study. You will find this information in the Introduction and Discussion sections.

7. **What methods are used to meet the stated objectives?** A scientific paper must report the methods in sufficient detail to permit replication of the experiments. This level of detail often makes for very difficult reading unless the reader is familiar with the research; however, these details are essential for critical evaluation of the work by other scientists. When you are reading a paper, it is often sufficient to understand the methods in a general way, rather than the procedural details.

8. **What are the major findings of the investigation?** The results of the study are explicitly stated in the Results section and are usually accompanied by figures and tables. The highlights of each figure and table will also be presented in the narrative portion of the text. Each of the objectives presented in the Introduction should be addressed in the Results section. Are the hypotheses stated in the Introduction supported or disproved?

9. **Are the stated conclusions supported by the data?** Carefully check the results and evaluate for yourself whether the conclusions are justified. Note possible sources of error in the methods, the data analysis, or interpretation.

10. **How do the results relate to the published findings of other authors?** The authors should explain whether their findings agree or disagree with previous research. Does this study resolve a conflict, or create a difference of opinion?

11. **What future research is suggested as a result of this investigation?**

12. **How would you rate the clarity of the writing?** The dense, concise style of technical writing is very different from other forms of composition. It is a highly efficient means of conveying complex information, but is often difficult to read.

13. **How was the research funded?** The Acknowledgements section will list all sources of funding for the research.

14. **Have the authors drawn upon all the appropriate references?** The Literature Cited section, which concludes the paper, lists the details of the sources which were consulted (and cited) for this investigation.

Source: "Review of a scientific article in the field of plant science." Robin Kimmerer. Originally edited by Nathan Anderson.

Writing Scientific Hypotheses

What is a hypothesis?

- A possible explanation to an observed phenomenon or event
- A tentative statement of a relationship between two or more variables.

A "good" scientific hypothesis is one that is *testable*. *Testable* means that you can perform a test (*e.g.,* experiment) to show how the variables might be related. The results of the test will determine whether you "reject" or "accept" your hypothesis. If you cannot test your hypothesis, then you cannot verify whether or not it is correct.

How to write a formalized hypothesis

1. Identify the **independent** and **dependent** variables that you are testing. The independent variable is the variable that you, the "scientist" control and the dependent variable is the one that you observe and/or measure. The dependent variable will change in response to changes in the independent variable.

   For example, if you are interested in the effect of energy consumption on economic growth, then energy consumption is the **independent** variable and economic growth is the **dependent** variable

2. Hypothesize how the two variables are **related**.

   For example, you might hypothesize that as energy consumption increases, economic growth will increase. This is a **positive direct relationship**. You could alternatively hypothesize that as energy consumption decreases, economic growth will decrease. This is a **negative direct relationship.** You might even hypothesize that as energy consumption increases, economic growth will decrease. This is an **inverse relationship.**

3. Write your hypothesis using an **IF/THEN** statement.

   IF <*insert dependent variable*> **IS** <*describe relation*> **RELATED TO** <*insert independent variable*> **THEN** <*insert the hypothesized relation between the variables*>

   Using the example of the positive relation between energy consumption and economic growth, you would hypothesize the following:

   IF economic growth **IS** positively **RELATED TO** energy consumption, **THEN** as energy consumption increases, economic growth will increase

   Caution! An IF/THEN statement is only a testable hypothesis if you describe the relation between the variables

Source: Access Excellence. *Writing Hypotheses: a student lesson*. Located at :
<http://www.accessexcellence.org/LC/TL/filson/writhypo.php>.

Research Project Proposal

After you have identified your research topic, your next step is to write a preliminary research proposal. The objective of your proposal is to present a plan of action that describes how you will investigate your research question. Remember to ask yourself, "Is this research plan feasible?"

Answer the following questions:

1. **Keywords**: List 3-5 words that describe the topic of your research
2. **Title**: Use keywords to clearly and concisely describe the content of your proposal
3. **Research Questions**: What questions are you trying to answer with your research?
4. **Hypothesis**: State the variables that you are testing and describe the expected relationship between the variables. Make sure your hypothesis is testable.
5. **Introduction/Background**: Why is this research question important? What made you ask your question in the first place? *Think big picture.* What work has previously been done on this topic? Use facts, statistics, and primary literature references to back up your statements.
6. **Methods**: Based on your hypothesis in Question 4, what variables do you need to measure to test this hypothesis? How will you measure these variables? Will you conduct primary or secondary research? Where? What time period? Who do you need to contact (*e.g.,* experts)?
7. **List at least 3-4 primary literature references on the back of this page.**

Part II. Collecting and Analyzing Data

The next step is to gather data to test your hypothesis. Will you conduct surveys, field measurements, or use database data? What kinds of questions will you ask in your surveys? What kinds of measurements do you need to take? Should you measure all individuals in your study or is a sample adequate? The first part of this section of the *Research Guide* will provide you with the tools to answer these questions and to gather the appropriate data to test your hypothesis. After you have gathered your data, the last part of this section will provide you with the tools to analyze your data and figure out what it all means.

Sampling Design: A Versatile Tool

- Are you asking questions about a group of objects or organisms?
- Are there too many objects or organisms in the group that you are studying to accurately measure each one?
- Are you limited in time and resources?

If you answered yes to any or all of these questions, you might want to select a sampling design to carry out your study.

Sampling design provides methods that can be readily implemented by those that new to the research process. Moreover, these tools can help answer important questions relating to the environment during any season. Here are examples of the kinds of problems that can be investigated via sampling:

- Percent cover of a type of vegetation (e.g., forest, lawn, or invasive species) in local parks or school grounds
- Numbers of different invertebrates in a stream or in a given area of lawn
- Moss cover on rocks or steps
- Attitudes of people toward recycling, car sharing, or other environmental topics
- Salinity levels in local streams
- Animal behavior (e.g. amounts of time spent feeding, resting, perching, in trees versus on the ground)

What *is* sampling?

In sampling, we gather data on an entire "population" by measuring only a subset of that population, known as the sample. A population consists of all of the individual elements in a defined area. Sampling can be contrasted with a census, which measures every element of a population in order to describe the characteristics of that population.

Why choose a sample over a census?

Conducting a census is obviously more costly in both time and resources. It is often easier to measure a subset of the population—the sample-- to get a good estimate, rather than to collect data on the entire population. For example, if we wanted to know the tree species composition of a forest it would be easier to sample a subset of trees rather than to sample every tree in the forest. To attain a good estimate of a population characteristic, such as tree species composition, you must choose a representative sample from the population. This can be done by randomly selecting sample points (e.g. individual trees) from the population.

The importance of being random

A simple random sample is a selection of points (individuals) chosen so that each point in the population has an equal chance of being selected. Random selection helps eliminate biases that the researcher might have (e.g. preferential sampling in either low or high density sites), and can be accomplished using a variety of simple methods. Each item in a "population" can be assigned a number. Then the simple random sample can be selected by using a random number table, a random number generator (see Resources), or pulling numbered slips of paper from a hat.

For example, if you wanted to sample your friends for their taste in music you might be biased to select those of your friends that you know like the same artists as you do, but if you randomly selected the friends to poll about their music taste you are likely to get a better picture.

Some examples of possible sampling points include:

- Individual lakes or streams (population - all lakes or streams in a geographic region)
- Individual students (population – entire student body)
- Cells in a grid (population – all cells in the grid)
- Cities/Towns (population – all cities/towns in a state or county)
- Local parks or natural areas (population – all parks in a county or state)
- Hours in a day, or ½ hours, or any other unit of time

Example You are studying monarch butterflies and you want to estimate the area of a field covered by milkweed, the monarch's larval food plant. Starting with a map of the area, you can overlay an imaginary grid of cells the size of your sampling plot, assign a number to each cell and then choose random numbers. If you know the size of the area in advance you can do this before visiting the field site. If not, you can pace out the length and width on the site and locate sampling points in the same way as noted above. You do not need a tape measure, but a compass is very helpful for locating your points in the field.

You need to choose a sampling method that is appropriate for answering the questions that you have. There are several methods:

Plot Method: estimation of number, cover, density, frequency, etc.
Line Intercept: estimation of number and cover.
Point Intercept: estimation of cover.
Random Time: estimation of changing phenomena (e.g., behavior).
Timed Meander: comparison of individuals present between groups.

Sampling Methods: ***Space***

Plot Method. Plots are most often circular or square, but could be any shape. You can use a hula-hoop or a square quadrat to define plot boundaries. Plots can also be set up using a measuring tape and marking flags. The plot method allows measurement of characteristics such as number, cover, density, frequency, among others.

Example To determine the cover of milkweed for your monarch butterfly study, you use the plot method with five 5m x 5m plots randomly placed in a 50m x 60m field (Figure 1-A). Let's say you estimate the cover in each of the five plots to be 0%, 5%, 30%, 40%, and 80%, respectively. Using these plot estimates you can calculate the percent cover of milkweed for the entire field. In this case you have found that an estimated 31 (mean) ± 14% (standard error) of the field is covered with milkweed.

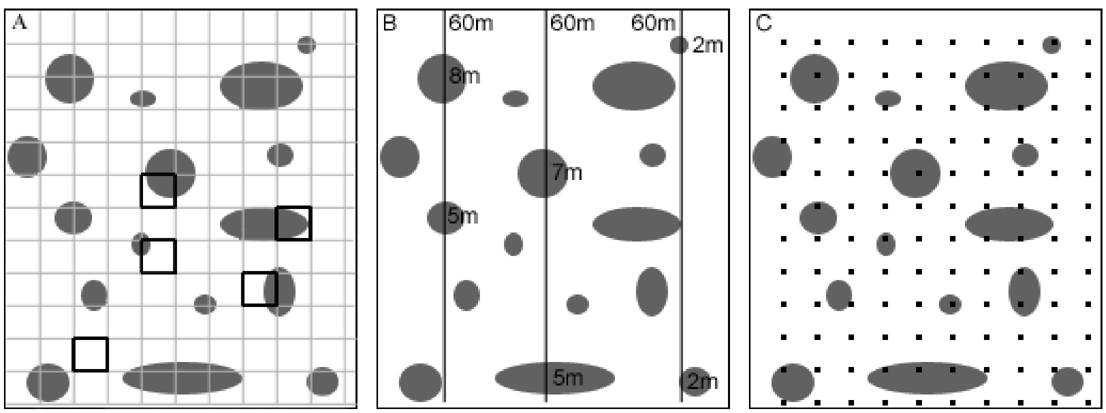


Figure 1. Depiction of the three spatial sampling methods used to assess the area of cover of milkweed patches (dark areas) in a 50m x 60m field. A) Plot method with 5 randomly placed plots. B) Line intercept method with three randomly placed transects. C) Point intercept method with systematic placement of equally spaced points (black dots) with the first point randomly placed.

The size of the plot that you choose depends on the organism you are sampling. To sample mobile organisms requires a larger plot size than for similarly sized sessile organisms. Table 1 shows suggested plot sizes for various organisms.

Table 1. Some suggested plot sizes for different study organisms.

Plot Area	**Organism**
1000 -10000 m^2	deer in a forest
50 - 100 m^2	trees in a forest
1 - 10 m^2	herbaceous plants on the forest floor, lawn, or field
0.1 – 0.3 m^2	mosses and lichens

Line Intercept. This method relies on a series of lines or transects that pass through the area of study. To apply line intercept, stretch out a measuring tape to form a transect line. Walk along the transect and record the length of the tape each time the tape intercepts the species of interest. The cover will be determined as the sum of lengths intersected by the species of interest, divided by the total length of the transect. If you are using multiple transects over an area, you can average cover values from each separate transect (if all transects are the same length) to come up with a final cover estimate. Because the species may overlap each other in space, it is possible to have a total estimated cover of greater than 100%.

Example Let's apply the line intercept method to estimate the cover of milkweed for your monarch butterfly study. Set up three randomly located transects (each 60 m long; see Figure 1-B) that cross the field. Transect 1 intersects a total of 13 m of milkweed (21.7%), transect 2, a total of 12 m (20%), and transect 3, only 4 m (6.7%). The mean percent cover estimate for the whole field would be calculated as the mean of these three numbers, or 16.1 $\pm$ 4.7%.

Point Intercept. This method uses a grid or a series of lines to determine sampling points. The sampling takes place either at randomly chosen points or at points spaced at equal intervals. To sample, simply record whether or not the species of interest is present at each chosen point on the sampling grid. This method works well for collecting data on species presence/absence, but requires many sample points. The benefit is that it is quick and relatively easy. The cover estimate is the number of points touching the item of interest (i.e., "hits") divided by the total points measured.

Example This time for the milkweed study, let's try the point intercept method with systematically located points (Figure 1-C). Out of 120 points sampled you find milkweed at 20 points for an approximate cover of 16.7%.

Sampling Methods: ***Time***

Random Time. Time as well as space can be sampled to answer questions of environmental interest. The random time method focuses on a particular site for a predetermined interval of time. An instantaneous sampling scheme would be comparable to the point intercept approach of spatial sampling, whereas a longer interval (e.g. 30 minute 'segment') would be more similar to the plot sampling scheme. You would use the 'plot' method to estimate, say, number of events or to take a sample of individuals or items arriving at a location (e.g. all cafeteria trays arriving between 12:22 and 12:24 pm as one sample unit). The 'point intercept' method is recommended for estimating proportion of time something is happening (e.g. the behavior example given on pg. 24). Selection of sampling time (e.g., 12:00 p.m. or 3:32 p.m.), just like in spatial sampling, should be determined randomly. For example, you can divide the day into intervals of a length appropriate to your study and then randomly choose times during which you will sample. This method works well for studying behaviors, actively changing events, or otherwise dynamic systems. Obviously you'll need to focus sampling effort on times of the day when particular events are known to occur. For example, you would not want to sample bat behavior during the mid-day hours when these creatures are roosting.

Timed Meander. This method uses the amount of time rather than the amount of space as a measure of sampling intensity. Choose an appropriate amount of time for sampling a site and then measure the characteristics of interest at a site for the chosen amount of time. The timed meander method is useful if you're collecting data on the presence/absence of organisms (plants, for example), and searching is required. The pre-determined search time assures that any differences between sites reflect reality rather than differences in sampling intensity.

You should sample as many plots, lines, points, time periods, or sites as time and resources allow. The more plots that you sample the closer your approximation will be to the real value. You should sample a minimum of three plots and if possible more.

Measurement Definitions

Density – Number of individuals per unit area (*e.g.,* 6 maple trees per hectare).

Cover – Percent of area covered by a species. Estimates can be continuous (*e.g.,* 20%, 3%, 62%) or you may choose to use cover classes to improve consistency. Here's one example of a system (modified from Daubenmire, 1959) using cover classes to sample aerial cover of plants in a sampling plot:

estimated percent cover	cover class
0-5	1
5-25	2
25-50	3
50-75	4
75-95	5
100	6

Frequency – Percentage of total plots where a species was found.

DBH – Diameter at breast height, a measurement used for trees and it is generally only measured for trees greater than 10 cm dbh and only those that are living. *Breast Height* is defined at 4.5 feet or 1.37 m in order to standardize measurements. There are special tape measures that give the diameter of a tree by simply measuring its circumference. If you do not have such a tape, just divide the circumference by pi, or 3.142 (*i.e.,* $D = C/\pi$).

Sampling Q & A

Q. What about sampling people? I would like to calculate the average and total ecological footprint of students and teachers in my school. If there are 800 students, and another 40 teachers and staff at the school, how large a sample will I need for this study?

A. In conducting this study, first, you may want to refer to the section in this Research Guide that discusses how to design a questionnaire (pg. 27). To determine the best sample size for your footprint study, refer to the resources section (pg. 26), where you'll find a link to a sample size calculator.

For your school's population of 800 students and 40 teachers, a 95% confidence level, and a confidence interval of 10 you would need to sample 86 randomly chosen students and 28 randomly chosen teachers and staff if you'd like to calculate the ecological footprint of each group separately. If you are measuring ecological footprint of students and staff combined, as one group, you can simply use 86 randomly chosen individuals from your school's total population of 840.

Q. How can I use sampling to study squirrel behavior? Specifically, we'd like to know the proportion of time squirrels spend on the ground versus time in trees.

A. There are several ways to do this, but here is one idea. You could use a technique called instantaneous counts. Think of the times of day when squirrels are active—say, 8 am until 5 pm at least during much of the school year. That gives you a total of 9 hours. Divide those hours into 18 time slots and make a table. Using a random number generator, assign each of the 18 time slots a number. Pick the 3 or 4 top numbers as your sampling time slots. Use the selected time slots to make a data form such as that shown below.

Time (randomly selected)	Grey Squirrel Observation Site – Thornden Park **Behavior recorded** during a 30 second snapshot of squirrel observation *Record number of squirrels engaged in the behaviors listed: **A**=in trees; **B**=on ground
0930	1-A 2-B
1330	2-A 1-B
0800	no squirrels observed
1630	1-A

During these times, visit your squirrel observation site with clipboard, data form, keen eyes and timepiece with a second hand. Remember that your observations are a snapshot of the squirrel behavior at the moment of observation. You may need to arrive early to your sampling site to allow you to survey the sampling area and to allow the squirrels to become accustomed to your presence. Once the appointed sampling time arrives you should make an instantaneous observation of the squirrel behaviors at that moment, or if multiple squirrels, then observations should be made in rapid sequence, one right after another. It may take you a few seconds to do this. You should only record one 'behavior' per squirrel. So a squirrel that is on the ground at your observation time cannot also be counted as in the tree, because it runs up a tree while you are at the site sampling. This is a useful 'snapshot' approach to measuring animal behavior.

To analyze the data, treat the "snapshots" as points, as we did in the spatial example provided earlier. So in this example, you sampled a total of 4 points.

Observation number	Total # of Squirrels	Proportion in trees vs. on ground	
		A	B
1	3	1/3	2/3
2	3	2/3	1/3
3	0	0	0
4	1	1	0
		2/3	1/3

These results tell you that squirrels in your study spent 2/3 of their time in trees (A), and 1/3 of their time on the ground (B).

Q. We'd like to initiate a waste composting project at our school, and need to estimate the amount of food discarded each day in the school cafeteria. We obviously can't weigh all the food that every single person throws away, so how can we use sampling to come up with an estimate for discarded food?

A. First identify central locations where food waste is discarded: a trash can near the dishwashing station, or a site where cafeteria staff clean up the trays. At those points, post someone with a pre-weighed bucket or plastic container. Rather than collecting all the food waste from everyone, take a sample. Let's try systematic sampling where you sample every 10th person or tray, for example. If your school is large, sample every 20th person.

Collect uneaten food from these selected trays into your bucket. If someone is throwing away a lunch bag, ask them to remove any leftover food and add it to your collection. Be sure to keep track of both your sample interval and number of diners you sample, in order to scale up and make estimates about food discarded by everyone eating at the cafeteria. Weigh your bucket, and from this sample you can estimate the amount of food thrown away each day at your school. This figure could make a strong case for starting your school compost program.

Another method you could use to gather the data for this study would be to sample a single tray from each table in the school cafeteria for a week, measuring amount of leftover food from these trays. Keep track of the total number of trays you sample. To estimate total amount of food discarded, multiply the mean amount thrown out per tray by the total number of trays in the population.

Sampling Resources

Random Numbers

Many random number generators are available online. The following is a table of 100 random numbers from 1 to 100, without repetition and it was created at the following site (http://stattrek.com/Tables/Random.aspx)

Random Numbers
030 028 059 067 072 056 004 033 019 088 053 058 098 052 061 081 048 074 023 075 092 016 070 008 068 014 049 099 071 094 062 006 095 021 054 083 097 100 018 064 010 077 089 026 041 082 073 080 051 078 060 091 009 065 024 020 085 063 003 084 066 093 013 079 055 007 002 040 046 076 037 027 038 031 086 029 032 050 015 057 005 012 069 042 096 025 017 034 045 011 035 090 047 036 043 001 087 022 044 039

Sample Size Calculator

You can use online sample size calculators to determine the number of people you need to interview for a given precision in your results. Sample size calculators for sampling using surveys are available at:

http://www.surveysystem.com/sscalc.htm
http://www.custominsight.com/articles/random-sample-calculator.asp

Source: Daubenmire, R. 1959. A canopy-coverage method of vegetational analyses. Northwest Science 33: 43-64.

How to Design a Questionnaire

Introduction

Students may use a survey in their research to collect information directly from people or organizations. Questionnaires are often used to collect such information. Well designed questionnaires are highly structured to allow the same types of information to be collected from a large number of people in the same way, so that the data can be analyzed quantitatively and systematically. Proper questionnaire design is essential to ensure that you obtain valid responses to the questions asked. There are two main objectives when designing a questionnaire:

1. Maximize the proportion of subjects answering the questionnaire (the response rate)

2. Obtain accurate and relevant information

To maximize the response rate, one must consider how to administer the questionnaire by establishing a rapport with the subject, explaining the purpose of the survey, and reminding those who have not responded. In order to obtain accurate relevant information, we have to give some thought to what questions we ask, how we ask them, the order we ask them in, and the general layout of the questionnaire.

How do I organize a survey?

Plan Ahead
Set aside time to research, prepare questions, and conduct preliminary survey in order to work out any potential problems with the questionnaire before the interview. Set up a timeline if necessary.

Identify Goals
Clearly identify the information that you want to obtain from the survey so that each question has a specific purpose and relevance.

Provide Instruction
Explain to the respondents why you are conducting the survey and provide any additional instructions that they will need to complete the questionnaire.

Length of Survey/Questionnaire
There are no universal agreements about the optimal length of questionnaires. However, short (1-2 pages) and simple questionnaires usually attract higher response rates than long (4 + pages) and complex ones.

What should I ask?

There are three types of information collected in a survey:

- Dependent Variables: Information we are primarily interested in learning about.
- Independent Variables: Information that might explain the dependent variables.
- Confounding Variables: Other factors related to both dependent and independent factors that may distort the results and have to be adjusted for.

Let us take as an example a regional survey to find out participants' level of climate change knowledge and attitudes. The *dependent factors* are the participants' level of relevant knowledge and attitudes. The *independent factors* might include the participants' education, background, or prior experiences with the subject of climate change. *Confounding variables* might include the quality of their education, since two people with equal education levels (*e.g.,* high school diploma) might have very knowledge about climate change depending on the quality of the school that they attended.

Types of Questions:

Closed Format: respondents are forced to choose between several given options.

Examples: multiple choice, yes/no, ranking, and use of a rating scale

Advantages of closed format:
- Easy and quick to fill in
- Minimize discrimination against the less literate (in self administered questionnaire) or the less articulate (in interview questionnaire)
- Easy to code, record, and analyze results quantitatively
- Easy to report results

You can use a combination of question types to obtain information, but beware that using too many different types may confuse respondents. Be consistent with the structure of the question when using the same type of questions. For example, when using a rating scale, in all questions assign the most positive response the highest numerical value (Very Satisfied = 5 on scale of 1 to 5). Be sure you have balanced responses available (for every Very Satisfied, have a Very Unsatisfied). For example: Rate the effectiveness of the recent school recycling education program on a scale of 1 to 5.

Open Format: the respondents can formulate their own answers. You might use the open format if you are looking for respondents to provide specific comments or feedback.

Advantages of open format:

- Allows exploration of the range of possible themes arising from an issue
- Can be used even if a comprehensive range of alternative choices cannot be compiled

How do I ask the questions?

Use short and simple sentences.
Short, simple sentences are generally less confusing and ambiguous than long, complex ones. As a rule of thumb, most sentences should contain no more than one or two clauses.

Ask for only one piece of information at a time.
For example, "Please rate the Global Environment Class in terms of its content and presentation" asks for two pieces of information at the same time. It should be divided into two parts: question one: "Please rate the class in terms of its content" and question two: "Please rate the class in terms of its presentation."

Minimize bias by avoiding leading questions.
People tend to answer questions in a way they perceive to be socially desired or in a way expected by the questioner. They are often led down this path by noticing clues in the questions. Many apparently neutral questions can potentially lead to bias. Encourage the respondent to pick a response from a list instead of including it in the question. For example, it is preferable to ask "What do you believe are the major forces behind recent climate change? Natural Forces, Human Forces, or a Combination of the two" as opposed to "Do you agree that humans are the major force behind recent climate change? Yes or No"

Avoid negatives if possible.
Negatives should be used sparingly. For example, instead of asking students whether they agree with the statement, "Coal plants should not be abolished," the statement should be rephrased as, "Coal plants should continue operating." Double negatives should never be used.

Ask precise questions.
Words may have different meanings. For example, if we ask students to rate an impact to the "health" of a subject, this term might mean several things to different people.

Another source of ambiguity is a failure to specify a frame of reference. For example, in the question, "How often do you recycle?" the time reference is missing. It might be rephrased as, "How many times have you filled your recycling bin in the past six months?"

Ensure those you ask have the necessary knowledge.
For example, the question, "Do you agree with restrictions on new coal plants found in the Clean Air Act?" is unsatisfactory. It asks for several pieces of information at the same time (there are many restrictions in the Act) and it also assumes participants know details of the restrictions and the Clean Air Act.

Use caution with sensitive issues.
It is often difficult to obtain truthful answers to sensitive questions. The question "Have you ever littered while no one is watching?" is likely to produce either no response or negative responses. Some less direct approaches:

- The casual approach: "By the way, have you ever happened to litter, maybe when no one was looking?" should be used as a last part of another decoy question.
- The numbered card approach: "Please pick one or more of the following items which correspond to how you view littering." In the list of choices, include: "I occasionally litter"
- The everybody approach: "As we all know, some people litter when they are left with no choice. Do you happen to be one of them?"
- The other people approach. Participants are given the scenario, "John occasionally tosses small pieces of litter out his car window." They were then asked, "Do you feel John is wrong? What penalty should be imposed for John? Have you done this in the past? Would you ever consider doing the above?"

How should I arrange the questions?
The order of the questions is also important in order to get the most information out of the participant.

Some general rules are:

- Go from general to specific.
- Go from easy to difficult.
- Go from factual to abstract.
- Start with closed format questions.
- Start with questions relevant to the main subject.
- Do not start with demographic and personal questions.

How should I administer the questionnaire?
There are several ways of administering questionnaires. For example, they may be completed independently (self administered) or read out loud in the form of an interview. Self administered questionnaires may be sent by post, email, or electronically online. Interview administered questionnaires may be completed over the telephone or in face to face interviews.

Advantages of self administered questionnaires include:
- Cheap and easy to administer.
- Preserve confidentiality.
- Can be completed at respondent's convenience.
- Can be administered in a standard manner.

Advantages of interview administered questionnaires include:
- Allow participation by illiterate people.
- Allow clarification of ambiguity.
- Targeting individuals who provide specific information required for your study
- Greater guarantee of a response.

The exact method of administration also depends on who the respondents are. For example, university lecturers may be more appropriately surveyed by email; older people by telephone interviews; train passengers by face to face interviews.

How do I know if I am ready?
Given the complexity of designing a questionnaire, it is impossible even for the experts to get it right the first time around. Questionnaires should be piloted on a small sample of people characteristic of those in the survey population. Ask each pilot respondent some questions about your survey design: effects of different wordings, what they have in mind when they give a particular answer, how they understand a particular word, length and appropriateness of the questions, etc. Improve the questionnaire by polishing the question order, wording, and layout.

How should I begin?
It is generally a good idea to have a personalized cover letter or an introductory statement that explains the purpose of the survey, the importance of the respondent's participation, the person who is responsible for the survey, and a statement guaranteeing confidentiality.

Many students have a difficult time talking to strangers when administering an interview surveys and questionnaires. A good way to start is:

> "Hello. My name is ___*(your name)*___ and I am student at _*(your school or institution)*. I'm working on a research project looking at __*(title of your research project)*_ for a college-credit class called 'The Global Environment.' I found your phone number [or email address] on the internet and I was wondering if you have a few minutes to answer some questions dealing with my research."

How should I end?

Always thank the respondent for participating in your questionnaire.

Final Words

Questionnaires must be carefully designed to yield valid information. You must pay meticulous attention to ensure that individual questions are relevant, appropriate, intelligible, precise, and unbiased. The order of the questions must be carefully arranged, and the layout of the questionnaire must be clear. It is wise to draft a clear personalized cover letter. Questionnaires must first be piloted and evaluated before the actual survey.

Online resources:

Online surveys can be developed for little or no cost through services such as Survey Monkey (http://www.surveymonkey.com/). This site and similar services may help you to set up your questions, administer your response, and analyze your responses.

Sources:

1. Abramson JH, Abramson ZH. (1999) Survey methods in community medicine. Edinburgh: Churchill Livingstone.
2. Leung, Wai-Ching (2001) How to conduct a survey. StudentBMJ 9:143-5.
3. Truckee Meadows Community College. Survey Guidelines. Obtained online: http://www.tmcc.edu/survey/conducting/

Secondary Data Sources for Research

What is secondary data research?

- Research that uses, describes, interprets, analyzes and evaluates the primary sources of data.
- Research that assesses, comments on, and discusses the evidence provided by primary sources.
- Research that is one or more steps removed from the event or information they refer to, being written after the fact, with the benefit of hindsight.

Why use secondary data sources?

- Not all research questions require the collection of data in the field. Secondary data is entirely **appropriate** and wholly adequate to draw conclusions and answer the question or solve the problem. Sometimes primary data collection is simply not necessary.
- It is far **cheaper and faster** to collect secondary data than to obtain primary data. For the same level of research budget a thorough examination of secondary sources can yield a great deal more information than can be had through a primary data collection exercise.
- The **time** involved in searching secondary sources is much less than that needed to complete primary data collection.
- Secondary sources of information can be as **accurate** as primary research. Large databases using large sample sizes can often yield far more accurate results than custom designed surveys from small sample sizes.
- It should not be forgotten that secondary data can play a substantial role in the **exploratory** phase of the research when the task at hand is to define the research problem and to generate hypotheses. The assembly and analysis of secondary data will always improve the researcher's understanding of the problem, the various lines of inquiry that could or should be followed, and the alternative courses of action which might be pursued.

Problems with using secondary data sources

Although the benefits of secondary sources are considerable, their shortcomings have to be acknowledged. There is a need to evaluate the quality of both the source of the data and the data itself. The main problems may be categorized as follows:

Definitions

The researcher must understand the definitions and units of measurement found in secondary data. Suppose, for example, researchers are interested in rural communities and their average family size. If published statistics are consulted, then a check must be done on how terms such as "family size" have been defined. They may refer only to the nucleus family or include the extended family. Definitions may change over time and where this is not recognized, erroneous conclusions may be drawn. Geographical areas may have their boundaries redefined, units of measurement and grades may change and imported goods can be reclassified from time to time for purposes of levying customs and excise duties.

Measurement error

When a researcher conducts fieldwork she/he may estimate inaccuracies in measurement by calculating the standard deviation and standard error. These numbers are often unavailable when using secondary data. The only solution is to try to contact the individuals who collected the original data to obtain information on the level of accuracy.

Source bias

Researchers have to be aware of vested interests when they consult secondary sources. Those responsible for their compilation may have reasons for wishing to present a more optimistic or pessimistic set of results for their organization.

Reliability

The reliability of published statistics may vary over time. It is not uncommon, for example, for the systems of collecting data to have changed over time but without any indication to the reader. Geographical or administrative boundaries may change or the basis for stratifying a sample may have altered. Other aspects of research methodology that affect the reliability of secondary data is a change in the sampling equipment, sample size, response rate, questionnaire design, or modes of analysis

Time scale

Most censuses take place at 10 year intervals, so data from this and other published sources may be out-of-date at the time the researcher wants to make use of the statistics. The time period during which secondary data was first compiled may have a substantial effect upon the nature of the data.

Source: Food and Agriculture Organization of the United Nations. *Marketing Research and Information Systems.* Rome, Italy, 1997. Located at http://www.fao.org/docrep/W3241E/w3241e03.htm.

Online Databases for Secondary Research

Databases with global, national, state, and local data are available online for free and can be used by students to conduct research. These databases are ideal for students who want to examine changes over time or conduct regional comparisons.

Global Databases

Name: EarthTrends: World Resource Institute (WRI)
Link: http://earthtrends.wri.org/#
Description: An online collection of information regarding the environmental, social, and economic trends that shape our world. EarthTrends gathers data from the world's leading statistical agencies, along with WRI-generated maps and analyses, into a single database for rapid searching and retrieving.

Name: International Energy Agency
Link: http://www.iea.org/Textbase/stats/index.asp
Description: The database includes global energy production, import, export, and consumption statistics for different sectors by country.

Name: United Nations (UN) Database
Link: http://data.un.org/
Description: All major UN databases and those of several international organizations are pooled into a single internet environment. Currently, there are 14 databases and 6 glossaries containing over 55 million data points and covering a whole range of statistics including population, industry, energy, trade and national accounts by country.

Name: UN Food and Agriculture Organization (FAO) Statistics
Link: http://faostat.fao.org/
Description: Time-series and cross sectional data relating to food, agriculture, fisheries, forestry production, consumption, trade, prices, and inputs for some 200 countries.

Name: UN FAO Aquastat
Link: http://www.fao.org/nr/water/aquastat/dbase/index.stm
Description: A global information system on water and agriculture. Its aim is to provide users interested in global, regional and national analyses with comprehensive information related to water resources and agricultural water management across the world, with emphasis on countries in Africa, Asia, Latin America and the Caribbean.

Name: UN World Health Organization Data and Statistics
Link: http://www.who.int/whosis/en/index.html
Description: An interactive database that brings together core health statistics for the 193 WHO Member States. It comprises more than 70 indicators, which can be accessed by way of a quick search, by major categories, or through user-defined tables.

Name: United States Central Intelligence Agency (CIA) World Factbook
Link: https://www.cia.gov/library/publications/the-world-factbook/
Description: Provides summaries of the demographics, geography, communications, government, economy, and military of countries around the world.

United States Databases

Name: AIRNow
Link: http://airnow.gov/
Description: Contains historical air quality measurements from sites across the U.S.

Name: AWS Truewind Navigator
Link: http://navigator.awstruewind.com/
Description: Interactive mapping tool from AWS Truewind, a wind energy company. The online mapping tool depicts the approximate annual average wind speed across a 2.5-km^2 wide grid across the United States created by using atmospheric models and historical weather data. The map is intended to provide a general indication of the wind resource over large areas, and should not be used to design specific wind projects or to estimate energy production.

Name: Major Land Resource Areas (MLRA) Explorer
Link: http://www.cei.psu.edu/mlra/
Description: Interactive map-based tool queries U.S. physiography, geology, land use and other data to generate reports. Provides specific subsets of the USDA Agriculture Data.

Name: NestWatch
Link: http://watch.birds.cornell.edu/nest/export/index
Description: NestWatch is a continent wide citizen-science project and nest-monitoring database of the Cornell Lab of Ornithology, funded by the National Science Foundation and developed in collaboration with the Smithsonian Migratory Bird Center. Of note is the ability to use Google Maps to explore nest data.

Name: North American Breeding Bird Survey (BBS)
Link: http://www.pwrc.usgs.gov/BBS/
Description: The BBS monitors the status and trends of North American bird populations. Data are collected by thousands of participants along thousands of randomly established roadside routes throughout the continent. Population data and population trend analyses are available on more than 400 bird species.

Name: Starkey Project
Link: http://www.fs.fed.us/pnw/starkey/index.shtml
Description: Long-term data sets available from a 10-year study in Oregon designed to measure the population response of deer and elk to the intensively managed forests and rangelands.

Name: U.S. Census
Link: http://www.census.gov/
Description: Economic and demographic statistics by area for populations in the U.S.

Name: U.S. Center for Disease Control National Center for Health Statistics
Link: http://www.cdc.gov/nchs/
Description: The Nation's principal health statistics agency. Data are collected from birth and death records, medical records, interview surveys, and through direct physical exams and laboratory testing.

Name: U.S. Department of Agriculture (USDA) Plants
Link: http://plants.usda.gov/
Description: Contains data on plants such as range, nativity, invasive status, wetland indicator status, ethnobotanical uses, wildlife value, and species life history information.

Name: U.S. Energy Information Administration
Link: http://www.eia.doe.gov/
Description: Official energy statistics from the US government on energy production from different types of energy sources and energy use within different sectors of the economy.

Name: U.S. Geological Survey (USGS) Water Data
Link: http://waterdata.usgs.gov/ny/nwis/rt
Description: Stream flow records available for many rivers in streams throughout the US.

Name: U.S. National Agriculture Statistics
Link: http://www.nass.usda.gov/
Description: The USDA's National Agricultural Statistics Service (NASS) conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. Production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use, and changes in the demographics of U.S. producers are only a few examples.

Name: U.S. National Oceanic & Atmospheric Administration National Climatic Data Center
Link: http://www.ncdc.noaa.gov/oa/about/about.html
Description: The world's largest active archive of weather data. Our mission is to provide access and stewardship to the Nation's resource of global climate and weather related data and information, and assess and monitor climate variation and change.

Name: Web Soil Survey (WSS)
Link: http://websoilsurvey.nrcs.usda.gov/app/
Description: Provides national and local soils data and information from the USDA's Natural Resources Conservation Service (NRCS). NRCS has soil maps and data available online for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future.

New York State (NYS) Databases

Name: NYS Breeding Bird Atlas
Link: http://www.dec.ny.gov/cfmx/extapps/bba/
Description: This database contains a comprehensive, statewide survey that reveals the current and historical distribution of breeding birds in New York.

Name: The New York State Department of Environmental Conservation (NYS DEC)
Link: http://www.dec.ny.gov/about/584.html
Description: Data are available on include monitoring, permitting, inspections, wildlife and habitat. Information on environmental permit applications is available using the DEC Permit Applications Search (DART)

Name: NYS DEC Air monitoring network
Link: http://www.dec.ny.gov/airmon/index.php
Description: Data on air pollutants from sites across NY. If more data are required, you can contact the DEC through the website and request more information.

Name: NYS Geographical Information System (GIS) Clearinghouse
Link: http://www.nysgis.state.ny.us/index.cfm
Description: Free, downloadable GIS maps are available for NY. Students may need to be familiar with GIS software platforms and data types in order to access the information. The NYS Interactive Mapping Gateway (at http://www.nysgis.state.ny.us/gateway/mg/) can be used to view and download digital orthoimagery of NY.

Name: School Power Naturally Performance Data
Link: http://www.powernaturally.org
Description: Contains daily and monthly data on power generated by solar panels located on the roofs of 50 schools across NYS.

Central New York Databases

Name: Derby Hill Bird Observatory
Link: http://www.derbyhill.org/DHBO/Counting_for_conservation.html
Description: Historical data are available on Onondaga county hawk migrations

Name: Onondaga Audubon Society.
Link: http://www.onondagaaudubon.org
Description: Audubon members conduct annual waterfowl counts, Christmas bird counts, nighthawk migration and other bird counts which may be available upon request. The website contains a checklist for all birds found in Onondaga County.

Name: Onondaga Creek Ecoblitz
Link: http://www.esf.edu/efb/limburg/EcoBlitz07/O-Ck_Survey.htm
Description: Spreadsheets with data on water chemistry, fish, plants, discharge, land cover collected during a one-day Creek study held in September 2007.

Name: Project Watershed
Link: http://projectwatershed.org/watershed_manage/
Description: A water quality database of the chemical, physical and biological properties of streams and lakes measured by volunteers and schools in Onondaga, Cortland, Oneida, and Madison counties. Website includes a query tool, lesson plans, and sampling protocols.

Name: SUNY-ESF Bioblitz
Link: http://www.esf.edu/efb/bioblitz/bioblitzres04.htm
Description: Lists all species (828) found during a 24 hour period at Beaver Lake Nature Center, Baldwinsville, NY, in May 2004.

Name: SUNY-ESF Environmental Monitoring
Link: http://www.esf.edu/hss/em/index.html
Description: Stream water chemistry data available from the Adirondacks since 1995. Meteorological data are also available from sites in the Adirondacks and around Syracuse. In the future, air quality data from Syracuse will be included.

Other Tools

Name: ArcGIS Explorer
Link: http://www.esri.com/software/arcexplorer/explorer.html
Description: A free, downloadable application that can be used to create custom maps and perform spatial analysis.

Introduction to Statistics

Scientific research is a process of guided learning. The objective of statistical methods is to make that process as efficient as possible. After establishing the problem (research question) to be studied, your hypothesis, and the experimental design, the next step is to decide which statistical test to use. Statistics will help you make conclusions based on your data in a scientifically defensible way.

There are two main features of statistics – *description* and *inference*.

- **Description** focuses simply on describing the sample of interest. Descriptive statistics are used to get a feel for the data, and are needed for inferential statistical tests. Some examples of descriptive statistics are: *Mean* (average), *Standard Deviation*, *Variance, Standard Error, and Regression*.
- **Inference** allows you to extend your conclusions from the sample to a broader population. Therefore your sample should be representative of the group you want to generalize to. Inference includes computing confidence intervals or conducting hypothesis tests such as a *t-test* or *F-test*, and *Correlation Analysis*.

Descriptive Statistics

- **Mean** – the sum of the observations divided by the number of observations (also known as average).
- **Median** – the value found at the exact middle of the data set. One way to compute the median is to list all values in numerical order, and then locate the value in the center of the sample.
- **Mode** – the value in the data set that occurs most frequently. To determine the mode, you can order the values, and then count each one. The most frequently occurring value is the mode.
- **Range** – the highest value minus the lowest value.
- **Variance** – similar to standard deviation, it is a measure of the spread of the distribution. In other words, it is a measure of how the individual observations are from the mean.
- **Standard Deviation** – a measure of the spread of the values in a sample. It is defined as the square root of the variance and has the same units as the observations.
- **Standard Error** – a measure of how closely your sample relates to the population. It can be used in combination with confidence intervals to establish a range of reasonable values for the population mean.

- **Regression Analysis** – a simple statistical tool used to describe or to model the relationship between two variables: one independent and another one dependent. For purposes of the research project we refer to the simple linear regression, in which the relationship is described by a straight line, $y=mx + b$.

- **Correlation Analysis** – one of the most common and most useful statistics. A correlation is a single number that determines the degree of relationship between two variables (we do not define independent and dependent variables).

Inference (hypothesis/significance tests and confidence intervals):

- **T-test for Comparing Two Means** – assesses whether the means of two groups are *significantly* different from each other (or if they are different by chance). This analysis is appropriate whenever you want to compare the means of two groups. Comparing two populations or two treatments is one of the most common situations in statistics. When comparing two means, the t-test takes into consideration the variability of your data. The variability of a given data set can lead to incorrect conclusions if statistical analyses are not performed.

- **Confidence Intervals** – a range around a measurement that expresses how precise the measurement is. For example, using a 95% confidence interval [$x \pm 1.96(SE)$] you can say that this interval will contain the population mean 95% of the time you compute such an interval from a sample.

Are regression and correlation analysis the same?

This is a common question among people interested in using statistics to analyze data. There are a few points that may help to clarify the use of both statistics:

- **Correlation** does not assume that one variable is dependent on the other(s) and is not concerned with the relationship between variables; instead it gives an estimate of the degree of linear association between the variables. In fact, correlation analysis tests for interdependence of the variables.

- **Regression**, on the other hand, attempts to describe the dependence of a variable on one (or more) explanatory variables; it assumes that there is a one-way functional relationship from the explanatory variable(s) to the response variable, regardless of whether the path of effect is direct or indirect.

See Appendix C for more information on statistics.

Part III. Presenting your Research

One of the most important aspects of research is sharing what you have learned with other scientists and the public. When you share your research, you are contributing to the scientific process by adding more information to a larger body of knowledge about a given topic. In the previous sections of the *Research Guide* you learned how to develop research questions and hypotheses and how to collect data to test your hypothesis. In this section, we will show you how to report the findings of your study. You will learn how to write and format your research report in the same way that scientists write for publication in scientific journals. Because researchers are not only expected to share their findings in print, but also orally, the last part of this section presents tips on preparing effective presentations.

Research Paper Outline

Introduction

- Organize your introduction in a logical order.
- Start with the big picture then narrow down to your topic.
- Use the background information from your proposal as a starting point.
- Include many references to convince the reader why this study is important.
- State your objective and hypothesis at the end of the introduction.

Methods

- Use subheadings for each section of your methods (*e.g.,* literature review, field research, lab analysis, statistical analysis).
- State your assumptions (*e.g.,* "Population will grow at the same rate as in 2007").
- State your sources if using secondary data sources such as databases.
- Provide the steps of your research procedure.
- Describe any statistics you use (*e.g.,* averages, standard deviation, regression).
- Use references if you are using methods from a previously published study.

Results

- Use the similar subheadings as in the methods section.
- For each section, state the major result you found.
- Refer to your figures and tables.
- References are not necessary in this section

Discussion

- Use subheadings that emphasize the implications of your research
- Interpret your results by referring to other studies. Why did you find these results?
- Use references to other studies to explain the implications of your research results.
- If appropriate, include policy recommendations using references.
- Conduct critical self evaluation. Highlight any methodological or experimental errors that may have influenced the results. Are there any issues that the reader needs to be aware of in order to properly interpret your data?

Conclusions

- Restate the major findings and implications of your research.
- What future research needs to be done to more fully answer your question?

Acknowledgements

- Who helped to guide your research? Who provided materials and funding?

References

- List all references that you cite.

How to Write a Scientific Paper

Writing a scientific paper that effectively conveys complex information is an art that requires practice and expertise. However, most scientific papers follow a standard format that can be easily adopted. The following pages will provide you with information about how to write the different sections of a scientific paper.

I. Sections of the Paper

The sections of a journal style paper appear in the following order:

Experimental process	Section of Paper
Summary of your research	Abstract
What is the problem?	Introduction
How did I solve the problem?	Materials and Methods
What did I find out?	Results
What does it mean?	Discussion
Who helped me?	Acknowledgments (optional)
Whose work did I refer to?	Literature Cited
Extra Information	Appendices (optional)

Main Section Headings: Each main section of the paper begins with a heading which should be capitalized, centered at the beginning of the section, and double spaced from the lines above and below. Example of a main section heading:

INTRODUCTION

Subheadings: When your paper reports on more than one experiment, use subheadings. Subheadings should be capitalized (first letter in each word), left justified, and either bold italics OR underlined. Example of a subheading:

Effects of Light Intensity on the Rate of Electron Transport

II. Title, Author Names, and Institutional Affiliations

Objective: The Title should concisely describe the contents of the paper. Use key words that you would associate strongly with the content of your paper (*e.g.,* the molecule studied, the organism used or studied, the treatment, the location of a field site, the response measured).

Format: The title should be centered at the top of page 1. The authors' names and institutional affiliation are centered below the title. For example:

Ducks Over-Winter in Barley Fields in Response to Increased Daily Mean Temperature

Ima Mallard, Ura Drake, and Woodruff Ducque
East High School

Authors are listed in the order in which they contributed to the project. The person who did the most work is listed first. If all authors did equal work, they are listed alphabetically.

III. Abstract

Objective: An abstract summarizes in one paragraph the major aspects of the entire paper. The abstract helps readers decide whether they want to read the rest of the paper. If you can catch someone's attention with an intriguing title, and then lure them in with an abstract that interests them, they might sit down and read your whole paper.

Structure: The length of your abstract should be kept to a 200-300 words. Limit your statements concerning each segment of the paper (*e.g.,* purpose, methods, results, etc.) to two or three sentences, if possible. Use the following outline to write your abstract:

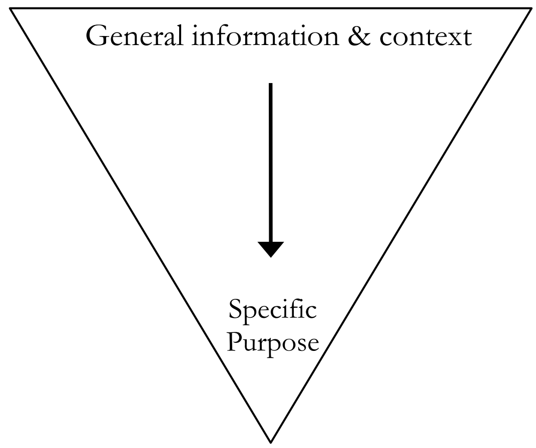
1. The question(s) you investigated (or purpose) (from Introduction).
   a. State the purpose/hypothesis very clearly in the first or second sentence.
2. The experimental design and methods used (from Methods).
   a. Clearly express the basic design of the study.
   b. Briefly describe the basic methodology used without excessive detail.
   c. Indicate the key techniques used.
3. The major findings including key quantitative results, or trends (from Results).
   a. Report those results which lead you to reject or accept your hypothesis
   b. Identify trends, relative change or differences, etc.
4. A brief summary of your interpretations and conclusions (from Discussion).
   a. Clearly state the implications of the answers your results gave you.

Although the Abstract is the first section of your paper, this section must be written last since it will summarize the paper.

IV. Introduction

Objective: Establish the *context* of the work reported by discussing the relevant primary research literature (with citations) and summarizing our current understanding of the problem you are investigating. State the *purpose* of the work in the form of the hypothesis, question, or problem you investigated. Very briefly explain the *rationale* for your methodological approach and anticipated results.

Structure: The Introduction structure can be thought of as an inverted triangle with the broadest, most general information at the top of the triangle and the specific problem you researched at the bottom. Organize the information to present the more general aspects of the topic at the beginning, then narrow toward the more specific topical information that provides context, finally arriving at your statement of purpose and rationale.



Use these steps to write your introduction:

1. **Clearly and concisely state the purpose and/or hypothesis of your investigation.** *Put this at the end of you introduction.* When you are first learning to write in this format it is okay to use a statement like, "The purpose of this study was to...." or "We investigated three possible mechanisms to explain…" or "I hypothesize that…"

   Now go back to the beginning of the introduction…

2. **Identify the subject area**. Use key words from your Title in the first few sentences of the Introduction to get it focused directly on topic. This insures that you get to the primary subject matter quickly without losing focus, or discussing information that is too general.

3. **Establish the context.** Provide a brief and balanced review of the published literature that is available on the subject. The key is to summarize what we knew about the specific problem before you did your experiments or studies. This is accomplished with a general review of the primary research literature (with citations) but should not include very specific, lengthy explanations that you will discuss in greater detail later in the Discussion. Lead the reader to your statement of purpose/hypothesis by focusing your literature review from the more general context to the more specific topic of interest to you.

4. **Provide a brief, clear statement of the rationale for your approach to the problem studied.** Why did you choose this kind of experiment or experimental design? What advantages does it confer in answering the particular question(s) you are posing? *Do not discuss the actual techniques or protocols used in your study – this will be done in the Materials and Methods.*

V. Materials and Methods

Objective: The validity of a study is judged by the quality of the methods used. Using concise and precise writing, describe where the study was conducted, the materials used in the study, how measurements were made, and how the data were analyzed (statistical tests). Explain why you chose to use certain methods. You should provide enough information so that other researchers can replicate your experiment.

Structure:

1. Define the scope of the study and describe study area (e.g., national analysis, regional, your high school). Including the physical and biological features of the site and precise location (i.e., elevation, latitude, longitude).

2. Describe the subject (e.g., bees in California, homes in New York, students at your high school) and when and where the study was carried out.

3. Describe your experimental OR sampling design. How was the experiment or study structured? For example, controls, treatments, the variable(s) measured, and how many samples were collected.

4. If you are using secondary sources of data, describe the datasets. Who collected the data? What years are you looking at? Include citations!!

5. Provide a rationale for the specific procedure or data you chose to use. If using a particular methodology, cite the source of your methods.

6. State your assumptions and provide justification.

7. Describe calculations – how were the data summarized and analyzed?
    a. For example, report averages standard deviation, t-tests, regression, etc.
    b. Describe sources of error in your calculations.

Style & Organization:

- Write your methods in a paragraph form – not a list.
- Provide a logical progression of ideas.
- Use subheadings.
- Use the past tense.
- Use a combination of active and passive voice.
- Use an appropriate level of detail so that someone could replicate your study.
- If you used standard methods from previously published studies, cite these methods instead of re-writing them.

Do not report any results in the Methods section!

VI. Results

Objective: Write a narrative (text) to present your key results, without interpretation. Use tables and figures to illustrate the key results. See section X. Figures and Tables (pg. 53).

Structure: Organize the Results section as a logical narrative. The sequence of tables and/or figures will parallel the organization of your narrative.

Types of results you might report:

- Trends (X increases or decreases over time)
- Correlations (as Y increases, X also increases)
- Differences (Y is greater than X)

Style & Organization:

- You must refer to each table and/or figure in the text and clearly indicate for the reader the key results that each conveys.
- Report key trends, correlations, differences rather than specific numbers.
- Report means and percents when possible.
- Figures and tables are numbered in the order in which you refer to them in the text.
- Figures and tables are numbered independently of each other. For example, if you present one figure and one table, they would be numbered Figure 1 and Table 1.
- Always enter the appropriate units when reporting data or summary statistics.

- Report your findings in the past tense.
- Figure legends go below the figure, table legends go above the table.
- Do not provide any interpretation of the data (i.e. why population is increasing) – this belongs in the discussion section.
- Do not present the same data in both a table and figure.
- Do not report raw data. Typically report only summary statistics in the body of the text unless the raw data is more critical. If you wish to include raw data, include them in an appendix.

Statistical test summaries are usually reported in parentheses with the test name and p-value after the results that they support. For example:

> "Males (180.5 ± 5.1 cm) averaged 12.5 cm taller than females (168 ± 7.6 cm) **(two-sample t-test, p < 0.001)**."

In this example, the average height of males was 180.5 cm and the standard deviation was 5.1 cm. The researchers used a statistical test called a two-sample t-test to determine whether the height of males was *statistically significantly* different than the height of the females.

Report negative results: They are important! If you did not get the anticipated results, it may mean your hypothesis was incorrect and needs to be reformulated, or perhaps you have stumbled onto something unexpected that warrants further study.

VII. Discussion

Objective: In this section you **interpret** your results based on previously published research and you explain how your new findings change our understanding of the problem. *Think big picture.* Why do you think that you got these results? Why are your results important? You must relate your work to the findings from previous studies conducted by yourself and other investigators. Do not introduce new results in the Discussion.

Structure: The topics of the discussion section should follow the same order as the Results section. Interpret/address the results of each of the experiments or studies presented in the Results. The Discussion will always connect to the Introduction by way of the question(s) or hypotheses you posed and the literature you cited. It does not simply repeat or rearrange the Introduction. Instead, it tells how your study has moved us forward from the place you left off at the end of the Introduction.

Questions to answer in your discussion:

- Do your results provide answers to your testable hypotheses? If so, how do you interpret your findings?
- Do your findings agree with what others have shown? If not, do they suggest an alternative explanation or perhaps an unforeseen design flaw in your experiment or theirs?
- Given your conclusions, what is our new understanding of the problem you investigated and outlined in the Introduction?
- If warranted, what would be the next step in your study, e.g., what experiments would you do next?

VIII. Acknowledgements

If, in your experiment, you received any significant help in designing, carrying out the work, or received donated materials from someone, you must acknowledge their assistance and the service or material provided. Authors always acknowledge outside reviewers of their drafts and any sources of funding that supported the research.

IX. Literature Cited

Provide an alphabetical listing (by the first author's last name) of the references that you actually cited in the body of your paper. List only those papers that you cited in the text, and only cite papers in the text that are included in this list. Ask your teacher to recommend a standard format for referencing (*e.g.,* MLA, APA).

X. Figures and Tables

Objective: To represent data in a clear and organized way. Each figure and table should stand on its own without having to refer back to the text. The text of the figure/table legend should describe the major result (*e.g.,* statistically significant trends) without repeating the data shown in the figure/table. Do not interpret the data and do not show the same data in a figure and a table. Decide whether a figure or table is the more effective way to present your data.

Tables: Present lists of numbers or text in columns, each column having a title or label

Figures: Figures are visual presentations of results, including graphs, diagrams, photos, drawings, schematics, maps, etc. Graphs are the most common type of figure.

Numbering: Tables and Figures are assigned numbers separately and in the sequence that you refer to them in the text of the results section. The first Table you refer to is Table 1, the next Table 2 and so forth. Similarly, the first Figure is Figure 1, the next Figure 2, etc.

Legend Position: Table legends are positioned above the Table, because tables are read from top to bottom. Figure legends are positioned below the figure, because figures are usually viewed from bottom to top.

Tips: Do not use a table when you wish to show a trend or a pattern of relationship between sets of values - these are better presented in a Figure.

XI. Appendices

Objective: Contains information that is non-essential to understanding of the paper, but may present information that further clarifies a point without burdening the body of the presentation

Examples of material that might be found in an appendix: raw data, maps (foldout type especially) & extra photographs, explanation of a mathematical procedures, diagrams of specialized equipment

Sources:

1. Department of Biology, Bates College (2002) *How to write a paper in scientific journal style and format* Located at: <http://abacus.bates.edu/~ganderso/biology/resources/writing/HTWtoc.html>
2. Kallet RH (2004) How to write the methods of a research paper. *Resp. Care* 49(10):1229-32

Citations and References

Citing is the process of giving credit to the sources you used to write your paper. Reference "citations" are located within the text and a "reference list," usually called a "Literature Cited" section, is located at the end of the work. Sometimes it can be difficult to determine which sources need to be credited.

When to cite: rule of thumb

If you knew a piece of information before you started doing research, generally you do not need to credit it. You also do not need to cite well-known facts, such as dates, which can be found in many encyclopedias. All other information such as methods, statistics, and ideas should always be cited in your papers.

Scientific literature citations

Citations from scientific papers are typically not formatted as quotations. Instead, paraphrase main ideas or state specific information from the article. Also, avoid using words such as "one study found," or "a recent study showed." State the main point of the study and be concise.

Unpublished data and personal communications

Sometimes a researcher has data that have not yet been published or has a conversation with someone else with unpublished data. In this case, we report "unpublished data" or "personal communication" instead of a year (*e.g.,* Smith, unpublished data).

Anatomy of a citation

Citations in the text are typically found within the sentence or at the end of the sentence that refers to the article. Be aware that there are a number of formats to choose from (see the 'Choosing a Format' section below). In general, citations are formatted either as names and dates within parenthesis (*e.g.,* Smith 2004) or as numbers within parenthesis that correspond to a numbered list at the end of the document (*e.g.,* 1). If there are two authors, both names are reported (*e.g.,* Smith and Jones 2004). If there are more than two authors the Latin abbreviation "et al." (and others) is used after the name of first author (*e.g.,* Smith et al. 2004). It is important that all citations are reported consistently throughout the document. For example,

> "Additionally, facilitation between nonnative invaders and native species (Richardson et al. 2000) may occur in stressful and disturbed areas (Smith et al. 2004; B. Von Holle, unpublished manuscript)." *Excerpt from:* Fridley, J.D., J.J. Stachowica, S. Naeem, D.F. Sax, E.W. Seabloom, M.D. Smith, T.J. Stohlgren, D. Tilman, and B.Von Holle. 2007. The invasion paradox: reconciling patterns and process in species invasions. Ecology. 88:3-17.

As you compile your list of cited sources, it is helpful to know what type of information you need to write down. Here is a mock citation with each of its important parts labeled:

Forrester, D.W, and A.J. Aquaguy. 2007. Linking water quality with forest type. *Natural World.* 32:39-42.	
Authors:	D. W. Forrester and A. J. Aquaguy
Title:	Linking water quality with forest type.
Title of Periodical:	Natural World.
Volume:	32:
Page(s):	39-42.
Year:	2007.

Choosing a Format

Each journal has its own format for citing and listing references which can be found in the section titled "Instructions for Authors" for that publication. Most of the formats journals choose are based on one of a few well known formats, some of which are listed here.

- **Publication Manual of the American Psychological Association, 5th edition**: psychology, education, and other social sciences.
- **MLA Handbook for Writers of Research Papers, 6th edition**: literature, arts, and humanities.
- **American Medical Association Manual of Style, 9th ed.**: medicine, health, and biological sciences.
- **A Manual for Writers of Term Papers, Theses, and Dissertations, 6th edition (Turabian)**: designed for college students to use with all subjects.
- **Chicago Manual of Style, 15th ed.**: used with all subjects in the "real world" by books, magazines, newspapers, and other non-scholarly publications.
- **Scientific Style and Format: The Council of Biology Editors Manual for Authors, Editors, and Publishers, 6th ed.**: biological, earth, and other sciences

Useful websites:

- http://www.chicagomanualofstyle.org/home.html
- http://www.dianahacker.com/resdoc/
- http://www.liu.edu/cwis/cwp/library/workbook/evaluate.htm#citing
- http://owl.english.purdue.edu/owl/

Final Paper Checklist

- ❑ Is the Title specific and informative?
- ❑ Does the Abstract and Table of Contents include all relevant parts of the paper?
- ❑ Have you included enough information in the Materials and Methods section to enable someone else to repeat your study?
- ❑ Have you explained in Materials and Methods the procedures for collecting all the data presented in the Results?
- ❑ Are figures and tables numbered consecutively in separate series?
- ❑ Is every figure and table cited correctly in the text?
- ❑ Do the data in each figure or table agree with your in-text discussion?
- ❑ Do any figures or tables present conflicting data or the same data?
- ❑ Are data in related figures or tables shown in a consistent manner?
- ❑ Is each table and figure understandable apart from the text?
- ❑ Are any important results missing from the Results section?
- ❑ Have you used enough headings and subheadings to guide the reader?
- ❑ Does the Discussion section address the major implications of your findings?
- ❑ Have you considered problems, inconsistent results, and counter-evidence?
- ❑ Have you cited all necessary sources?
- ❑ Are all sources cited in the text listed in the Literature Cited section?
- ❑ Does the Literature Cited section include any sources not cited in the text?

PowerPoint Tips

Communicating your research results to the public is one of the most important steps of the research process. However, even the most exciting research results become dull quickly if the oral presentation is not well done. To create an effective and professional PowerPoint presentation of your research use the following tips:

Outline:

1. Title slide – title of presentation, authors, school name
2. Introduction
3. Methods
4. Results
5. Discussion/Conclusion
6. Acknowledgments/References

Design tips:

- Use the slide master feature in PowerPoint (View → Master → Slide Master) to create a consistent and simple design template.
- Be consistent with elements such as font, colors, and background through the presentation.
- Every slide should have a heading with the same format (text size, font and color)
- Use simple backgrounds – patterned backgrounds obscure the text
- Use contrasting colors. Font colors should be in the range of whites to yellow for dark backgrounds and black to dark blue for light backgrounds. Never use red and green.
- Use sans serif fonts (ex., Arial, Calibri, Comic Sans, Century Gothic, Verdana)
- Do not use serif fonts (ex., Times New Roman, Garamond, Palatino Linotype)
- Font size: Headings +32 point, Body 20-30 point, References 14-18pt
- Use the 8 foot test – Can you read the text on the screen when you stand 8 feet back from your computer? If not, make the font bigger.
- Use grids and guides in the drawing tool bar for even spacing of text and images
- Use high quality images. Low resolution images will distort and look grainy when projected onto a large screen.
- If you have a bulleted list of text, it can effective to 'unveil' each bullet using the function: Slide show → custom animation → add effect → entrance → appear

Keep it simple:

- Avoid the use of flashy transitions such as text fly-ins. These features are distracting.
- Overuse of special effects, such as animation and sounds, may make your presentation seem "cutesy" and unprofessional.
- Limit the text to a maximum of 6 words per line and 6 lines of text per slide.
- Use key phrases (not sentences) and include only essential information.
- Limit punctuation and AVOID PUTTING WORDS IN ALL CAPITAL LETTERS.
- Use white space – <u>Do not</u> crowd each slide with too much text and too many images
- Limit the use of numbers, because they will overwhelm your audience. Instead of presenting a data table, use visual aids such as graphs and use relative numbers such as percentages.
- Limit the total number of slides in the presentation. Less can be more. Presenters who constantly "flip" to the next slide are likely to lose the attention of their audience.

Presentation style:

- During the title slide introduce your study and hint at the take-home message.
- During each slide remember to state the major point or conclusion.
- <u>Do not</u> read from your slides. The content of your slides is for the audience, not for the presenter.
- Face your audience and talk to your audience. Do not face or talk to the screen.
- Make eye contact with your audience. Smile.
- Never overestimate your audience (or their attention span). Remember – you are the expert.
- Time your remarks on each slide. When you bring up a new slide give your audience a moment of silence to digest the content of the slide.

- Time your whole presentation – a rule of thumb is one slide per minute.
- Do not go over your time – it is unprofessional.
- If presenting with a partner, determine ahead of time who will present which slides.
- Save time for questions at the end.
- Anticipate questions from the audience by preparing extra slides that you can present during the Q&A.

Prepare for the worst:

- Have a Plan B in the event of technical difficulties, such as an extra flash drive with a copy of your presentation, a laptop, transparencies, or handouts.
- Arrive as early as possible to the room in which you will be presenting to check that the equipment and your presentation are working properly.
- Practice with someone who has never seen your presentation. Ask them for honest feedback about colors, content, and graphics you've included.

Practice, Practice, Practice!

Appendices

Appendix A: Project Timeline

All updates are due at the start of class.
You should be prepared to talk about your assignment in class.

No late work will be accepted!

Creating a Research Proposal

		Due Dates:
1.	Brainstorming	In class
2.	Creative Writing	In class
3.	Ten Questions	__________
4.	Annotated Bibliography	__________
5.	Narrowing Your Questions: 10 to 1	__________
6.	Researcher Interview	__________
7.	Proposal #1	__________
8.	Peer Review	In class
9.	Final Proposal	Due 1 week after peer review

Project Updates

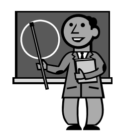
		Due Dates:
1.	Introduction	__________
2.	Methodology	__________
3.	Existing Data Analysis	__________
4.	Project Updates	__________
5.	Preliminary Results: Your Data to Date	__________

Project Results

Due Dates:

1. Preliminary Results ___________
2. Hypothesis Testing/ Statistical Analysis ___________
3. Discussion ___________
4. Problems and Further Questions ___________

Project Presentations



Due Dates:

1. Power Point Presentation ___________
2. Defend your position ___________
3. 2nd Power Point ___________
4. Final Results ___________
5. 3rd and Final Power Point ___________

Appendix B: Weekly Research Checkup

Every Monday you are expected to have completed the following questions/tasks and give a 2 minute summary of your progress on your research to the class. This will keep everybody focused as well as providing you with the opportunity to use your peers for advice.

Note to the Teachers: By requiring continuous accountability, the weekly research checkup activity has proven to be very effective in helping students to advance with their projects.

1) Name and contact information of one new person you have contacted regarding your project.

2) One new observation from your field site (soil seemed dryer today, birds were absent, pond was clearer, etc) or an observation about your study subject.

3) List two new references to use for your research.

4) New problems or concerns about any part of your research project.

5) An explanation/summary of your week's data.

Appendix C: Reference Page

Author:	
Title:	
Title of Periodical:	
Volume:	
Page(s):	
Year:	
Author:	
Title:	
Title of Periodical:	
Volume:	
Page(s):	
Year:	
Author:	
Title:	
Title of Periodical:	
Volume:	
Page(s):	
Year:	

Appendix D: Laboratory Notebook

Appendix E: Statistical Tests

INFERENTIAL STATISTICS

1. Performing the t-test

The formula for the t-statistic is a ratio. The top part of the ratio (numerator) is just the difference between the two means. The equation for calculating the t-statistic is:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where $\overline{X_1}$ is the mean of group 1, $\overline{X_2}$ is the mean of group 2, n_1 is the number of observations in group 1, n_2 is the number of observations in group 2, and s_1^2 is the sample variance of group 1, and s_2^2 is the sample variance of group 2.

The t-statistic will be positive if the first mean is larger than the second and negative if it is smaller. Once you compute the t-statistic you have to look it up in a table of significance (also known as the t distribution) to test whether the ratio is large enough to say that the difference between the groups is not likely due to random chance.

To test the significance, you need to set a risk level (called the alpha level). In most cases, the "rule of thumb" is to set the alpha level at 0.05. This means that five times out of a hundred you would find a statistically significant difference between the means even if there were none (i.e., by "chance"). You also need to determine the degrees of freedom (df) for the test. In the t-test, the degree of freedom equals the sum of the samples size in both groups minus two ($df = (n_1 + n_2) - 2$). Given the alpha level, the df, and the t-statistic, you can find the t-value in a standard table of significance to determine whether the t-statistic you calculated is large enough to be significant. If the t-statistics is greater than the t-value listed in the table, you can conclude that the difference between the means for the two groups is significant (even given the variability). Therefore, you can reject the null hypothesis (see p. 10) of no difference between group means. If the t-statistic you calculated is smaller than the t-value in the table, you conclude that the difference between the means is not large enough. Therefore, you fail to reject the null hypothesis, and conclude that you don't have sufficient evidence to claim that the observed difference is not due to random chance.

One-way analysis of variance (ANOVA) is used to test for differences among means of two or more independent groups. Typically, however, the One-way ANOVA is used to test for differences among at least three groups, since the two-group case can be covered by a t-test. When there are only two means to compare, the t-test and the F-test are equivalent; the relation between ANOVA and **t** is given by $F = t^2$.

1.1 Using EXCEL for t-tests (option 1):

Enter the values of the data in columns or rows. Click on an empty cell, and select *Insert>Function*. In the *Paste function* window, go to *Function category* menu (left) and select *Statistical*. At your right you will have the *Function name* menu, select **TTest**. A new window will pop in the screen. Click on *Array 1*, and go to your data in the spreadsheet to select the data in your first column (or row, x). Then click on *Array 2*, go to your data in the spreadsheet and select the data in your second column (or row) y. On the option *Tails,* type **2** (for two tailed distribution, applies for null hypothesis of no differences between the means), and on the option *Type* type **3** (for unequal variances between the means) or 2 (for equal variances between the means). This method provides the p-value for a two-tailed t-test. If the value is less than 0.05, the null hypothesis is rejected.

1.2 Using EXCEL for t-tests (option 2):

Enter the values of the data in columns or rows. Click on *Tools, Data Analysis, t-test: Two-Sample Assuming Unequal Variances,* and click *OK*. Select the first column or row of data and place in the window *Input Variable 1 Range*. Select the second column or row of data and place in the window *Input Variable 2 Range*. Click *OK*. This method provides a table of data including means, and variances of each variable. The table also includes the calculated t-value (t Stat), the table t-value (critical value), and the p-values for one or two-tailed t-tests.

Example:

t-test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	70.45454545	60.18181818
Variance	123.4727273	114.1636364
Observations	11	11
Hypothesized Mean Difference	0	
df	20	
t Stat	2.210169858	
P(T<=t) one-tail	0.019456522	
t Critical one-tail	1.724718004	
P(T<=t) two-tail	0.038913045	
t Critical two-tail	2.085962478	
t stat > than critical value, so REJECT null hypothesis		

Table of critical t-value for two-tailed distributions

P / DF	0.2	0.1	0.05	0.02	0.01	0.005	0.002	0.001
1	3.078	6.314	12.71	31.82	63.66	127.3	318.3	636.6
2	1.886	2.92	4.303	6.965	9.925	14.09	22.33	31.6
3	1.638	2.353	3.182	4.541	5.841	7.453	10.22	12.92
4	1.533	2.132	2.776	3.747	4.604	5.598	7.173	8.61
5	1.476	2.015	2.571	3.365	4.032	4.773	5.893	6.869
6	1.44	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7	1.415	1.895	2.365	2.998	3.499	4.029	4.785	5.408
8	1.397	1.86	2.306	2.897	3.355	3.833	4.501	5.041
9	1.383	1.833	2.262	2.821	3.25	3.69	4.297	4.781
10	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11	1.363	1.796	2.201	2.718	3.106	3.497	4.025	4.437
12	1.356	1.782	2.179	2.681	3.055	3.428	3.93	4.318
13	1.35	1.771	2.16	2.65	3.012	3.372	3.852	4.221
14	1.345	1.761	2.145	2.625	2.977	3.326	3.787	4.14
15	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16	1.337	1.746	2.12	2.584	2.921	3.252	3.686	4.015
17	1.333	1.74	2.11	2.567	2.898	3.222	3.646	3.965
18	1.33	1.734	2.101	2.552	2.878	3.197	3.61	3.922
19	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.85
21	1.323	1.721	2.08	2.518	2.831	3.135	3.527	3.819
22	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23	1.319	1.714	2.069	2.5	2.807	3.104	3.485	3.768
24	1.318	1.711	2.064	2.492	2.797	3.09	3.467	3.745
25	1.316	1.708	2.06	2.485	2.787	3.078	3.45	3.725
26	1.315	1.706	2.056	2.479	2.779	3.067	3.435	3.707
27	1.314	1.703	2.052	2.473	2.771	3.057	3.421	3.69
28	1.313	1.701	2.048	2.467	2.763	3.047	3.408	3.674
29	1.311	1.699	2.045	2.462	2.756	3.038	3.396	3.659
30	1.31	1.697	2.042	2.457	2.75	3.03	3.385	3.646
31	1.309	1.695	2.04	2.453	2.744	3.022	3.375	3.633
32	1.309	1.694	2.037	2.449	2.738	3.015	3.365	3.622
33	1.308	1.692	2.035	2.445	2.733	3.008	3.356	3.611
34	1.307	1.691	2.032	2.441	2.728	3.002	3.348	3.601
35	1.306	1.69	2.03	2.438	2.724	2.996	3.34	3.591
36	1.306	1.688	2.028	2.434	2.719	2.991	3.333	3.582
37	1.305	1.687	2.026	2.431	2.715	2.985	3.326	3.574
38	1.304	1.686	2.024	2.429	2.712	2.98	3.319	3.566
39	1.304	1.685	2.023	2.426	2.708	2.976	3.313	3.558
40	1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.551
42	1.302	1.682	2.018	2.418	2.698	2.963	3.296	3.538
44	1.301	1.68	2.015	2.414	2.692	2.956	3.286	3.526
46	1.3	1.679	2.013	2.41	2.687	2.949	3.277	3.515
48	1.299	1.677	2.011	2.407	2.682	2.943	3.269	3.505
50	1.299	1.676	2.009	2.403	2.678	2.937	3.261	3.496
60	1.296	1.671	2	2.39	2.66	2.915	3.232	3.46
70	1.294	1.667	1.994	2.381	2.648	2.899	3.211	3.435
80	1.292	1.664	1.99	2.374	2.639	2.887	3.195	3.416
90	1.291	1.662	1.987	2.369	2.632	2.878	3.183	3.402
100	1.29	1.66	1.984	2.364	2.626	2.871	3.174	3.391
120	1.289	1.658	1.98	2.358	2.617	2.86	3.16	3.373
150	1.287	1.655	1.976	2.351	2.609	2.849	3.145	3.357
200	1.286	1.652	1.972	2.345	2.601	2.839	3.131	3.34
300	1.284	1.65	1.968	2.339	2.592	2.828	3.118	3.323
500	1.283	1.648	1.965	2.334	2.586	2.82	3.107	3.31
∞	1.282	1.645	1.96	2.326	2.576	2.807	3.09	3.291

Retrieved on November 2008 from http://www.socialresearchmethods.net/

2. **Correlation Analysis**

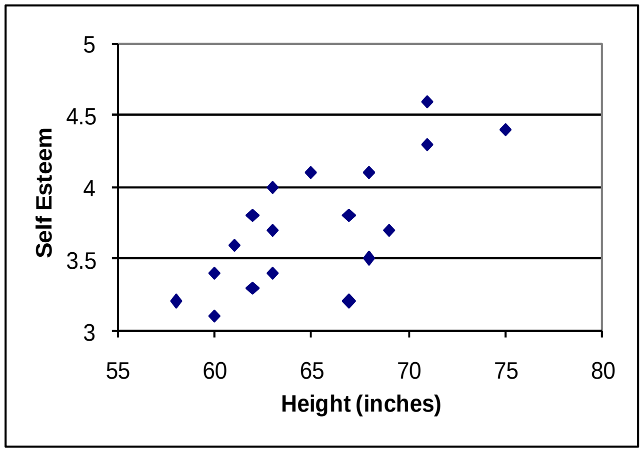
A correlation is a single number (r) that determines the degree of relationship (in terms of linear association) between two variables.

For example, let's assume that we want to look at the relationship between two variables, height (in inches) and self-esteem. Perhaps we have a hypothesis that how tall you are affects your self-esteem (incidentally, I don't think we have to worry about the direction of causality here -- it's not likely that self esteem causes your height!). We collect some information on twenty individuals (all male -- we know that the average height differs for males and females so, to keep this example simple we'll just use males). Height is measured in inches. Self esteem is measured based on the average of 10 1-to-5 rating items (where higher scores mean higher self esteem).

Here are data for the 20 cases (these data are made up to illustrate what a correlation is):

Person	Height (inches)	Self Esteem
1	68	4.1
2	71	4.6
3	62	3.8
4	75	4.4
5	58	3.2
6	60	3.1
7	67	3.8
8	68	4.1
9	71	4.3
10	69	3.7
11	68	3.5
12	67	3.2
13	63	3.7
14	62	3.3
15	60	3.4
16	63	4.0
17	65	4.1
18	67	3.8
19	63	3.4
20	61	3.6

If we make a scatter-plot of the data using Excel, we would see the following:



You should immediately see in the scatter-plot that the relationship between the variables is a positive one because if you were to fit a single straight line through the dots it would have a positive slope or move up from left to right. Since the correlation is nothing more than a quantitative estimate of the relationship, we would expect a positive correlation.

What does a "positive relationship" mean in this context?

It means that, in general, higher scores on one variable tend to be paired with higher scores on the other and that lower scores on one variable tend to be paired with lower scores on the other. You should confirm visually that this is generally true in the plot above.

Calculating the Correlation Coefficient

The formula for the correlation coefficient is:

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[(N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

We use the symbol **r** to stand for the correlation. The **r** value will always be between -1.0 and +1.0. If the correlation is negative, we have a negative relationship; if it's positive, the relationship is positive.

To interpret how strong your data are correlated you can use the guidelines in the table below.

Interpretation of the size of a correlation		
Correlation	Negative	Positive
Small	−0.3 to −0.1	0.1 to 0.3
Medium	−0.5 to −0.3	0.3 to 0.5
Large	−1.0 to −0.5	0.5 to 1.0

Several authors have offered guidelines for the interpretation of a correlation coefficient. It has been observed, however, that all such criteria are in some ways arbitrary and should not be observed too strictly. This is because the interpretation of a correlation coefficient depends on the context and purposes. A correlation of 0.9 may be very low if one is verifying a physical law using high-quality instruments, but may be regarded as very high in the social sciences where there may be a greater contribution from complicating factors.

It is important to remember that "large" and "small" should not be taken as synonyms for "good" and "bad" in terms of determining that a correlation is of a certain size. For example, a correlation of 1.0 or −1.0 indicates that the two variables analyzed are equivalent. Scientifically, this more frequently indicates a trivial result than a profound one. For example, consider discovering a correlation of 1.0 between how many feet tall a group of people are and the number of inches from the bottom of their feet to the top of their heads.

To test for the significance of the correlation coefficient r, you can use the Correlation Critical Values table below. After defining your alpha level (risk level) and the degrees of freedom (n-2), you can look for the critical value in the table. If your calculated **r** value is higher than the critical value in the table, you can conclude that the two variables studied are significantly correlated. If your calculated **r** value is lower than the critical value in the table, you can conclude that the two variables are NOT significantly correlated.

2.1 Using EXCEL for correlations:

Enter the values of both sets of the data (assumed to be related to each other, x and y) in columns or rows. Click on an empty cell, and select *Insert>Function*. In the *Paste function* window, go to *Function category* menu (left) and select *Statistical*. At your right you will have the *Function name* menu, select **Correl** or **Pearson**. A new window will pop in the screen. Click on *Array 1*, and go to your data in the spreadsheet to select the data in your first column (or row, x). Then click on *Array 2*, go to your data in the spreadsheet and select the data in your second column (or row) y. Click OK, and you will have the **r** value for your data.

Table of critical r-value for two tailed distributions

Level of Significance (p)				
df (n-2):	**0.1**	**0.05**	**0.02**	**0.01**
1	0.988	0.997	0.9995	0.9999
2	0.9	0.95	0.98	0.99
3	0.805	0.878	0.934	0.959
4	0.729	0.811	0.882	0.917
5	0.669	0.754	0.833	0.874
6	0.622	0.707	0.789	0.834
7	0.582	0.666	0.75	0.798
8	0.549	0.632	0.716	0.765
9	0.521	0.602	0.685	0.735
10	0.497	0.576	0.658	0.708
11	0.476	0.553	0.634	0.684
12	0.458	0.532	0.612	0.661
13	0.441	0.514	0.592	0.641
14	0.426	0.497	0.574	0.623
15	0.412	0.482	0.558	0.606
16	0.4	0.468	0.542	0.59
17	0.389	0.456	0.528	0.575
18	0.378	0.444	0.516	0.561
19	0.369	0.433	0.503	0.549
20	0.36	0.423	0.492	0.537
21	0.352	0.413	0.482	0.526
22	0.344	0.404	0.472	0.515
23	0.337	0.396	0.462	0.505
24	0.33	0.388	0.453	0.496
25	0.323	0.381	0.445	0.487
26	0.317	0.374	0.437	0.479
27	0.311	0.367	0.43	0.471
28	0.306	0.361	0.423	0.463
29	0.301	0.355	0.416	0.456
30	0.296	0.349	0.409	0.449
35	0.275	0.325	0.381	0.418
40	0.257	0.304	0.358	0.393
45	0.243	0.288	0.338	0.372
50	0.231	0.273	0.322	0.354
60	0.211	0.25	0.295	0.325
70	0.195	0.232	0.274	0.303
80	0.183	0.217	0.256	0.283
90	0.173	0.205	0.242	0.267
100	0.164	0.195	0.23	0.254

Appendix F: Research Paper Rubric

Scoring for each section:
4 = Exemplary. Student exceeds expectations and excels in the category.
3 = Accomplished. Student includes all necessary elements and meets expectations.
2 = Developing. Student meets some expectations, but elements are missing/incomplete.
1 = Beginning. Student attempts to include elements, but most are missing/incomplete.
0 = Missing. The student did not attempt to include the required elements.

General (10 total points):	
Well written and easy to read	
Spelling, punctuation and grammar	
Logical flow and organization	
Clear and concise (uses fewest words possible to make point)	
Uses predominantly active voice (more exciting to read)	
Uses headings and subheadings to visually organize the material	
Report handed in on time.	
Comments:	**Score:**
Title (4 points):	
Clearly and concisely describes the study	
Includes pertinent information	
Comments:	**Score:**
Abstract (4 points)	
Summarizes the research question	
Summarizes the methods	
States **major** findings	
States the significance of the findings	
Comments:	**Score:**
Introduction (12 points):	
Demonstrates solid understanding (4 points)	
Tone is authoritative and confident	
Uses relevant scientific or technical words, concepts, and theories	
Demonstrates familiarity with work previously done on this topic	
No major informational gaps in the argument presented	
Need for research on this topic is clearly established (rationale)	
Comments:	**Score:**

References (4 points)	
At least 5 references from the scientific literature	
References are appropriate and properly used	
References are properly cited, e.g. (Haydn and Mozart 1932)	
All important points are backed up with a cited reference	
	Score:
Research question (4 points)	
Objectives of the study are clearly stated	
Hypothesis is clearly stated, specific, and testable	
	Score:
Comments:	**Score:**
Materials and Methods (20 points):	
Well designed (4 points)	
Research design is a well-constructed test of the stated hypothesis.	
Data source or materials and equipment suit the research question	
Use of data source or materials and equipment is justified	
If appropriate, calibration procedures are identified and explained	
	Score:
Well illustrated: EXPERIMENT PROJECT ONLY (4 points)	
Pertinent diagrams and/or photographs included	
Diagrams are appropriate and informative	
Photographs are appropriate and informative	
	Score:
Well described: DATA SET PROJECTS ONLY (4 points)	
Data source (*e.g.,* website or scientific paper) is cited and described	
Optional: Raw data is included at the end of the paper and labeled as an Appendix.	
	Score:
Variables identified (4 points)	
Identifies experimentally- or mathematically-manipulated variables	
All potentially confounding variables are identified	
Expected effects of all variables are stated and justified	
	Score:
Experimental methods (4 points)	
Includes controls for confounding variables where appropriate	
Alternative methods are explored, where applicable	
Detailed enough to be repeatable, but not overly detailed	
	Score:

Relevant descriptive statistics (e.g., mean, std. dev.) are described	
Statistical analysis procedures described	
Proposed analysis is appropriate for addressing the hypothesis	
Analyses chosen are justified	
	Score:
Comments:	**Score:**
Results (12 points):	
Use of Figures (graphs) and Tables (4 points)	
Results correspond with the stated methods	
Where appropriate, data are presented in Figures and Tables	
Axes, titles and legends of tables and figures are properly labeled	
Figures and Tables are professional-looking and easy to interpret	
Appropriate types of Figures (line vs. bar) are used	
Does not interpret (explain) the results	
	Score:
Prose description (4 points)	
All calculations not in Figures and Tables are included in the text	
Each Figure or Table presented is described in the text.	
Figures and Tables are cited in the text that describe them	
	Score:
Analytical methods (4 points)	
Relevant descriptive statistics (*e.g.,* mean, std. dev) are presented	
Relevant analytical statistics (*t*-test results) are presented	
No important analyses are omitted	
Data and data analysis are presented in a logical order	
	Score:
Comments:	**Score:**
Discussion and Conclusions (12 points):	
Explains the results (4 points)	
States whether the hypothesis was supported by the results	
Presents a logical explanation/interpretation of results	
Explains the significance of all results	
Provides evidence from other studies to support explanations (citations)	
No extraneous information is presented	
	Score:
Discusses implications research (4 points)	
Describes how these results fit into the "big picture"	
Discuss how results change understanding of study subject	

Discusses implications research (4 points)	
Describes how these results fit into the "big picture"	
Discuss how results change understanding of study subject	
Discusses the practical applications of the results	
Includes policy suggestions if relevant	
Demonstrates creative and critical thinking	
	Score:
Demonstrates solid understanding (4 points)	
Tone is authoritative and confident	
Words, concepts, and theories are used properly	
Discusses possible reasons for unexpected results	
Identifies and discusses all major potential sources of error	
The writer anticipates the reader's concerns, biases or arguments	
	Score:
Comments:	**Score:**
Conclusion (4 points)	
Concise summary of the paper	
Restates major findings	
Restates significance of the findings	
Generates ideas and questions to guide future research	
Comments:	**Score:**
Literature Cited (4 points):	
All citations in text are listed in this section	
Correct citation format is used	
Comments:	**Score:**
Final Comments:	**Total Score**

Appendix G: Oral Presentation Rubric

Project Name:	School:	Reviewer Name:
Student Names:		

DESCRIPTION	SCORE (0 to 4, or N/A)
I. OBJECTIVES AND HYPOTHESES	
A. Research objectives are clearly stated	
B. Hypotheses are specific and testable	
C. Student explains relevance to environmental science	
II. METHODS	
A. Study design is described in detail	
B. All variables identified and properly measured	
C. Methods are rigorous and appropriate to the hypotheses	
III. RESULTS	
A. Correct use and understanding of data processing and statistics	
B. Clear presentation of results, including figures and tables	
IV. DISCUSSION AND CONCLUSIONS	
A. Conclusions supported by data and analysis	
B. Identifies limitations and scope of the study	
C. Discusses new research questions	
V. REFERENCES	
A. References are cited when appropriate	
B. Literature review is sufficient and credible	
VI. PRESENTATION	
A. Quality of visual aids/multimedia	
B. Quality of oral presentation	
C. Student demonstrates high degree of professionalism	
Comments TOTAL SCORE	
TOTAL POSSIBLE SCORE	

GENERAL SCORING

4 = Exemplary. Student exceeds expectations and excels in the category and all of its elements.
3 = Accomplished. Student clearly includes all of the necessary elements and meets all of the expectations
2 = Developing. Student meet some of the expectations, but some elements are missing or incomplete.
1 = Beginning. Student have made an attempt to include elements in this category, but most elements are missing or incomplete.
0 = Missing. The student made no attempt to include the elements required in this section.
N/A = Not applicable. The category and its elements are not applicable to this presentation. For example, if you are evaluating a poster and the student is not available to present the research and answer questions, the "VI.B. Quality of oral presentation" should be scored as N/A.

I. OBJECTIVES AND HYPOTHESES

A. Research objectives are clearly stated in terms of a general research question that is relevant to an existing body of research. The students provide a context for the hypothesis and their research.
B. Hypothesis is specific and testable. Students clearly identify the independent and dependent variables and present the hypothesized relationship between those variables AND the presented hypothesis can be evaluated using the scientific method.
C. Student explains relevance to environmental science

II. METHODS

A. The study design is described with sufficient detail to be replicated by another scientist. Time and location of research are mentioned. If sampling was used, the population and the sampling technique (*e.g.,* stratified random) are identified. Presentation of methods is clear, and avoids extraneous details (*e.g.,* how a random number table was generated, the company from which materials were purchased).
B. All primary variables (*i.e.*, manipulated variables, response variables, other variables central to the study) are clearly identified and defined. All important potential confounding factors are identified and discussed. Solid understanding of the focal system is demonstrated. Students describe measurement techniques for all variables, including specific equipment used. Calibration methods (*e.g.,* the use of standards) are included where appropriate. Techniques are appropriate for advanced high school students.

C. Methods are rigorous and the experimental design clearly addresses the research goals. Controls for potentially confounding variables are included where appropriate. Sample size and replicates are appropriate for the research goals. Methods address the research goals in a reasonably simple and direct manner. Alternative methods are explored where applicable.

III. RESULTS

A. Analysis includes correct processing of data; adequate statistical analysis (descriptive statistics with a measure of variability and test statistics are reported); AND student exhibits an adequate understanding of the analysis.
B. Appropriate use AND explanation AND readability of figures/tables/graphs

IV. DISCUSSION AND CONCLUSIONS

A. Conclusions are realistic, accurate, and within the scope of the project.
B. Suggests realistic improvements, identifies limitations, and identifies the scope of the study

V. REFERENCES

A. Four statements appropriately referenced within text of presentation, citations found in multiple sections of the presentation or 5 or more citations all in one section
B. References are sufficient and credible (references slide/section present). Four primary references provided with sufficient detail that audience could locate each article or 5 or more references without sufficient detail to locate

*If statements needing citations are not cited, -1 point.

VI. PRESENTATION

A. Visual aids are readable at appropriate distances, arranged in a logical order, and contain an appropriate amount of information
B. Oral Presentation: Language is almost always appropriate, grammar is correct, appropriate tone of voice and speed, some vocal fillers may be used, eye contact is present during most of the presentation, some movement and idiosyncrasies may be present but are not distracting
C. Professionalism: Dress is not casual, shows courtesy to questioners, acknowledges at least his/her teacher, answers questions, makes attempt to answer when student obviously does not know answer

Appendix H: Student Post-Assessment

Rank the following statements from 1 to 5, with 5 = *strongly agree*, 4 = *agree*, 3 = *neither agree nor disagree*, 2 = *disagree*, 1 = *strongly disagree*

The research project: **Score**

- Project objectives were clearly stated _____
- Assignments asked me to integrate information from various sources _____
- Project requirements challenged me intellectually _____
- I worked hard to meet the requirements of the this project _____
- I learned a great deal from this project _____

The instructors:

- Explained important ideas clearly _____
- Provided clear grading standards _____
- Gave timely feedback on my academic performance _____
- Was accessible to help with the project _____
- Challenged me to think in new ways _____
- Held the class to high standards _____
- Provided guidance in meeting those standards _____

What did you like about the project?

What could be improved about the project?

How would you make your suggested improvement?

In order to better serve the students and teachers in the NSF GK12 program, we are continually looking to improve our educational material. We would appreciate receiving comments or suggestions on the *Research Guide for Students and Teachers.*

Please send any feedback to:

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