Tips for Instructors seeking to increase quantitative content in Biology course material

This is a short guide intended to help any Biology instructor thinking about increasing the quantitative content of their course. This is part of an effort to increase quantitative literacy across the Biology curriculum.

I have so much content to cover already! How can I add something new?

You may not need to take things out of your existing course to make room for new content and assignments. You may be able to adapt existing assignments and activities slightly to teach quantitative skills. Do you have a lab activity or assignment where the students generate their own data? Are there topics that are inherently "numbers heavy" where you could add a small exercise to illustrate the concept? Are there things you have them do by hand (draw a graph, for example) that you could have students do differently, perhaps with new challenges?

Our goal is that, instead of having a "quant methods in Biology" course, we integrate quantitative skills in various courses, and coordinate across courses so that skills are "laddered". In first and second year, we focus on teaching students how to handle data, make graphs, and develop an understanding of which graph to make when. Statistical analysis becomes more prevalent in third and fourth year, but we leave it up to the course instructors to have detailed discussion of the assumptions and purposes of various statistical tests. Details on what skills and concepts we are covering in which courses is summarized in the Appendix to this guide.

Once you have identified existing topics, concepts and activities that could be adapted, then we can provide resources to help you develop and implement them (see below).

What resources are there to help me create new content?

You are not alone! Amy Hurford and Yolanda Wiersma have worked collaboratively with course instructors to develop content. We have been able to hire TA support each semester. These TAs have the skills to "translate" your existing content to conform to the software and format of the other courses that already have quantitative content. This will make the style and format of exercises consistent across courses, which will make it easier for our students to learn and retain the information.

The "Quant TAs" will also be available to offer help during your course (they can be added to your Brightspace shell in the week(s) you are doing the quant work, and can hold office hours for your course in those weeks. Once we are in the new building, we envision having a quantitative resources "help centre" staffed by graduate students, which will be a resource for both you, and your students).

What software do I need?

We are training our students to use R, with the RStudio platform. R/RStudio are Open Source, which means they are free, which we see as a tremendous advantage for students. R/RStudio can run on PC or

Mac computers, and there is even a cloud-based version for students using Chromebooks. R is recognized as a valued skill in the work force and is in widespread use in many areas of Biology.

We have developed a general guide to using R, which we introduce students to in BIOL 1001. This guide is written as a reference document that students will likely use and refer to throughout their Biology program. If you have not used R before, spending some time working through this guide will quickly help you learn the basics of the software. You can access the Biology Rguide here.

We are hosting all of the course guides (current and future) on a GitHub repository. This allows them to be Open Access, and makes it easy to update and alter individual guides from year-to-year. You do not have to learn how to use GitHub (although we are happy to show you if you are interested!), if you would like to visit the other guides on GitHub, the links are at the end of this document and in section 1.1 of the Biology RGuide.

Why should I do this?

Biology is becoming quantitative. Teaching our students fundamental skills will increase their success when they graduate, whether in the workforce or in graduate school. Feedback from our students who have already completed some of the course work below has been positive. For example:

> "Learning concepts like data wrangling and being able to extract desirable information from large datasets is extremely applicable to the field of conservation. Interestingly, as I approach graduation I have been actively applying for jobs in my area, and I have noticed a significant amount of job ads valuing skills in GIS and quantitative analysis with an emphasis on the candidate being knowledgeable in RStudio. Therefore, having spent the past couple of months expanding my knowledge of this software and its uses I have been more confident to highlight this as one of my skills to future employers."(student in BIOL 4651)

> "Getting to work more with R Studio also reinforced how much I enjoy the particular challenge that coding-type work brings and being introduced to more resources to learn more about R was fantastic. This combined with remote learning has gotten me thinking about what kind of conservation or ecology related career I might like and/or realistically be able to get. Technical skills are useful and in demand." (student in BIOL 4651)

How should I weave this new material into my class?

Our experience to date suggests several tips for effectively integrating quantitative skills into your course:

- Introduce the concept in a lecture or lab introduction without requiring the students to do math or programming. Illustrate the quantitative concepts with examples relevant to course topics.
- Include readings (textbook, research papers) with quantitative content
- Include a Discussion Thread in the Brightspace shell for the course and encourage students to do peer-to-peer help (see this chapter of the RGuide for tips to share with students).
- Developing a marking rubric and plan in collaborating with the Quant TA

APPENDIX: Biology Courses and Quantitative Learning Outcomes

Course	Concepts taught	Skills Taught
BIOL 1001 Principles of Biology	• Why quantitative skills are important. • What different forms of graphs communicate and how to decide which format of graph to use. • The importance of asking for help	• Basic R use • Data entry • Making a scatter plot • Making a bar plot • Making a box plot • How to ask for help
BIOL 1002 Principles of Biology	• The importance of clean tabular data • How data frames are organized in R • How data frames can be linked	• Use of the dplyr package, including use of pipes • Selecting subsets of data • Creating new data columns based on existing columns • Filtering data • Removing "NA" entries • Cleaning data and making a simple plot • Grouping and joining data
BIOL 2010 Botany	Material development in progress	
BIOL 2600 Principles of Ecology	• Exponential vs. logistic growth • Trophic cascades	• Use of the deSolve package • Coding and graphing different forms of population growth • Using "for" loops • Using comments effectively • Plotting multiple datasets on a single plot
BIOL 3295 Population and Evolutionary Ecology	• Data frame management • Population growth • Discrete vs. continuous data • Density dependence/logistic growth, solving the equations in R • Ordinary differential equations	• Converting dates to numeric data • Working with different formats for date data • Using the seq function • Using "for" loops • Creating a data frame to document population growth • Use of the deSolve, data.table and popbio packages • Writing custom functions
BIOL 4651 Conservation GIS Module	• What is a Geographic Information System • Vector vs. Raster data • The importance of metadata	• Use of the sf, stars and ggplot2 packages • Reading in and plotting raster and vector data

	• Dealing with projections • Raster algebra	• Reading the CRS file • Editing the CRS file to change projection • Changing colour schemes in a map • Simple raster algebra • Extracting data from a raster using points and using a polygon • Creating a points shapefile from tabular data
BIOL 4651 Quantitative Methods Module	• Data wrangling • Effective visualization of data • Introduction to univariate statistical analysis • Introduction to multivariate analysis	• Use of the dplyr, vegan and ggplot2 packages • Review of querying, filtering, grouping and joining data • Making plots in ggplot2 • Constructing a glm • Constructing a multivariate ordination