BIOL 621: (Graduate) Ecology

Fall 2025 Syllabus

Basic information

Instructor: Dr. Gareth J Russell, russell@njit.edu, 973 596 6412

Meeting time: Fridays, 1pm to 3:50pm

Location: The Swan Room, CKB 4th floor, NJIT campus

Office hours: By appointment

Pre-requisites: None

Course description

This year's graduate Ecology course will cover a variety of fundamental ecological topics **through a mathematical and computational lens**. A mathematical model (and the computational realization of that model) is just a formalization of a theory—an *idea*—about how nature operates. Examining such models helps us clarify our thinking and test it against the real world.

Roughly speaking, each class focuses on an ecological topic and introduces one or more computational topics, with the ecological topic providing the motivation for the computational topics.

Learning objectives

1. Understand the breadth of computational techniques employed in the modern scientific enterprise (as exemplified by ecology).
2. Understand different computing paradigms (procedural, functional, object-oriented, etc.) and their relative merits.
3. Understand the power and range of computing applications (symbolic solving, numerical intregration and simulation, linear algebra, image processing, visualization, data processing, etc.).
4. Be able to translate a concept into an algorithm and then into actual code.
5. Explore in more depth some specific computational techniques that apply to your own interests.
6. Learn some of the mathematical and computational underpinnings of our understanding of the natural world.

Software and texts

We will be using the *Mathematica* software package in this course. I assume that you will bring to class a laptop capable of running it (Windows, MacOS and Linux are all ok, Chromebooks and tablets are not ok). Install it as soon as you can, and let me know asap if you have any problems.

How do I get *Mathematica*?

This has recently changed slightly; let me know if something doesn't work. If you already have Mathematica but it isn't the latest version (14.3), please get that.

1. Go to https://account.wolfram.com/
2. Select "Single Sign-On (SSO)"
3. Enter your NJIT or Rutgers e-mail address as appropriate. (Rutgers has the same license as NJIT, so it is simpler if Rutgers students get the software from Rutgers.)
4. Complete your institutional sign-in.
5. Once in the Wolfram account page, click "Products and Services" in the menu.
6. Select Wolfram Mathematica (*not* "Wolfram Mathematica Online").
7. Assuming your hard drive has around 10GB of free space or more, download "Desktop app + local documentation Version 14.3". If it is nearly full and you can't free up space, you can download "Desktop app (web documentation only)".
8. The downloaded app is not Mathematica: it just a small downloader. Run/execute it and it will then download Mathematica and prompt you to install it. This download is large (can be 8–9 GB) so make sure you are on a decent internet connection.
9. Test all is well by launching Mathematica and typing 1+1 followed by Shift-Return (aka Shift-Enter). After a short pause you should get the answer 2. Amazing!
10. (After you have installed and tested the actual software, if you weren't prompted to, I suggest you find any left-over downloads (installers, disk images, etc.) and delete them (and empty the trash) so they are not taking up unnecessary hard drive space. What these look like will likely be different on different platforms. If you are not sure, ask me about it in class.)

Why *Mathematica?*

Mathematica is a popular software package among mathematicians and physicists, less so among biologists, who tend to use R, MATLAB etc. The language it runs is called the *Wolfram Language*. We use it in this course for a number of reasons.

- It is the language/software that I, your instructor, know the best, and the course materials (see below) were developed in it over many years.

- *Mathematica* has the widest array of abilities of any software package on the market, which means we can also explore a wide range of computational topics without having to switch environments. The base software includes everything from symbolically solving differential equations to mapping geospatial data to image processing to neural networks and more.
- *Mathematica* uses a *notebook* interface that was, until recently, unique. Now pretty much every language has a notebook version, but this one is still the easiest to use.
- *The Wolfram language* is the most internally consistent of any of the high-level languages. By analogy to a regular language, it has a consistent and regular grammar and syntax. This makes these aspects easier to learn.

But importantly, the point of the course is not to learn a specific language, but to learn the principles of computation, and for that we could use any one of a number of software languages. Once you understand the principles, learning another language is not very difficult.

Why not *Mathematica?*

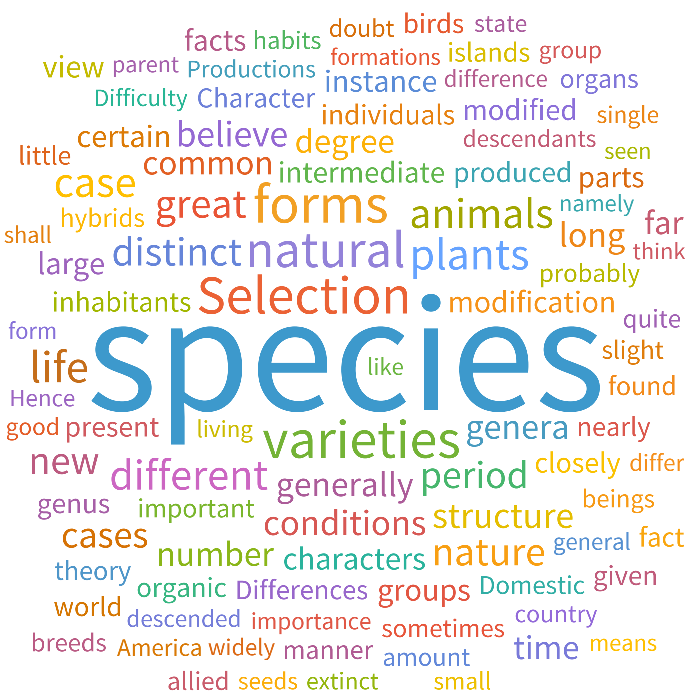
A couple of reasons

- Unlike, say, R, *Mathematica* is not free. It is a commercial software package that universities purchase. In that sense it is the same as, for example, MATLAB. (Technical note: the Wolfram *language* is open source, and anyone could in theory write software to interpret and run it. But in reality of course, only Wolfram offers such software, and that is what they charge for.)
- The Wolfram language is *so* large that it can seem overwhelming. But stick to the basics and you will be doing cool things very quickly.

Here is something you can do in one short line of code:

In[ ]:=
```
WordCloud[ExampleData[{"Text", "OriginOfSpecies"}]]
```

Out[ ]=



The course notebooks

There is no set external textbook for the course. Instead, the main material is a series of *Mathematica* notebooks that you will download from Canvas.

If you want some printed backup on the theory component of the course, I recommend you get any one of the many good primers of mathematical ecology, such as:

- *An Illustrated Guide to Theoretical Ecology* by Ted Case
- *A Primer of Ecological Theory* by Joan Roughgarden

Quite a few of the examples in the notebooks are based on the Case book.

Assessment

Component	Grade percentage
Homeworks	40
Term paper	50
Participation in class	10

What is participation? In this small, graduate level class, it means being alert in class, asking questions, trying to answer them, and generally not hiding in a corner. It doesn't matter if you are an MS student, a PhD student, or even an undergraduate taking the class by special permission — everyone can, and should contribute. As long as you make that effort, you will get 10. I will let you know quickly if your participation grade starts to drop!

Topic outline

Given that this is a small, graduate-level class, the syllabus, especially towards the second half of the semester, is flexible so that we can explore topics that align with students' interests. Below is a *typical* progression.

Date	2025–09–05
Class	1.
Chapter title	**Introduction**
Ecological topic(s)	Ecology and the units of ecology.
Computational topic(s)	Software platforms, Mathematica, notebooks, getting help. Knowledge, semantics.
In class activites	Making a nice notebook: "my biography". Using the documentation to figure out how to do something.
Term paper homework	Start looking for candidate articles.
Reading and thinking homework	TBD
To turn in	Your biography notebook and any candidate papers.

Date	2025–09–12
Class	2.
Chapter title	**Four Kinds of Population Growth**
Ecological topic(s)	Populations in time.
Computational topic(s)	Discrete fuctions and recursion. Continuous functions and symbolic calculus. Plotting data and functions.
In class activites	Using options to make and style plots.
Term paper homework	Continue looking for candidate articles.
Reading and thinking homework	TBD
To turn in	Any remaining candidate papers.

Date	2025–09–19
Class	3.
Chapter title	**The Space–Time Continuum**
Ecological topic(s)	Populations in space (part 1).
Computational topic(s)	Simulations and numerical calculus.
In class activites	Writing a function and using it.
Term paper homework	Discrete–time population growth.
Reading and thinking homework	Find an interesting image or a biological structure (landscape, organism with interesting pattern, leaf, etc.) and bring it to the next class.
To turn in	

Date	2025–09–26
Class	4.
Chapter title	**The Game of Life**
Ecological topic(s)	Populations in space (part 2).
Computational topic(s)	Data arrays, rasters and maps. Convolution and filters.
In class activites	Image processing. Making a map.
Term paper homework	Write proposal for term paper.
Reading and thinking homework	TBD
To turn in	Proposal

Date	2025–10–03
Class	5.
Chapter title	**The Third Horseman**
Ecological topic(s)	Limits to growth.
Computational topic(s)	Randomness and chaos. Bifurcation plots. Maybe fractals.
In class activites	Writing your own functions.
Term paper homework	Finalize term paper topic and begin working on it. Also,
Reading and thinking homework	TBD
To turn in	

Date	2025–10–10
Class	6.
Chapter title	**From Egg to Butterfly**
Ecological topic(s)	Life histories.
Computational topic(s)	Matrix algebra. Eigenvectors, eigenvalues and stability (part I).
In class activites	Making a Leslie matrix and performing a sensitiviy analysis.
Term paper homework	Work on term paper.
Reading and thinking homework	
To turn in	

Date	2025–10–17
Class	7.
Chapter title	**No More Fish in the Sea**
Ecological topic(s)	Consumers and harvests.
Computational topic(s)	Matrix algebra. Eigenvectors, eigenvalues and stability (part 2).
In class activites	Finding an optimal harvesting strategy.
Term paper homework	Work on term paper.
Reading and thinking homework	
To turn in	Working draft of term paper.

Date	2025–10–24
Class	8.
Chapter title	**Naure Red in Tooth and Claw**
Ecological topic(s)	Predators and prey.
Computational topic(s)	State space plots, isoclines, fixed points, vector and stream plots.
In class activites	Work on term paper.
Term paper homework	Work on term paper.
Reading and thinking homework	
To turn in	

Date	2025–10–31
Class	9.
Chapter title	**It's a Dog Eat Dog World**
Ecological topic(s)	Competition.
Computational topic(s)	Interactive interfaces.
In class activites	Term paper troubleshooting. Student–led review of concepts.
Term paper homework	Work on term paper.
Reading and thinking homework	
To turn in	

Date	2025–11–07
Class	10.
Chapter title	**TBD (new chapter)**
Ecological topic(s)	Species distributions.
Computational topic(s)	Big data.
In class activites	Work on term paper.
Term paper homework	Work on term paper.
Reading and thinking homework	
To turn in	

Date	2025–11–14
Class	11.
Chapter title	**TBD**
Ecological topic(s)	TBD
Computational topic(s)	TBD
In class activites	Work on term paper.
Term paper homework	
Reading and thinking homework	
To turn in	

Date	2025–11–21
Class	12.
Chapter title	**TBD**
Ecological topic(s)	TBD
Computational topic(s)	TBD
In class activites	Work on term paper.
Term paper homework	
Reading and thinking homework	
To turn in	

Date	2025–11–26
Class	13.
Chapter title	**TBD**
Ecological topic(s)	TBD
Computational topic(s)	TBD
In class activites	Presentations of term paper projects.
Term paper homework	Finalize projects based on feedback.
Reading and thinking homework	
To turn in	

Date	2025–12–05
Class	14.
Chapter title	**TBD**
Ecological topic(s)	TBD
Computational topic(s)	TBD
In class activites	Presentations of term paper projects.
Term paper homework	Finalize projects based on feedback.
Reading and thinking homework	
To turn in	