Data-driven Decision Making: Antarctic Fisheries

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### Authors

Jessie Golding1, Desiree Andersen1, Ellen Bledsoe1

1 School of Natural Resources and the Environment

University of Arizona, Tucson, AZ

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# Module Overview

## Background

This module was originally designed as the fourth and final section in a lower division undergraduate course (Wildlife and Fisheries Conservation Science 223 - Dealing with Data in the Wild). The course is meant to fulfill a general education requirement at the University of Arizona and therefore includes material designed to meet general education requirements pertaining to writing and quantitative skills. It also fulfills requirements for majors in Renewable and Natural Resources and Climate Change and Society. The course prerequisite was high school algebra.

The content of the full course (as originally designed) can be found [here](https://biodiversitydatasciencecorp.github.io/DataInTheWild_Website/).

## Topics Covered and Keywords

The lessons in this module cover–in some capacity–the following topics:

### Ecology:

1. Ecosystem services
2. Sustainability
3. Population growth models
   1. Exponential vs. logistic growth
   2. Carrying capacity
4. Maximum Sustainable Yield (MSY)
5. Traditional Ecological Knowledge (TEK) and multiple ways of knowing
6. GIS

### Data Science and Computer Programming:

1. Data visualization
2. Combining datasets (`bind\_rows`)
3. Making decisions (`case\_when`)
4. Plotting spatial data
5. Generative AI example

## Student Learning Outcomes

The overall course learning outcomes, which guided the development of this module, are as follows:

1. Define, differentiate, and explain the nature and application of computational methods for acquiring, managing, analyzing, visualizing, and sharing data as it relates to real-world natural resource scenarios;
2. Associate, examine, and compare how to infer meaning and insight from data through written, visual, and verbal communication to multiple audiences;
3. Summarize, implement, and appraise multiple perspectives and make meaningful connections across disciplines and social positions, think conceptually and critically, and solve problems with data informed approaches.

The specific learning outcomes for this module are as follows:

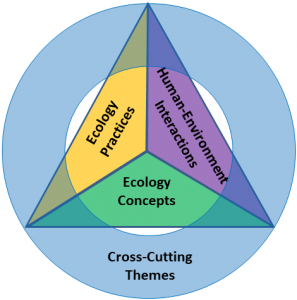
1. *Ecosystem services* and *human impact on ecological systems*
   * Students will be able to define ecosystem services, describe some of the ways humans impact ecological systems, and explain in general terms how impacts on ecosystems might affect ecosystem services.
2. *Population growth: exponential vs logistic growth, carrying capacity*
   * Students will be able to define exponential and logistic growth, as well as visually identify population growth type with graphical representations
   * Students will be able to define the concept of carrying capacity and explain how it relates to sustainability and maximum yield
   * Students will be able to describe how simulated data can be used in combination with real world data to make inference about populations
3. *Population growth: maximum sustainable yield and sustainable harvest*
   * Students will be able to define harvest and maximum yields and connect these concepts to sustainability
4. *Traditional ecological knowledge and spatial data*
   * Students will be able to define traditional ecological knowledge
   * Students will be able to identify and describe how traditional ecological knowledge can be represented with mapping technology (GIS)
   * Students will be able to run code to create maps (using GIS) that show data derived from both scientific literature and traditional ecological knowledge

## Rationale behind the Antarctic Research Station

These learning outcomes are achieved throughout the course using a hypothetical setting of an Antarctic research station. This hypothetical scenario provides students with the opportunity to think about real world data problems, while also engaging with the material in a fun and entertaining way. Thus, this module as part of the course, takes place in Antarctica. The previous three modules have covered scenarios that concern a disruption of the research station food supply and this module builds upon those previous scenarios. However, this module is also designed to work as a standalone module. The hypothetical setting for the module is therefore an Antarctic research station that must find ways to get food (fish) in ways that are sustainable and minimally damaging to the environment.

# 4-Dimensional Ecology Education

This module is designed using the [Four-Dimensional Ecological Education Framework](https://www.esa.org/4dee/) (4DEE). This framework contains 4 core dimensions for teaching ecology: (1) Core Ecological Concepts; (2) Ecology Practices; (3) Human-Environment Interactions; and (4) Cross-Cutting Themes.



Core Ecological Concepts include ecosystem services, population growth and dynamics, and carrying capacity.

Ecology Practicesinclude understanding data, data visualization, and computer programming.

Human-Environment Interactions include the importance of ecosystem services for humans, maximum sustainable yield, and traditional ecological knowledge.

Cross-cutting Themes are the connectivity of ecological systems (e.g., population dynamics impact communities) and data-driven decision making for natural resource management.

Taken together, this module includes the following interactions:

1. Core Ecological Concepts \* Ecology Practices
2. Core Ecological Concepts \* Human-Environment Interactions
3. Ecology Practices \* Human-Environment Interactions
4. Core Ecological Concepts \* Ecology Practices \* Human-Environment Interactions
5. Core Ecological Concepts \* Ecology Practices \* Human-Environment Interactions \* Cross-cutting Themes

# Implementation

There are a number of different ways these lessons can be used.

### No computer programming

If your students have not been working in the R coding language, we do not recommend using the computer programming aspects of these lessons.

The powerpoints and active learning activities for ecosystem servicesand population growth and carrying capacity can be used as stand-alone activities.

### With computer programming (R language)

These lessons are designed for students who have experience using the R programming language. As written, the lessons use the `tidyverse` (specifically, `dplyr` and `ggplot`) but can be easily modified for base R or Python.

If you will be using the computer programming sections of these lessons, there are 2 different approaches that we recommend. In both of the following options, we highly recommend using the “Visual Editor” in RStudio for the RMarkdown files.

#### Using Posit Cloud

If you are using Posit Cloud, you can upload all of the files from the folder of the lesson you are using into a Posit Cloud project, except the .Rproj file. As long as all files are uploaded directly to Posit Cloud (e.g., not put into any folders within Posit Cloud), all file paths should be relative and work without need for editing. See below for more information on file naming conventions and how each file can be used.

#### Using RStudio on Individual Computers

If you are using RStudio on individual computers, each lesson is self-contained within its folder. Download the entire folder to your computer. Open the folder and double-click on the .Rproj file to open the RStudio Project. All file paths should be relative and work without need for editing. See below for more information on file naming conventions and how each file can be used.

# Material Organization

## Files Names and Folder Structure

This module contains six lessons and two assignments.

Lessons are in-class materials which students use with the guidance of an instructor. Assignments are assessment materials completed by students. These can be completed during class with students able to ask questions and get help or outside of class.

### Lessons

Some lessons have a corresponding powerpoint while others do not. Lessons 2-5 use computer programming in R.

File Names:

* ***Lesson[#]\_project.Rproj***: the file for the RStudio Project
* ***Lesson[#]\_[Subject].Rmd***: RMarkdown lesson outline with empty code chunks for students to fill in while the instructor live-codes.
* ***Lesson[#]\_[Subject]\_Instructor.Rmd***: RMarkdown file with all the code for the lesson, used as a reference by the instructor while live-coding the lesson.
* ***Lesson[#]\_[Subject]\_Instructor.pdf***: PDF version of the instructor copy. These can be provided to students after live-coding as a reference.
* ***[topic].csv***: CSV file containing data used in the lesson
* **images folder**: folder containing images used in the lesson .Rmd files. This folder should be uploaded to Posit Cloud/RStudio as a folder with the same name so file paths remain consistent.

### Lesson Outlines

#### Lesson 1: Ecosystem Services

This lesson is lecture and discussion based; there is no coding.

* Module overview
* Have students brainstorm what ecosystem services they already know
* Present ecosystem services
* Discussion (large or small group) about the pros and cons of ascribing monetary value to ecosystem services
* Small group discussion: ecosystem service scenarios
* Full class reporting back
* Connect to Mission Antarctica–what ecosystem services are important to us?
  + If your class has not been using the “Mission Antarctica” scenario, present students with the idea that they are trying to set up a self-sustaining research station in Antarctica.

#### Lesson 2: Introduction to Population Growth

This lesson involves lecture, discussion, and coding.

Powerpoint:

* Brief overview of fisheries and fisheries management
* Connecting concepts of ecosystem services to environmental sustainability
* How do we manage fisheries? In order to understand fisheries management, we need to understand how populations change and grow!
* Foundations of population growth
* Exponential vs. logistic population growth
* Carrying capacity

Working with the data through code:

* Take a look at data from 4 different populations around our Antarctic station
* Explore exponential vs. logistic populations and intrinsic rates of growth through data visualization

#### Lesson 3: Applying Population Growth

This lesson can be taught entirely in RStudio or Posit Cloud.

* Use data visualization and comparison to simulated data to determine whether the population of Antarctic toothfish near our station shows exponential or logistic growth.

#### Lesson 4: Carrying Capacity and Sustainable Harvesting

This lesson can be taught entirely in RStudio or Posit Cloud.

* Review from previous lesson
* Calculate how many fish we would need to feed the station for a year. Is this number sustainable?
* Have students spend a few minutes working to interpret the MSY figure; discuss as a class. What makes this harvest value sustainable?
* Calculate maximum sustainable yield.

#### Lesson 5: Spatial Data

This lesson involves lecture, discussion, and coding. This lesson will likely take more than 1 class period.

* Start with the powerpoint discussing traditional ecological knowledge (TEK)
* *Optional:* discussion about multiple ways of knowing
* How might we learn from Inuit practices at our research station? Tracking whales to find good fishing spots!
* Working with spatial data in R
  + Discuss GIS, coordinate systems, and plotting spatial data
* Add sea ice and whale tracks to the plots
* *Optional*: simulating data with generative AI

#### Lesson 6: Wrap-up

This lesson is primarily a discussion.

* Review everything we’ve covered in the module
* Have students create a concept map connecting all of the ecological topics covered in the module
* Discuss what decisions we should make about fishing based on the data we’ve collected

### Assignments

While assignments are generally used as assessment tools for students to apply concepts covered in class, they can also be used in-class as practice tools.

Both assignments, as currently developed, use computer programming. These assignments were a bit challenging for students, so allowing class time for students to work on them and get help may be a good idea.

File Names:

* ***Assignment\_[Subject].Rprj***: the file for the RStudio Project
* ***Assignment\_[Subject].Rmd***: RMarkdown outline with empty code chunks for students to fill in.
* ***[topic].csv***: CSV file containing data used in the assignment
* ***Assignment\_[Subject]\_AnswerKey.pdf***: PDF document with the expected output for all assignment questions which involve coding. This document can be provided to students during the assignment for student’s to check their answers and self-iterate through the code until they are able to produce the output successfully.
* ***Assignment\_[Subject]\_AnswerKey.Rmd***: RMarkdown file with all the code used to create the answer key PDF (above). Should not be provided to the student.
* ***Assignment\_[Subject]\_Instructor.Rmd***: RMarkdown file with all the code for the assignment; you can consider this the instructor’s answer key for the code. Should not be provided to the student.
* ***Assignment\_[Subject]\_Instructor.pdf***: PDF version of the instructor’s key for the coding portion of the assignment. These should not be provided to the student until after the assignment has been completed and turned in.
* **images folder**: folder containing images used in the assignment .Rmd files. This folder should be uploaded to Posit Cloud/RStudio as a folder with the same name so file paths remain consistent.