Course Change Request

New Course Proposal

Date Submitted: 12/19/19 10:52 am

Viewing: EVPP 556 : Aquatic Invertebrate Ecology

Last edit: 12/19/19 10:52 am

Changes proposed by: slister1

Are you completing this form on someone else's behalf?

No

Effective Term: Fall 2020

Subject Code: EVPP - Environmental Science & Policy

Course Number: 556

Bundled Courses:

Is this course replacing another course? No

Equivalent Courses:

Catalog Title: Aquatic Invertebrate Ecology

Banner Title: Aquatic Invertebrate Ecology

Will section titles vary by semester? No

Credits: 4

Schedule Type: Lecture w/Lab

Hours of Lecture or Seminar per week: 2 h 40 min

Hours of Lab or Studio per week: 2 h 40 min

Repeatable: May only be taken once for credit (NR)
GRADUATE ONLY

Default Grade Mode: Graduate Regular

Recommended Prerequisite(s):

Recommended Corequisite(s):

In Workflow

1. **ESP Chair**
2. **SC Curriculum Committee**
3. SC Associate Dean
4. Assoc Provost-Graduate
5. Registrar-Courses
6. Banner

Approval Path

1. 12/20/19 10:52 am
   A. Alonso Aguirre (aaguirr3):
   Approved for ESP Chair

Required Prerequisite(s) / Corequisite(s) (Updates only):

Registrar's Office Use Only - Required Prerequisite(s)/Corequisite(s):

And/Or	(	Course/Test Code	Min Grade/Score	Academic Level	)	Concurrency?

Registration Restrictions (Updates only):

Registrar's Office Use Only - Registration Restrictions:

Field(s) of Study:

Class(es):

Level(s):

Degree(s):

School(s):

Catalog Description:

Through lecture, field collections, and laboratory study, students will understand phylogeny, physiology, life histories, behaviors, trophic importance, adaptations, conservation significance and response to global environmental change of aquatic invertebrates. Students will identify invertebrates using appropriate literature and methods and use proper curation to preserve them. Students will become familiar with methods for measuring aquatic invertebrate density, biomass, and diversity.

Justification:

It compliments our Aquatic Ecology Masters concentration and increases our offerings for combined lecture and laboratory classes.

Does this course cover material which crosses into another department? No

Learning Outcomes:

By the end of this course, students should

- be able to identify aquatic invertebrates to genus using appropriate literature, characters, and methods.
- use proper curation methods for preserving aquatic invertebrates.
- understand the phylogeny, life histories, behaviors, trophic importance, adaptations to life in water, conservation significance, and global environmental change of aquatic invertebrates in different ecosystems.
- be able to explain the ecological relationships between aquatic invertebrates and their environment.
- be familiar with methods for measuring aquatic invertebrate density, biomass, and diversity.

Attach Syllabus

EVPP 556 Syllabus.pdf

Additional Attachments

Staffing:

Dr. Amy Fowler

Relationship to Existing Programs:

Is another combined lecture and laboratory course for Aquatic Ecology Masters concentration.

Relationship to Existing Courses:

None, this is a new course.

Additional Comments:

Reviewer Comments

Key: 16714

AQUATIC INVERTEBRATE ECOLOGY
EVPP 556/ BIOL XXX Fall 20XX
Lecture/Lab Wednesday and Thursday 4:30 – 7:10pm Exploratory L502

Instructor
Dr. Amy Fowler
Department of Environmental Science and Policy
Office: David King 3037
Office hours: Wednesday and Thursday 2:00 - 4:00pm and by appointment
Email: afowler6@gmu.edu

Goals of this Course
By the end of this course, students should

- be able to identify aquatic invertebrates to genus using appropriate literature, characters, and methods.
- use proper curation methods for preserving aquatic invertebrates.
- understand the phylogeny, life histories, behaviors, trophic importance, adaptations to life in water, conservation significance, and global environmental change of aquatic invertebrates in different ecosystems.
- be able to explain the ecological relationships between aquatic invertebrates and their environment.
- be familiar with methods for measuring aquatic invertebrate density, biomass, and diversity.

Reading
There is no required textbook for this course. However, students are free to choose one or all of the following excellent reference books to support their study of aquatic invertebrates:

Pechenik J. 2014. Biology of the invertebrates, 7th edition. McGraw-Hill Press, New York, NY.

Voshell Jr., JR. 2002. A guide to common freshwater invertebrates of North America. The McDonald & Woodward Publishing Company, Blacksburg, VA.

Thorp JH & AP Covich. 2010. Ecology and classification of North American freshwater invertebrates. Academic Press, Elsevier, Burlington, MA.

Merritt RW & KW Cummins. 2008. An introduction to the aquatic insects of North America, 4th edition. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Pollock LW. 1998. A practical guide to the marine animals of northeastern North America. Rutgers University Press, New Brunswick, NJ.

Carlton JT. 2007. The Light and Smith manual: Intertidal invertebrates from central California to Oregon. University of California Press, Oakland, CA.

Gosner KL. 1999. A field guide to the Atlantic seashore: From the Bay of Fundy to Cape Hatteras. Peterson Field Guides. Houghton Mifflin Harcourt, New York, NY.

Grading and Assignments
This course is designed with a flexible schedule in mind; class meetings will encompass both lecture and lab on the same day. This course will have both a lecture (45%) and laboratory grade (55%): three exams (15% each), a final laboratory identification quiz (15%), vouchered invertebrate collections and associated laboratory notebook (20%), and draft (5%) and final laboratory synthesis report (15%). Final grades for graduates will be assigned for graduates using the university-wide system for grading graduate courses:

A	(94 - 100 %)	B-	(80 - 82.99 %)
A-	(90 - 93.99 %)	C	(70 - 72.99 %)
B+	(87 - 89.99 %)	F	(< 70 %)
B	(83 - 86.99 %)		

Final grades will be assigned for undergraduates based on a standard plus/minus scale:

A (94 - 100 %)	C+ (77 - 79.99 %)
A- (90 - 93.99 %)	C (73 - 76.99 %)
B+ (87 - 89.99 %)	C- (70 - 72.99 %)
B (83 - 86.99 %)	D (60 - 69.99 %)
B- (80 - 82.99 %)	F (< 60 %)

Midterm, Quizzes and Final Examination: The questions on tests will cover material presented in lectures, laboratory, and field trips. The laboratory quiz (15%) is intended to both encourage and reward students who make a concentrated effort to learn how to identify aquatic invertebrates (there are no make-ups for late arrivals or unexcused absences). The three exams (45%) will be on the material presented during the course, covering all material presented including lectures, laboratory exercises, and field methods. Exams will include true/false, essay questions, short answer, fill-ins, interpretation of data, and labeling of diagrams, figures, and photos. **Graduate students** will receive extended versions of the quizzes and exams.

Laboratory Identifications, Voucher Collection, Laboratory Notebook, and Final Lab report: The purpose of the laboratory is to introduce students to the diversity of aquatic invertebrates through field sampling and laboratory identification using dichotomous keys and preservation. Collection and preservation techniques will emphasize the proper methods employed by natural history museums and will be accomplished during laboratory sessions and on students' own time. One week near the end of the course will be devoted to learning community metrics and appropriate analyses that will be used to compare between ecosystems. Laboratory sessions will culminate in individual laboratory reports due at the end of the semester (including introduction, methods, results, conclusions, cited references) comparing the communities of aquatic invertebrates found in each ecosystem. In addition, each student will prepare vouchered invertebrate collections and associated laboratory notebooks throughout the course of the semester and will turn in these at the end of the semester. Students can retrieve these before January 15, 2019, if they choose to keep them. If not, they will be added to our growing collection. See additional laboratory syllabus for more detailed instructions. **Graduate students** are required to prepare a longer individual laboratory report and larger number of vouchered invertebrates for their collection.

Extra Credit: Students can bring in a short article from a newspaper or magazine (online or print), or a clip from a radio station or television news program (or educational program) from the past 6 months on the topic of aquatic invertebrate ecology (from any perspective) to share with the class. Students must send their chosen articles or multi-media to Dr. Fowler **48 hours in advance of the class**, and she will send it to the rest of the class if it is appropriate. Be prepared to give a short 2-5 minute explanation of why you chose the piece, how it links to this course, and how it advances the field of aquatic invertebrate ecology. Each student will be able to present one article or clip per week (a possibility of 15 weeks). Each presentation will count for one extra point on the final exam for a maximum of 15 extra points. (This idea courtesy of AC Willox, University of Guelph).

Practical Matters

It is not possible to master this material without regular class attendance, especially since there is no textbook; I will use some different examples and incorporate material from other sources. The PowerPoint lectures, posted on Blackboard after class, are ***not*** *a substitute for lecture attendance*. Students should focus on taking detailed notes of lectures and synthesizing the information with the ideas illustrated in the slides. Occasionally videos will be shown, and students will be responsible for knowing the organisms as well as the concepts they illustrate. Students are responsible for everything discussed in lecture, announced changes in the syllabus, and any handouts distributed in class. All of that is fair game for quizzes and exams.

Please adhere to the list below during lecture and lab:

Be prepared for class.
Do not be late to class (classes will start on time and no makeup quizzes will be given).
Cell phones are **not** to be used in any way, under *any* circumstances during lecture/lab, and should be turned OFF and stowed out of sight for the duration of every lecture/lab. Computers may be used during lab for help in identifying organisms.

Late assignments will be penalized at least 10% for each 24-hour interval that they are late. Assignments > 1 week late will not be accepted unless you have medical or other valid *documented* reasons for the delay. In certain cases,

students will be allowed to take the exam at a unique time - this will usually be held in my office **before** the scheduled class exam. The only valid reasons for missing an assignment deadline or an examination are those accepted by the University (see http://catalog.gmu.edu/content.php?catoid=5&navoid=104) and include death in the immediate family and major illness of the student.

Academic Integrity: It is expected that students adhere to the George Mason University Honor Code as it relates to integrity regarding coursework and grades. The Honor Code reads as follows: "To promote a stronger sense of mutual responsibility, respect, trust, and fairness among all members of the George Mason University community and with the desire for greater academic and personal achievement, we, the student members of the University Community have set forth this: Student members of the George Mason University community pledge not to cheat, plagiarize, steal and/or lie in matters related to academic work." More information about the Honor Code, including definitions of cheating, lying, and plagiarism, can be found at the Office of Academic Integrity website at http://oai.gmu.edu. Students should read these statements and understand their implications and how they apply to this course. Any violation of the code of academic integrity will result in a severe penalty assessed on the final grade. This penalty will range from a **minimum** of a full letter grade reduction to an F for the course. All academic integrity violations will be reported to the Chair of the Department of Environmental Science and Policy, the Dean of the College of Science, and the Director of the Academic Integrity Board.

Any assignment turned in for a grade in this course must reflect your work and your work only.

Student Disabilities: If you are a student with a disability and you need academic accommodations, please see me and contact Disability Services at 703.993.2474 or ods.gmu.edu. All academic accommodations must be arranged through that office at the beginning of the semester.

Useful Resources

The following sources may be useful resources for you throughout this course and are good places to discover more information about aquatic invertebrates.

Carnegie Museum of Natural History – Aquatic Macroinvertebrate Collection, http://www.macroinvertebrates.org/#/
West Virginia Department of Environmental Protection – Guide to Aquatic Invertebrates, http://www.dep.wv.gov/WWE/getinvolved/sos/Pages/Benthics.aspx
University of New Brunswick – Interactive Key to the Benthic Macroinvertebrate Orders and Families of North America - http://www.unb.ca/research/institutes/cri/bmi/benthic_key.html
Natural History Museum, http://www.nhm.ac.uk/our-science/departments-and-staff/life-sciences/invertebrates.html
The Field Museum, https://www.fieldmuseum.org/science/research/area/invertebrates and http://emuweb.fieldmuseum.org/iz/Query.php
Smithsonian National Museum of Natural History, http://invertebrates.si.edu/ and http://collections.nmnh.si.edu/search/iz/
New Scientist, https://www.newscientist.com/subject/earth/
Science Daily, https://www.sciencedaily.com/news/plants_animals/

Peer-reviewed Journals

George Mason's library system has reasonably good access to journals that will be useful in this course. Students should focus on using these sources and not depend on ILL (Interlibrary Loan) for their final laboratory report (it could take too long to get your articles). The list below is divided into two categories – "Most Useful" and "Additional Journals" categories to help you get started.

Most Useful

Invertebrate Biology
American Entomologist
American Zoologist
Environmental Entomology
Functional Ecology
Crustaceana
Journal of Crustacean Biology
Invertebrate Reproduction and Development

Additional Journals

Nature
Science
Biological Bulletin
Ecology
Journal of Experimental Biology
Marine and Freshwater Research
Journal of Experimental Marine Biology and Ecology
Current Biology

Invertebrate Zoology

Hydrobiologia

Wk	Date	Lecture topic	Lab topic
1	30 Aug 31 Aug	Abiotic differences in aquatic habitats	Dichotomous keys Curation of specimens Microscope introduction
2	6 Sept 7 Sept	Abiotic differences in aquatic habitats	Marine Invertebrates
3	13 Sept 14 Sept	Aquatic invertebrate diversity, body plans, evolutionary relationships	Marine Invertebrates
4	20 Sept 21 Sept	Ecological interactions at individual level – herbivory, territoriality, predation, predator avoidance, competition, mimicry	Marine Invertebrates
5	27 Sept 28 Sept	**Sept 27: First EXAM** Ecological interactions at individual level – commensalism, mutualism, parasitism	Marine Invertebrates
6	4 Oct 5 Oct	No lecture, just lab	**<u>* Field day to SERC Wed – be prepared *</u>** Brackish water Invertebrates
7	11 Oct 12 Oct	Ecological interactions at population level – spatial patterns of abundance, hybridization, mating systems	Brackish water Invertebrates
8	18 Oct 19 Oct	Ecological interactions at community level – larval and adult dispersal, inter- and intra-specific competition, keystone sp. and competitive exclusion	Brackish water Invertebrates
9	25 Oct 26 Oct	Ecological interactions at community level – niche structures and shifts, Lotka-Volterra, intermediate disturbance hypothesis	**<u>* Field day Wed – be prepared *</u>** Freshwater stream Invertebrates
10	1 Nov	**Nov 1: Second EXAM**	Freshwater stream Invertebrates

	2 Nov	Ecological interactions at community level – parasites and disease, direct and indirect effects	
11	8 Nov 9 Nov	Ecological interactions at ecosystem level – top-down vs. bottom-up	Freshwater stream Invertebrates
12	15 Nov 16 Nov	Ecological interactions at the ecosystem level	Analyses for lab reports
13	22 Nov 23 Nov	**Thanksgiving break** **Thanksgiving break**	**Thanksgiving break**
14	29 Nov 30 Nov	Anthropogenic Impacts and Invasions	Draft laboratory report due by **5pm Nov 26**. No scheduled lab - Work on voucher collections
15	6 Dec 7 Dec	Pollution ecology – Biological assessment, Indicator organisms	No scheduled lab - Work on voucher collections **Sight and key quiz Thurs, Dec 7** Vouchered collections and lab notebooks due to my office by **5pm Dec 8** and Final reports due via email **midnight Dec 8**

FINAL EXAM – WEDNESDAY, DECEMBER 13, 2017

EXPLORATORY L502

4:30 – 7:15 PM

AQUATIC INVERTEBRATE ECOLOGY
EVPP / EVPP XXX Fall 20XX
LAB SYLLABUS

Laboratory Identifications, Voucher Collection, Laboratory Notebook, and Final Lab report: The purpose of the laboratory is to introduce students to the diversity of aquatic invertebrates through field sampling and laboratory identification using dichotomous keys and preservation. Collection and preservation techniques will emphasize the proper methods employed by natural history museums and will be accomplished during laboratory sessions and on students' own time. One week near the end of the course will be devoted to learning community metrics and appropriate analyses that will be used to compare between ecosystems. Laboratory sessions will culminate in individual laboratory reports due at the end of the semester (including introduction, methods, results, conclusions, cited references) comparing the communities of aquatic invertebrates found in each ecosystem. In addition, each student will prepare vouchered invertebrate collections and associated laboratory notebooks throughout the course of the semester and will turn in these at the end of the semester. Students can retrieve these before January 15, 2019, if they choose to keep them. If not, they will be added to our growing collection. See additional laboratory syllabus for more detailed instructions.

Due Dates

Draft Laboratory report: 5pm Nov 26
Voucher collections and lab notebooks: 5pm Dec 8
Final Laboratory report: 12am Dec 8

Expectations

You are expected to attend labs and stay the entire laboratory period.

You should take detailed notes on the specimens that you identify during the lab period, as you will teach your peers how to identify specimens for the sight quiz at the end of the semester.

You cannot bring food or drink into the lab.

Please wear closed-toed shoes and appropriate clothing to lab.

There are two field trips (see class syllabus) to collect specimens. These trips may leave campus before class and return after class. You are required to provide your own appropriate clothing and rain gear, daypack, water bottle, and snacks, and are welcome to bring waders to the freshwater stream day.

Guidelines for Aquatic Invertebrate Voucher Collection and Notebooks

LABORATORY PROCEDURES: Students will work together to sift through the replicates of algae (marine), oysters (estuarine), and sediment/detritus (freshwater) to collect invertebrates. Students will sort organisms into major groups and preserve. The following lab periods, students will use keys provided to identify each individual down to the lowest taxonomic group. Particular protocols related to specimen retrieval from vials will be explored.

NOTEBOOK: Students will use the collected specimens to learn identification using keys and noting primary characteristics. Each student will be expected to record these observations in their notebook, which may be used during the final sight quiz for key identifications. In addition to the actual organisms, students will keep a lab notebook where they will record data for each specimen. In EVERY lab in which organisms are observed, sketch organisms and show indication of scale as well as record the descriptions that you used in the key.

Leave one page in the front of your notebook to be used as your specimens recorded page. At the top of the page, you should have the following columns:

Specimen ID	Ecosystem	Date Collected / Identified	Sample Info	Initials of Identifier	Species / Taxa	Count	Preservative	Notes
AF01	MARINE	Sept 3 / Sept 14 2017	Algae AF	AEF	Crepidula fornicata	2	75% Ethanol	Gastropoda

The specimen ID will be unique to each student. Use your first and last initials (AF for me) and start at 01. The next specimen that is identified from your collection would be AF02, then AF03, etc. For another student their unique code could be GH01 or ZA01, etc.

The Ecosystem will be 1 of 3: Marine, Estuarine, or Freshwater.

Date Collected was when the sample was collected from the field. Date Identified is when you or a peer identified it in the lab.

Sample Information tells you more about the actual sample from which the specimen came. For instance, we will have multiple replicates, so in this case, this specimen is from the algae that I examined, replicate AF.

Because you will not always identify all of the organisms that you found in the sample (you peer may identify it for you), the intitals of the actual person that identified it are important.

Of course, you'll need the name of the specimen, down to the lowest identifiable unit – sometimes species, sometimes family.

The count of how many you have in your particular sample.

Preservative indicates whether the specimen is in either 75% ethanol or 4% formalin.

And any notes about the specimen – what are the larger taxonomic groups that it belongs to, or anything that will help you remember it.

From Robin Wilson. 2005. Marine invertebrate sample processing procedures. Museum Victoria, Australia, 25pp.

Taxon	**Fixation**	**Preservation**	**Comments**
Annelida (Leeches, Oligochaete, Polychaetes)	4% formalin	70% ethanol	Leeches and some polychaete families are easier to identify if anaesthetised, but this is generally impractical in large benthic studies.
Crustacea	4% formalin	70% ethanol	
Bryozoa (= Ectoprocta)	70% ethanol	70% ethanol	
Cnidaria	4% formalin	70% ethanol	
Echinodermata	70% ethanol	70% ethanol	Formalin will render many echinoderms unidentifiable, especially holothurians.
Mollusca	4% formalin	70% ethanol	
Platyhelminthes	4% formalin	70% ethanol	Fix living specimens on frozen 4% formalin or narcotise (freezing or propylene phenoxytol or MgCl2). Otherwise probably unidentifiable.
Porifera	70% ethanol	70% ethanol	Formalin will render most sponges unidentifiable
Pycnogonida	70% ethanol	70% ethanol	
Sipuncula	4% formalin	70% ethanol	

VOUCHERS: Vouchers collections are one or preferably a few representatives of each species set aside to form reference specimens against which new material is compared. Building, documenting and maintaining a voucher collection is an important and valuable process. Voucher specimens deposited for grading should be sorted into separate containers according to the specimen ID in the accompanying laboratory notebook. Each vial should contain only one taxa, however it is helpful to have multiple individuals of the same taxa in the jar.

Students will turn in vouchered aquatic invertebrate collections and associated field collection and laboratory notebooks from each of the three ecosystems sampled as noted on the class syllabus.

The collection ID that you created above will be written with pencil on a waterproof piece of paper and placed inside the vial, along with the preservative and specimen. This is the only link between the specimen in the jar and the information about the specimen. Do not use ballpoint or other kinds of ink, which can run and disappear with time.

Graduate Level Rubric for Vouchered Collection for Each Ecosystem*

Category	5	4	3	2	Marine	Estuarine	Freshwater
Required elements of voucher collection	Collection includes a minimum of 8 specimens.	Collection includes 6-7 specimens.	Collection includes 4-5 specimens.	Collection includes 2-3 specimens.			
Content/accuracy	All 8 specimens are correctly identified and have labels with correct information.	6-7 specimens are correctly identified and have labels with correct information.	4-5 specimens are correctly identified OR some specimens have incomplete labels.	2-3 specimens are correctly identified OR most have incomplete labels.			
Required elements of lab/field notebook	All 8 specimens have field and laboratory notes.	6-7 specimens have field and laboratory notes.	4-5 specimens have field and laboratory notes.	2-3 specimens have field and laboratory notes.			

Total for each ecosystem= 15 points

*May change due to numbers of observed taxa. If change occurs, students will receive an update rubric.

Undergraduate Level Rubric for Vouchered Collection for Each Ecosystem*

Category	5	4	3	2	Marine	Estuarine	Freshwater
Required elements of voucher collection	Collection includes a minimum of 5 specimens.	Collection includes 4 specimens.	Collection includes 3-2 specimens.	Collection includes 1 Specimen.			
Content/accuracy	All 5 specimens are correctly identified and have labels with correct information.	4 specimens are correctly identified and have labels with correct information.	3-2 specimens are correctly identified OR some specimens have incomplete labels.	1 specimen is correctly identified OR most have incomplete labels.			
Required elements of lab/field notebook	All 5 specimens have field and laboratory notes.	4 specimens have field and laboratory notes.	3-2 specimens have field and laboratory notes.	1 specimen has field and laboratory notes.			

Total for each ecosystem= 15 points

*May change due to numbers of observed taxa. If change occurs, students will receive an update rubric.

Guidelines for Final Laboratory Report

The culmination of all the work in the field and lab is a research paper. The purpose of this paper is to integrate field and laboratory data in a comparison of two aquatic ecosystems.

Examples of topics for hypothesis (not limited to these) and questions for exploration:

Do different taxonomic groups show differing patterns of species richness between the two ecosystems? Why or Why not?

Species found in the two different environments have specialized physiological, behavioral, or morphological characteristics that allow them to live there. What was the single most abundant species in each community? Why do you think it was the most abundant species?

Richness, evenness, and diversity measures will be the same (or different) between the two ecosystems based on latitude/salinity gradient. How do the indices differ across communities? Would your conclusions about these communities be different depending on which diversity index you used?

Why might indices vary from several plots sampled from the same community? What are some sources of error in determining the index for each sample or community?

Do you think we can adequately compare these two ecosystems based on the sampling program we did? Why or why not? How could you make the data better?

Draft due via email to Dr. Fowler (afowler6@gmu.edu) as **Lab_draft_LASTNAME**. Refer to syllabus regarding late penalties and any evidence of plagiarism. You will be graded on completeness in your display and analysis of the data, accurate and coherent discussion of the results, and a dedicated attempt to relate the results to current

theory and class topics. This draft will be graded in the same way as the final.

Final due via email to Dr. Fowler (afowler6@gmu.edu) as **Lab_final_LASTNAME**. Refer to syllabus regarding late penalties and any evidence of plagiarism. You will be graded on completeness in your display and analysis of the data, accurate and coherent discussion of the results, and a dedicated attempt to relate the results to current theory and class topics.

Must contain: Title, Name, Abstract, Introduction, Methods, Results, Discussion, Literature cited

Length: Graduate students: 4,000 words maximum not including title, name and date, abstract, and references
Undergraduate students: 2,000 words maximum not including title, name and date, abstract, and references

Title: 10 words maximum

Name and Date

Abstract: 250 words maximum. Needs 1-2 sentences from the introduction, methods, results, and implications of results.

Introduction: Should include the purpose/objective, the scientific literature relevant to the subject, and the questions tested and hypotheses. At least **5 (Undergraduate)** or **10 (Graduate)** cited works (from relevant literature, NOT textbooks or laboratory keys). Answer the following questions:

Why was this study performed?
What do you expect to gain from the project – broader picture?
What is the specific purpose of the study?
What was the question(s) tested? What was the hypothesis for each?
Is the hypothesis reasonable? What evidence is there to justify that?
What knowledge already exists about this subject?

Not a hypothesis: "It was hypothesized that there is a significant relationship between salinity and aquatic invertebrate community diversity."

Hypothesis: "It was hypothesized that as the water salinity increases, the diversity of the associated aquatic invertebrate community also increases."

Methods: Include subsections for the ecosystems and all statistical analyses used. Make sure to include enough detail for the reader to understand how you tested your hypothesis and clarify the rationale for the procedure in case they want to reproduce the results. Describe what you did in the order in which you did it – all verbs in the past tense. Remember, no results here – you can write that you recorded the results or how you recorded the results. Answer the following questions:

What materials were used? Always quantify anything you can, such as time elapsed, temperature, mass, volume, etc.
How were they used?
Why were they used like that? Explain the rationale to potential critics
Where and when was the work done? Include dates and GPS coordinates, if applicable.
What kinds of analyses did you use?
Include any calculations used to obtain results.

Results: Examine all the data you collected and decide what related significantly to your hypothesis. How will you turn that into a story? Divide up into 2 sections, paralleling those from the methods section. All sentences should be in the past tense. Only summarize data through general trends and differences, but do not discuss implications. Include at least 2 graphical representations of your data (either graph or table form), including figure

legends. Avoid 3-D and pie charts. Tables are best if you have large amounts of exact data, whereas figures are best for dramatic illustration of important trends within the experiment. If you feel that your readers won't get the full impact of the results you obtained just by looking at the numbers, then a figure might be appropriate. Data in a table should not be duplicated in a graph or in the text. If you can cover the data in one sentence of text, it should not be put into a table or graph. All graphs should have x- and y-axes titled. All tables should have columns and rows labeled, as well as the units of measurement. Figure legends should explain any symbols or abbreviations and should give the reader enough information to understand the data without reading the accompanying text. Figures and tables should be numbered separately and should be referred to in the text by number (i.e., The activity decreased after five minutes (Fig. 1)).

Discussion: This section should not just be a restatement of the results but should emphasize interpretation of the data, relating the data to existing theory and knowledge. Was your hypothesis proved or disproved, correct or incorrect? In writing this section, you should start with explaining whether that data supported your hypothesis and the logic that allows you to accept or reject your original hypotheses, acknowledge any anomalous data or deviations from what you expected, relate findings to earlier work in the same area, and explore the theoretical and/or practical implications of the findings. You should also be able to suggest future experiments that might clarify areas of doubt in your results. Suggestions for the improvement of techniques or experimental design may also be included here. Make sure you do not overreach conclusions based on your limited data set. At least **5** cited works in addition to those used in the Introduction (from relevant literature, NOT textbooks or laboratory keys).

Literature Cited: At least least **5 (Undergraduate)** or **10 (Graduate)** cited works (from relevant literature, NOT textbooks or laboratory keys). The listing should be alphabetized by the last names of the authors. Use the reference style of the "Scientific Style and Format" (http://www.scientificstyleandformat.org/Tools/SSF-Citation-Quick-Guide.html). When citing references in the text, do not use footnotes; instead, refer to articles by the author's name and the date the paper was published. For example: Fox (1988) investigated the hormones on the nest-building behavior of catbirds. Hormones are known to influence the nest-building behavior of catbirds (Fox, 1988). In the text, when citing papers that have two authors, both names must be listed. When three or more authors are involved, the Latin *et al. (et alia)* meaning "and others" may be used. A paper by Smith, Lynch, Merrill, and Beam published in 1989 would be cited in the text as: Smith et al. (1989) have shown that...

General Comments on Style

1. All scientific names (genus and species) must be italicized.
2. Use the metric system of measurements. Abbreviations of units are used without a following period.
3. Be aware that the word *data* is plural while *datum* is singular. This affects the choice of a correct verb. The word *species* is used both as a singular and as a plural.
4. Numbers should be written as numerals when they are greater than ten or when they are associated with measurements; for example, 6 mm or 2 g but *two* explanations of *six* factors. When one list includes numbers over and under ten, all numbers in the list may be expressed as numerals; for example, 17 sunfish, 13 bass, and 2 trout. Never start a sentence with numerals. Spell all numbers beginning sentences.
5. Be sure to divide paragraphs correctly and to use starting and ending sentences that indicate the purpose of the paragraph. A report or a section of a report should not be one long paragraph.
6. Every sentence must have a subject and a verb.
7. Avoid using the first person, I or we, in writing. Keep your writing impersonal, in the third person. Instead of saying, "We weighed the frogs and put them in a glass jar," write, "The frogs were weighed and put in a glass jar." Along with this, scientists are often encouraged to write in the active voice, not passive.
8. Avoid the use of slang and contractions.
9. Be consistent in the use of tense throughout a paragraph--do not switch between past and present. It is best to use past tense.

10. Be sure that pronouns refer to antecedents. For example, in the statement, "Sometimes cecropia caterpillars are in cherry trees but they are hard to find," does "they" refer to caterpillars or trees?

After writing a report, read it over, watching especially for lack of precision and for ambiguity. Each sentence should present a clear message. The following examples illustrate lack of precision:

1. "The sample was incubated in mixture A minus B plus C." Does the mixture lack both B and C or lack B and contain C?
2. The title "Protection against Carcinogenesis by Antioxidants" leaves the reader wondering whether antioxidants protect from or cause cancer.

The only way to prevent such errors is to read and think about what you write. Learn to reread and edit your work.

Written research paper rubric (adapted from Biological Inquiry and Analysis, 2011). 100 points total

	Example of an excellent report
Title 5pts	Title is detailed, specific, concise, and conveys the objective of experiment.
Introduction 10 pts	Clearly, concisely and logically presents all key components; relevant and correctly cited background information that supports the purpose of the project and main ideas. No extraneous information included that detracts from the main ideas.
Question and hypothesis 10 pts	Question is informative, creative and interesting, and well thought out. Question addresses an important biological concept or problem. Hypothesis clearly tests the question and is testable.
Methods 20 pts	Methods described how the hypothesis was tested. Concisely, clearly and chronologically describes procedures used so that knowledgeable reader could replicate experiment. Methods used are appropriate for study.
Results 20 pts	Results clearly and effectively displayed/ presented relevant data. Contains a concise, well-organized narrative text and tables/ figures that show results, without any discussion. Tables and figures have appropriate legends/ captions and can be understood on their own without reading the narrative text. If there were problems collecting valid data, then author states what the problem was that makes the data invalid.
Discussion 20 pts	Concisely, clearly and logically presents all components: supports or rejects hypothesis*, formulates argument for conclusions referring back to biological rationale, evaluates experimental design, evaluates reliability of data, states implications of results, suggests next investigation steps, and ends paper with final conclusion. *If you believe an error occurred, describe what you believe happened and discuss how this impacted your ability to make conclusions regarding your hypothesis
Literature Cited 5 pts	References are used to support background information or examples relevant to findings. References are cited in the text and listed alphabetically in the bibliography.
Grammar, organization and wording 10 pts	Excellent organization and flow of paper content, appropriate word choice, few grammatical and spelling errors and good sentence structure. Name and date included, file correctly named.