Robustness of ADBM predicted food webs

Abstract

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1 Introduction

1.1 Background on anthropogenic changes and its impact on food web

Anthropogenic changes such as climate change and habitat destruction is a threat to biodiversity and can lead to food web collapse. Climate change can lead to the collapse of a food web (Ullah et al. 2018). Primary extinctions in a food web can give rise to further secondary extinctions in a food web resulting in collapse of the food web. The impact of this extinction is dependent on the complexity and structure of the food web (reference).

1.2 Briefly explain work done by Jennifer Dunne on species extinctions

Simulation of primary species loss has been conducted in observed food webs and model food webs from terrestrial and aquatic ecosystems where robustness was measured in terms of secondary extinctions (Jennifer A. Dunne, Williams, and Martinez 2002; Jennifer A. Dunne and Williams 2009). These studies showed that the robustness of the food webs increases with food web connectance. When canonical experiments in natural ecosystems are not possible, this provides an alternate solution to investigate the impact of primary extinctions in a food web.

1.3 ADBM predicted food webs

The allometric diet breadth model (ADBM) was the first model able to predict food web connectance (i.e. the number of realised links divided by total number of possible links) and structure (i.e. the arrangement of those links) (Beckerman, Petchey, and Warren 2006; Petchey et al. 2008). ADBM uses foraging theory specifically the contingency model (MacArthur and Pianka 1966) to predict the diet of each potential consumer and thereby the food web structure.

1.4 Robustness of ADBM predicted food webs

In Gupta et al. (2021), the ADBM parameterised with approximate Bayesian computation overestimated the food web connectance when compared with the observed connectance. It is crucial to investigate the implication of this overestimation in the robustness of predicted food webs. We suspect that the ADBM predicted food webs would be more robust as compared to the observed food webs.

1.5 What we do in this study

In this study, we simulate primary species loss in 12 food webs predicted from the ADBM to quantify the secondary loss of extinctions. We use three different approaches of species removal: (i) most connected species, (ii) random species and (iii) least connected species to understand how the outcome varies among these approaches.

2 Materials and methods

2.1 Allometric Diet Breadth Model (ADBM)

The allometric diet breadth model (ADBM) is based on optimal foraging theory, specifically the contingency foraging model (MacArthur and Pianka 1966). The ADBM predicts the set of prey species a consumer should feed upon to maximise its rate of energy intake (Petchey et al. 2008). The foraging variables in the model: energy content of the resources, handling times of the prey, space clearance rate and prey densities are allometrically scaled to the body sizes of the species.

2.2 Food web data

The observed food webs that we fit the ADBM to belong to marine, freshwater and terrestrial ecosystems (Table 1). The observed connectance of these food webs is from 0.03 to 0.24 and there are 29 to 239 species. The food webs contain primary producers, herbivores, carnivores, parasites, and parasitoids. They also contain various types of feeding interactions, including predation, herbivory, bacterivory, parasitism, pathogenic, and parasitoid.

Table 1: Information about the food webs predicted using the ADBM.

Common food web name (Original Publication)	Predation matrix source	General ecosystem	Number of species	Connectance	Type of interactions
Benguela Pelagic (Yodzis 1998)	Brose et al. (2005)	Marine	30	0.21	Predation
Broadstone Stream (taxonomic aggregation) (Woodward and Hildrew 2001; Woodward et al. 2005)	Brose et al. (2005)	Freshwater	29	0.19	Predation
Broom (Memmott et al. 2000)	Brose et al. (2005)	Terrestrial	60	0.03	Herbivory, Parasitism, Predation, Pathogenic
Capinteria (Lafferty et al. 2006)	Hechinger et al. (2011)	Marine (Salt Marsh)	88	0.08	Predator-parasite, Parasite-parasite
Caricaie Lakes (Cattin et al. 2004)	Brose et al. (2005)	Freshwater	158	0.05	Predation, Parasitism
Grasslands (Dawah et al. 1995)	Brose et al. (2005)	Terrestrial	65	0.03	Herbivory, Parasitism
Mill Stream (Ledger, Edwards, Woodward unpublished)	Brose et al. (2005)	Freshwater	80	0.06	Herbivory, Predation
Skipwith Pond (Warren 1989)	Brose et al. (2005)	Freshwater	71	0.07	Predation
Small Reef (Opitz 1996 Table 8.6.2)	Alyssa R. Cirtwill and Anna Eklöf (2018)	Marine (Reef)	239	0.06	Predation, Herbivory
Tuesday Lake (Jonsson et al. 2005)	Brose et al. (2005)	Freshwater	73	0.08	Predation
Ythan (Emmerson and Raffaelli 2004)	Alyssa R. Cirtwill and Anna Eklöf (2018)	Marine (Estuarine)	85	0.04	Predation
Broadstone Stream (size aggregation) (Woodward et al. 2010)	Guy Woodward. (2021)	Freshwater	29	0.24	Predation

2.3 Species removal

We implemented the primary species removal method from Jennifer A. Dunne and Williams (2009) by sequentially removing species using one of three criteria: removal of (i) the most-connected species, (ii) the least-connected species and (iii) randomly chosen species. The most-connected and least-connected criteria are based on the degree (i.e. total number of links to resource and links from consumer for each species) of species. Given a primary removal if any remaining species lost all of their resource species, or any cannibalistic species lost all of their resource species except the cannibalistic links, they are dropped from the web and were recorded as a secondary extinction. Then the next appropriate species are removed determining the most- and least-connected species based on the web remaining after all prior primary removals and secondary extinctions had occurred. This process was carried out until all species were extinct from the web.

Robustness (R) of food web was quantified as the proportion of species subjected to primary removals that resulted in a total loss (i.e. primary removals plus secondary extinctions) of some specified proportion of the species. In our study, we use R_{50}, primary extinctions that result in at least 50 per cent of total species loss (Jennifer A. Dunne, Williams, and Martinez 2002; J. Dunne, Williams, and Martinez 2004; Jennifer A. Dunne and Williams 2009). Therefore, there is no secondary extinction in a maximally robust community ($R_{50} = 0.50$), whereas in a minimally robust community ($R_{50} = 1/S$) there is extensive secondary extinctions (i.e. at least $S/2 - 1$).

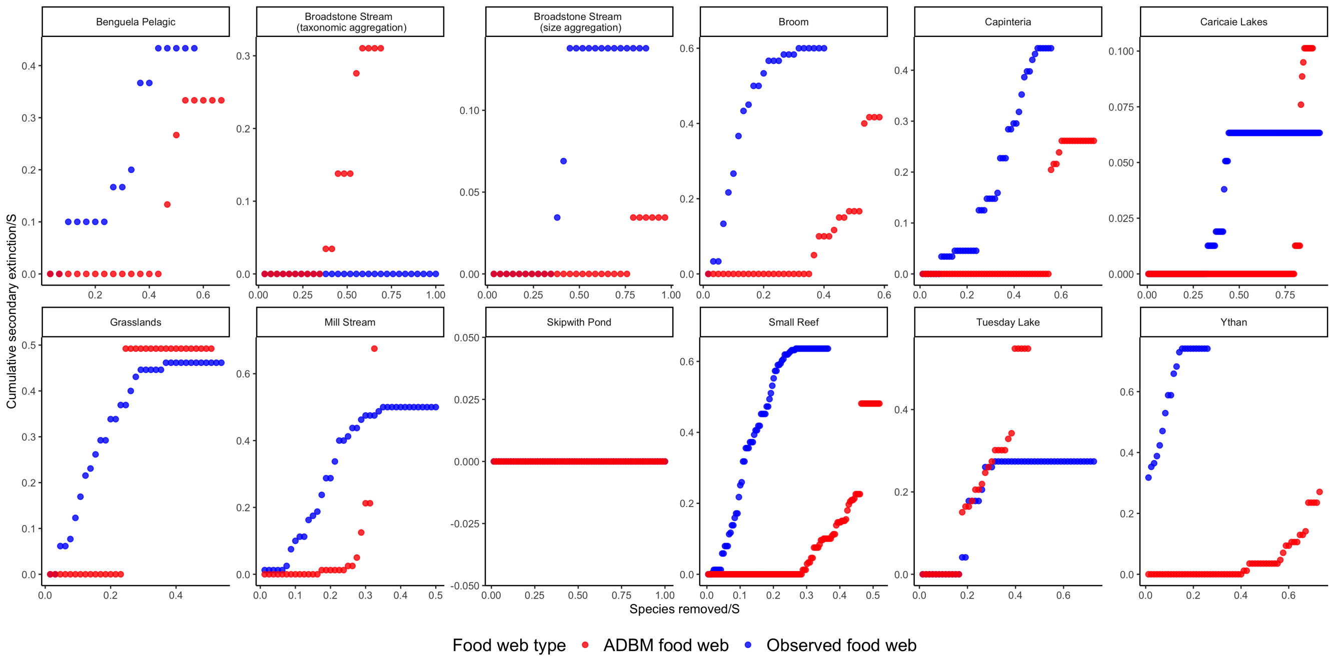

Figure 1: Cumulative secondary extinctions for 12 food webs across different ecosystems.

3 Results

3.1 Explain the secondary extinction curves

3.1.1 Compare the results from the different methods

3.2 Explain the outlier food webs: where the stability of ADBM predicted food webs is lower than empirical food webs

3.3 Explain the robustness plots

3.3.1 Compare the results from the different methods

4 Discussion

4.1 What does overestimation of connectance imply in terms of stability?

4.2 Discuss how the robustness is dependent on the TSS of the predicted food web

- Would a higher TSS imply a higher difference in the robustness between predicted and observed food web?

4.3 Compare the results from our study with results from other food web models (Jennifer A. Dunne and Williams (2009))

4.4 Explain that the ADBM can only predicts contiguous diets

4.5 Future prospect of using a dynamical model to model the temporal dynamics of the ADBM predicted food web

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