Networks and the Environment
Workshop Plan

1 Background

The purpose of this workshop is to explore network theory and the environment. To provide context, this workshop is framed as a game where students pretend to be applied mathematicians hired by the government to advise on climate change and the Arctic. Students will build food webs for the Arctic and use network theory to help analyze them.

There are two worksheets that accompany this workshop. The first worksheet contains a series of questions to help analyze a food web. The second worksheet provides space for computations relating to the food web. The worksheets are intended to be used together (i.e. computations from Worksheet 2 will help with questions in Worksheet 1).

We also provide a basic list of species for both terrestrial and marine ecosystems in the Arctic. We encourage students to build the food webs using the provided species lists as a base, but perhaps adding or removing species as desired. We suggest that the focus be on building and analysing a food web, rather than the accuracy of the food web itself.

We have compiled an answer guide for Worksheet 1. We do not provide an answer guide for Worksheet 2 as answers will vary depending on the configuration of the food web.

This workshop was designed to take approximately 30 – 45 minutes to complete.

2 Workshop Plan

Provide context!

Start by telling the students that we're going to play a game. Imagine we are applied mathematicians (working with biologists) and need to advise the government on how we expect climate change to affect Arctic ecosystems and what we can do to mitigate it. Briefly discuss the Arctic and why it is threatened by climate change.

Introduce food webs.

Ask students to brainstorm Questions 1-4 on Worksheet 1 (possibly do one question at a time). Then discuss.

Build the food webs.

- Introduce a simple example food web to use for demonstrations throughout (e.g. a small food web with an owl, small birds, mouse, grass, and insects).
- Then break the students into groups and hand out either the terrestrial Arctic ecosystem species list or the marine Arctic ecosystem species list (or equivalent). Have the students construct a food web for their respective ecosystems. There is space at the top of Worksheet 2 to draw the food web.

How to interpret food webs using network theory.

Introduce some of the terms (e.g. in-degree, out-degree). Ask the students to brainstorm Question 5 on Worksheet 1.

Introduce the adjacency matrix.

- Introduce the adjacency matrix as a way to organise network data and represent the network for calculations.
- First demonstrate using the simple example, and then each group can do the same for their respective food webs using the space provided under Question 2 on Worksheet 2.

Calculate and analyze some simple network statistics.

- Add up the row and column totals in the adjacency matrix. These are the in and out degrees for each species.
- Work through Questions 3 and 4 in Worksheet 2.

Do some node deletions and/or additions.

- Have the students fill out the table in Question 5 on Worksheet 2.
- Node deletions represent primary extinctions. Node additions could represent invasive species or species that might move further north with climate change.

Final Reflections

Work through Questions 6 and 7 on Worksheet 1.

Presentations

Have each group present their findings. Presentations may include:

- Which species are most vulnerable? How do you know?
- How might climate change affect the food web?
- What can we do to mitigate any negative effects?

Final Discussion

The instructors guide a final discussion and wrap-up. Topics could include:

- Compare the results of each group and look for trends (e.g. does higher connectance lead to fewer secondary extinctions?).
- What is the effect of removing highly connected species vs. less connected ones?
- Implications for management and policy decisions?
- Would it be a good idea to introduce another species to counter-act the effects of losing or gaining another? Can we use network theory to help inform this decision?
- Based on your analysis, what can we say about how climate change might affect the Arctic?

Extras

- Brainstorm other applications for network theory and the environment. This is Question 8 on Worksheet 1.
- Show some examples of more complicated food webs (e.g. see the Food Web Gallery at http://www.foodwebs.org/).

3 References

Newman, M.E.J. (2010). *Networks: an introduction.* Oxford University Press Inc., New York.