Prey body mass and richness underlie the persistence of a top predator.

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Electronic supplementary materials

Appendix 1 - Supporting results

MCMC steps:

For each outcome $\mathcal{R}$, we followed the following five recursive steps:

S1: If at parameter θ, then propose a move to θ'. A step size drawn from a random normal distribution centered at zero, truncated between a minimum and maximum value. The first step in the MCMC is to propose a new set of parameters θ' given an initial value of θ. For example, if the initial body mass of three species was a vector (0.1, 0.3, 0.4), we might drew a random value from a normal distribution (say 0.1) and add it to each body mass. This new vector (0.2, 0.4, 0.5) would be θ'.

S2: Run the simulation using θ' and assess $\mathcal{R}$.

The second step of the MCMC is to run the simulation using the new parameters and to determine whether $\mathcal{R}$ occurred (e.g. whether the predator persisted or not).

S3: If $\mathcal{R}$ occurs, then accept θ', otherwise stay at θ

In this third step, if $\mathcal{R}$ occurred, we take *θ'* as the new starting value, otherwise we go back to the initial value in step 1. This ensures that as the number of iterations increases, the MCMC converges towards the body masses (*θ*) where the predator is more likely to persist.

S4: Record θ, θ' and $\mathcal{R}$ as well as the final abundance of all species in the community at the end of the simulation

S5: Return to S1

Table SA1: The prey species used for the feeding trials with the predator *Leptagrion*, their average body mass and the densities we used for the feeding trials.

Prey	Mean Body Mass (mg)	Densities
Culex sp 1	0.1771	1, 2, 5, 7, 10, 20, 30, 50
Culex sp 2	0.0906	1, 2, 5, 7, 10, 20
Forcypomia	0.0737	1, 2, 5, 7, 10, 20, 30, 60
Oligochaete	0.1242	1, 2, 5, 7, 10, 20, 30, 60
Psychodidae	0.2198	1, 2, 5, 10, 30
Scirtes sp 1	0.3286	1, 2, 5, 10, 30

Scirtes sp 2	0.4344	1, 2, 3, 4, 5, 6
Tipulid	0.2935	1, 2, 3, 4, 5, 6, 10, 17

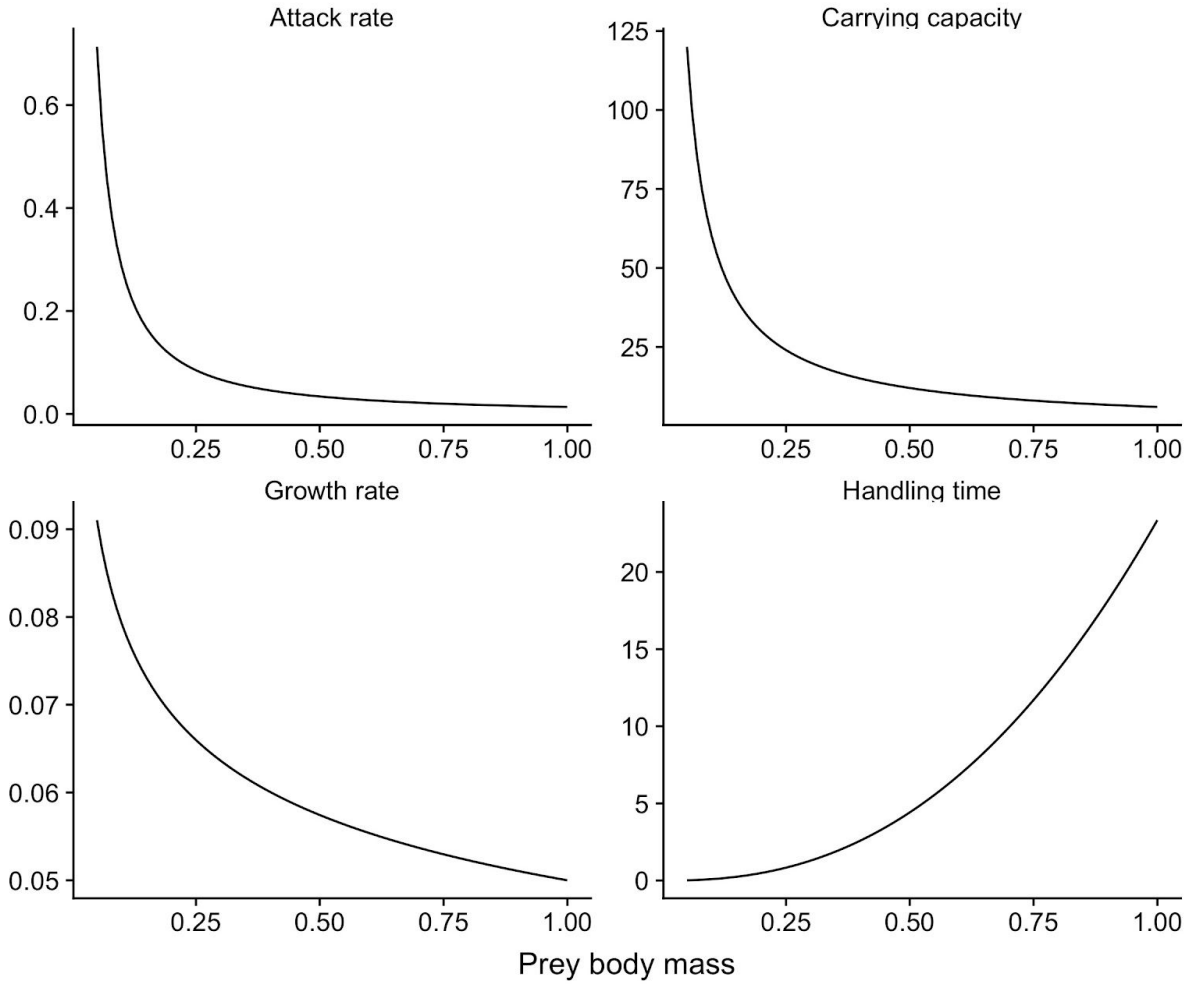

Figure SA1: The attack rate, carrying capacity and growth rate decrease with prey body mass, the handling time increases with prey body mass (Parameters in tables 1 and 2).

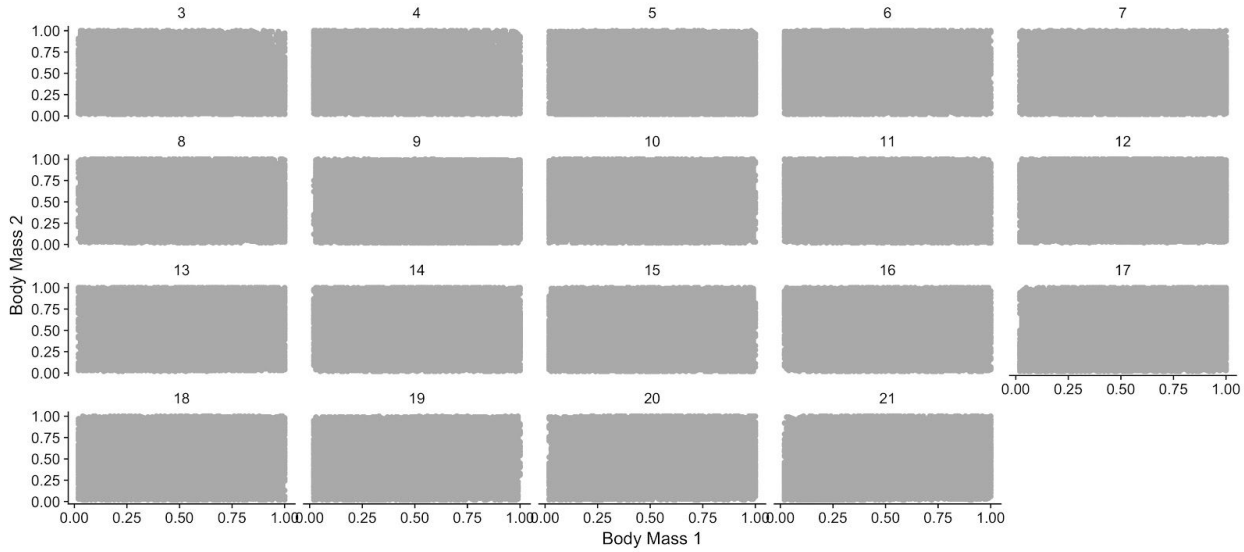

Figure SA2: Parameter space is well covered in the Monte Carlo sampling. As the number of species increases, most values for body mass of the prey 1 and 2 are represented. All other prey show a similar coverage. Each panel shows the diversity being considered.

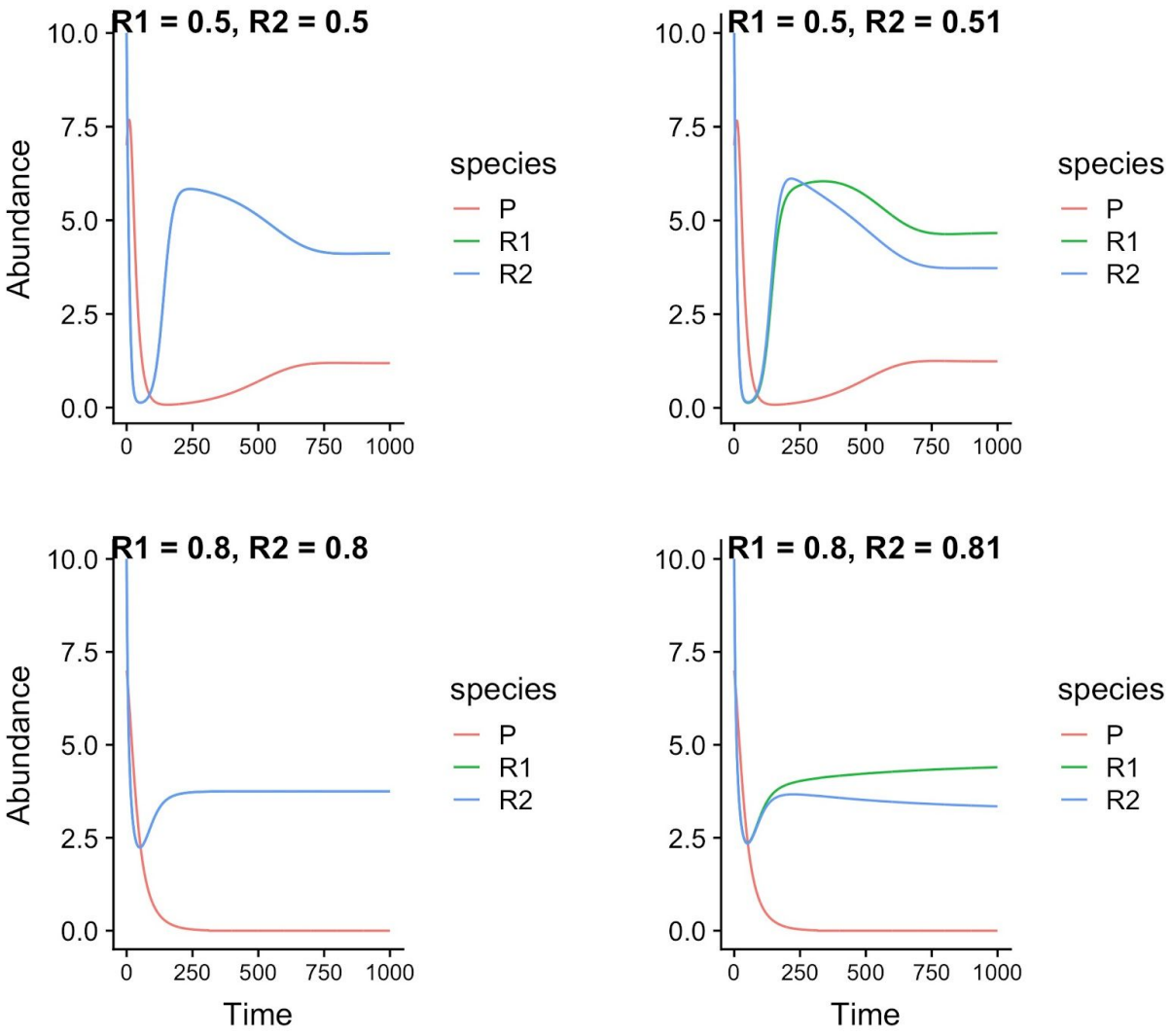

Figure SA3: Time series of two prey species and the predator. If the body mass of both prey is high the predator will go extinct. Body masses of each prey species are presented above each graph. All a-d show prey species that have high competitive interaction strengths since they are close in body mass. a) and b) show two prey species with intermediate body mass, c) and d) show two prey species with large prey mass.

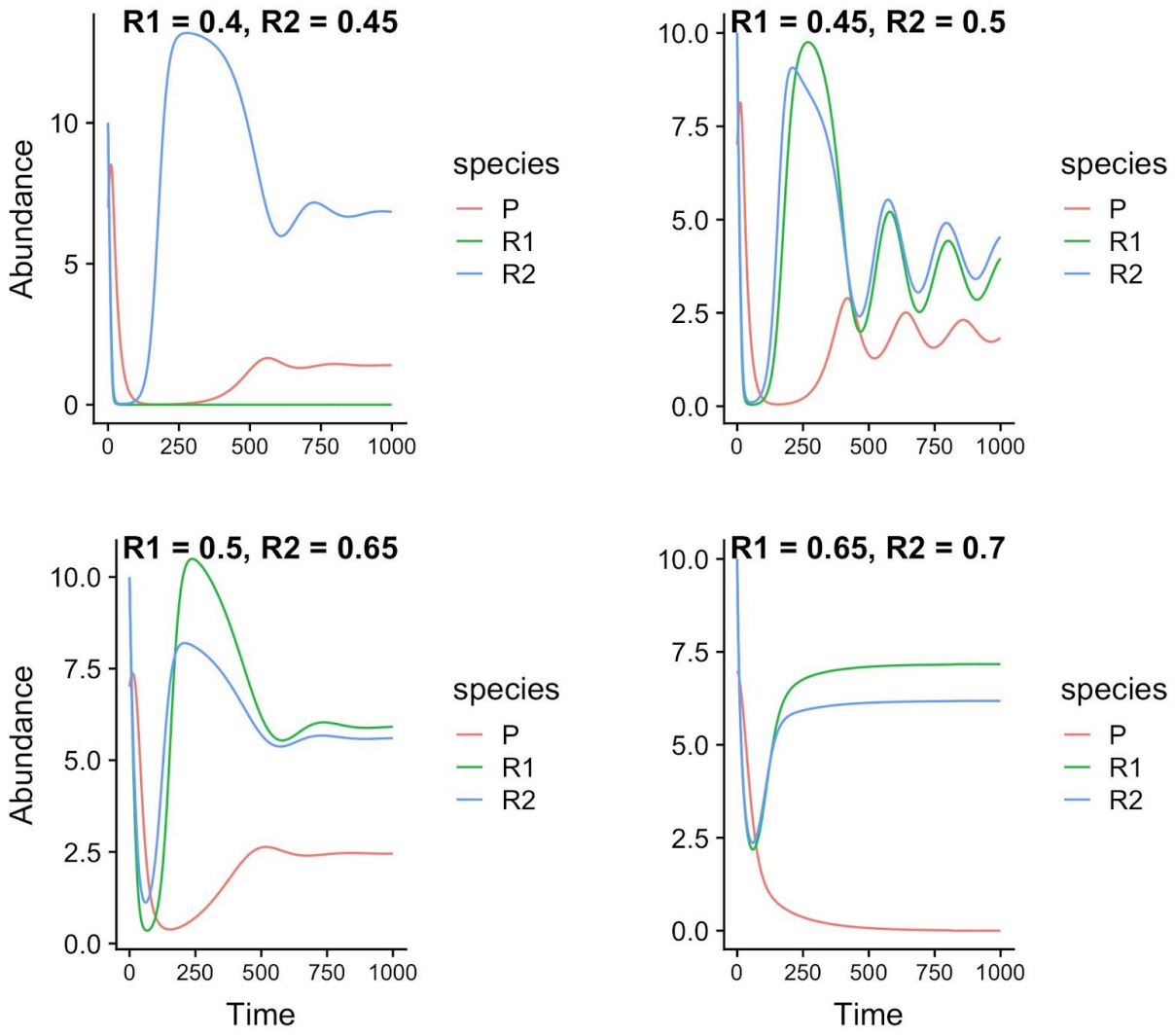

Figure SA4: Time series of two prey species and the predator. The body mass of each prey species is presented above each graph. Panels a- d show prey species that have low competitive interaction strengths since they differ in body mass. a) The predator and the largest prey persist, the prey with the smaller body mass goes extinct due to predation and competition. b) and c) Both prey species and the predator persist through time since the smallest prey has an intermediate body mass. d) The predator goes extinct when both prey are large.

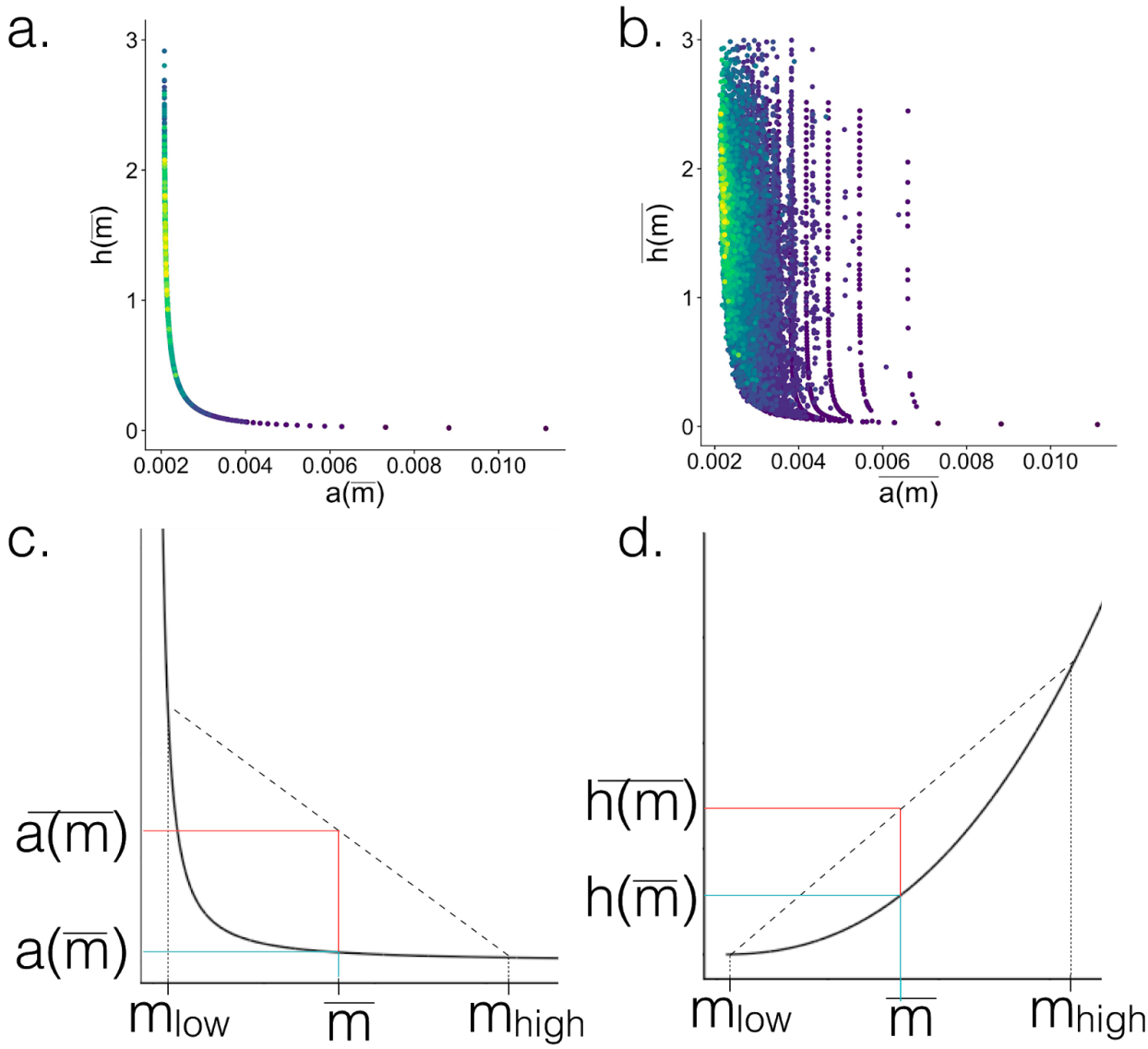

Figure SA5: Jensen's inequality alters the effective attack rate and handling time as prey diversity increases. a) As diversity increases, the average body mass of the prey increases causing an increase in the handling time $h(\overline{m})$ but a decrease in the attack rate $a(\overline{m})$. b) Due to Jensen's inequality, increasing diversity increases the combination of effective attack rates and effective handling times (compare to panel a). Given the upward curvature of the attack rate c) and the handling time d), we expect that the effective attack rat and the effective handling time will be higher than the attack rate and the handing time of the mean body mass.

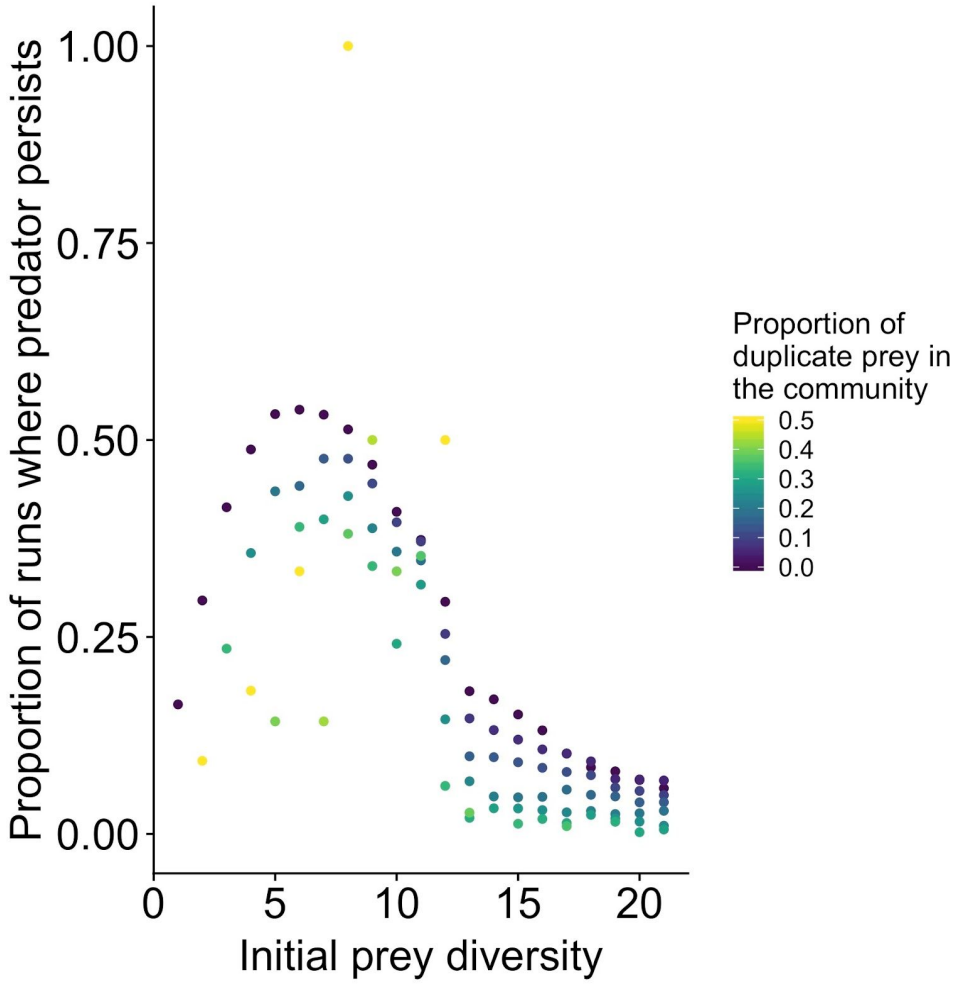

Figure SA6: The probability that the predator persistent has a unimodal relationship with prey diversity. Since prey that are close to each other in body mass have higher competition coefficients, we calculated the proportion of species in a run that had the same body mass. As the proportion of prey species with the same body mass increases, predator persistence decreases. But this decrease is relatively small compared to the effects of having small or large prey (Figure 4).

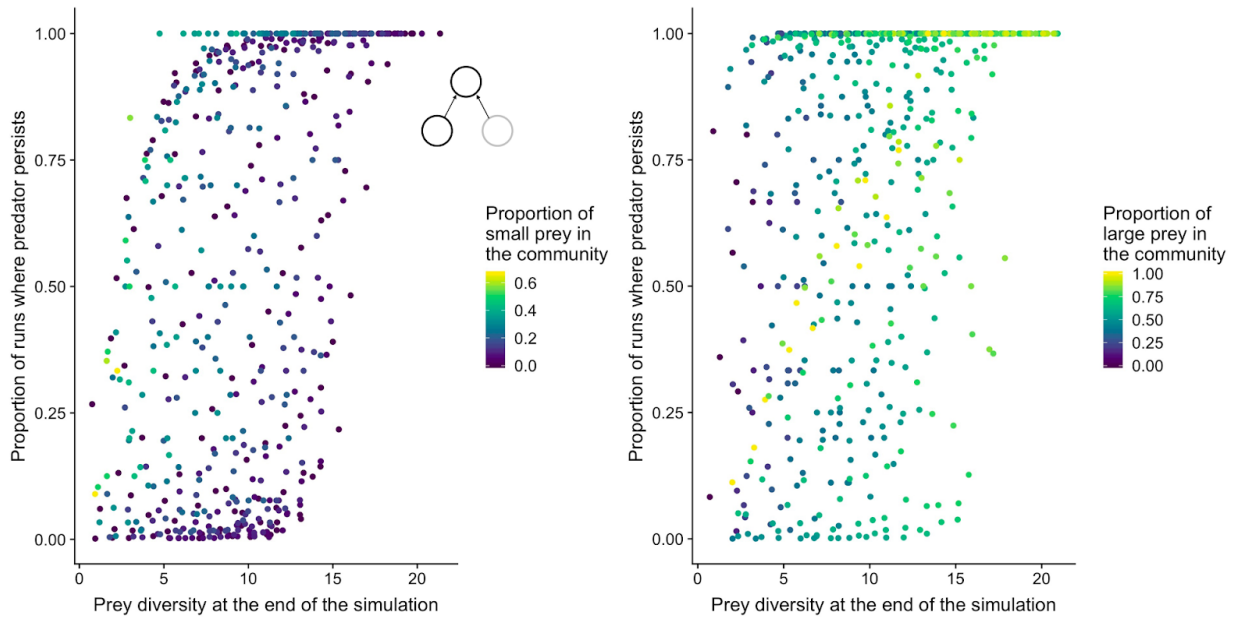

Figure SA7: a) As the proportion of small prey in the community increases, the proportion of runs where the predator persists decreases slightly. b) For any given predator persistence, higher final prey diversity occurs when the run had a higher proportion of large prey species.

Appendix 2 - Asymmetric competition

The model we presented assumes that competition is symmetrical with regards to the trait. That is, there is no benefit of being large or small in the outcome of competition. Arguably, this may not be the case. Evidence suggests that the outcome of competition is dependent on the body size of the individuals, where larger individuals outcompete smaller individuals [1,2]. In certain cases smaller individuals can also outcompete larger individuals [e.g. 3]. Here, however, we will only analyze the case where larger individuals outcompete smaller individuals.

Asymmetric competition reduces the window of persistence of the whole community (Figure SA8, SA9). Persistence only occurs when both prey are intermediate in body mass *and* the competition is not vastly asymmetric, that is, their body masses are close (Figure SA8c). If both prey are small, but one prey is very small, the latter will go extinct due to predator overconsumption (Figure SA8a). Similarly, if the both prey are large, where the predator cannot persist, and the larger prey will outcompete the smaller prey. Due to the asymmetry in competition, the smaller prey will extinct much faster than in the case of symmetric competition (Figure SA8d vs Appendix 1 - Figure SA4d).

Predator persistence occurs less frequently when prey species compete asymmetrically (Figure SA10) and it decreases with diversity.

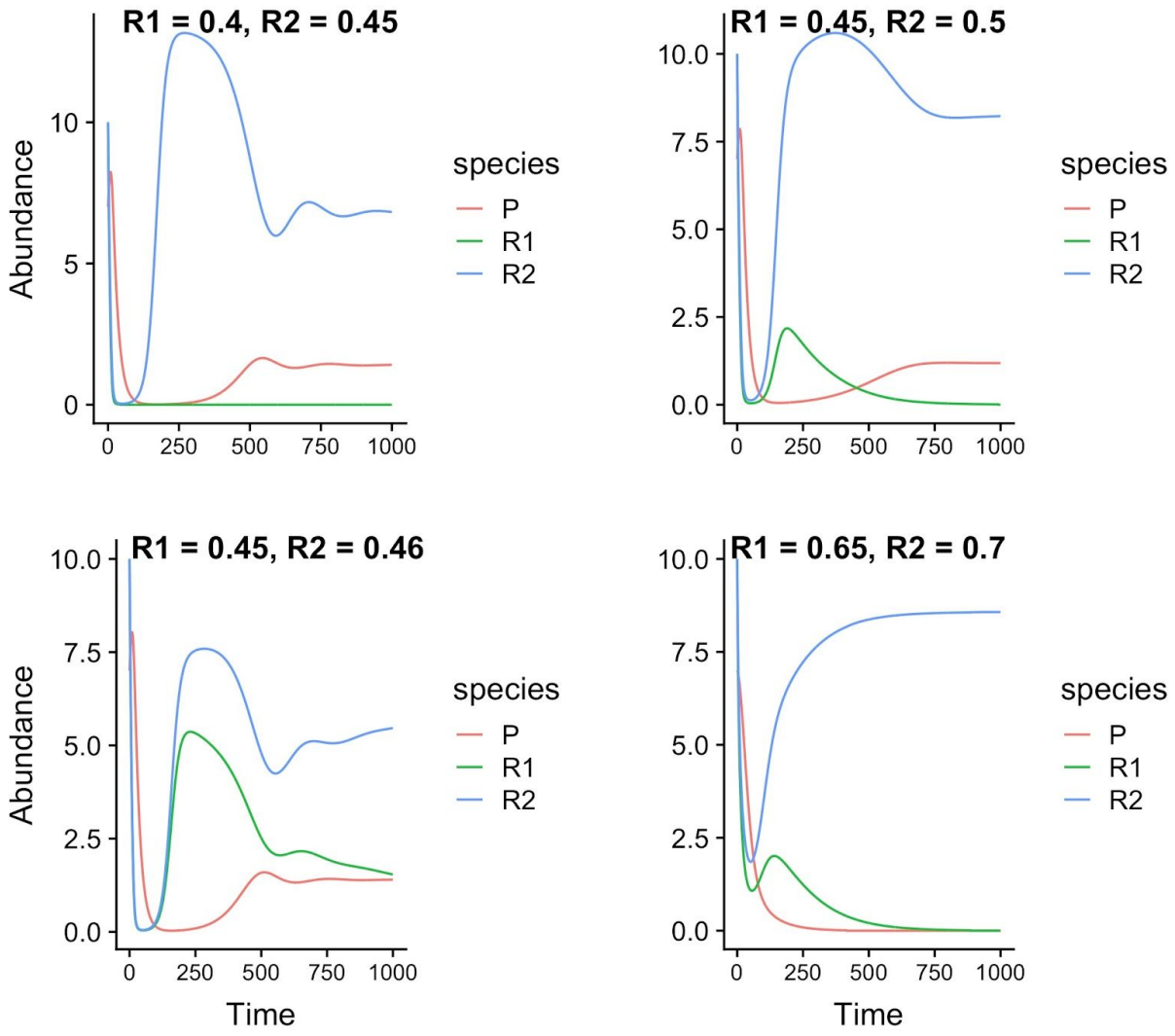

Figure SA8: Time series of two prey species and the predator. The body mass of each prey species is presented above each graph. Panels a- d show prey species that have low competitive interaction strengths since they differ in body mass. a) and b) The predator and the largest prey persist, but the smaller prey goes extinct. c) Both prey species and the predator temporarily persist. d) The predator goes extinct when both prey are large.

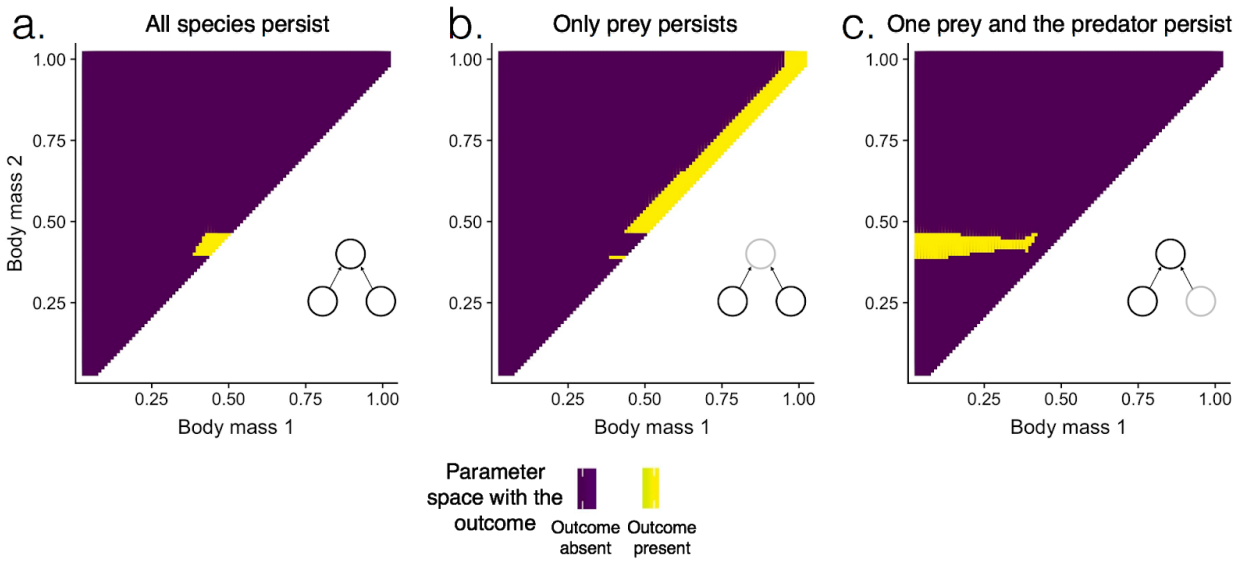

Figure SA9: Predator persistence is constrained to two intermediate similarly sized prey or one intermediate and one large prey. Prey competitively exclude each other unless they are similarly sized (1:1 edge). On the x axis is the body mass of prey 1, and on the y axis is the body mass of prey 2. Panels a-c show the combinations parameter space with a certain outcome, where yellow represents that the outcome of interest is present and purple is absent: a) both prey species and the predator persists; b) the predator goes extinct and only the two prey persist;. c) one prey and the predator persist and one prey goes extinct (in every case the smaller prey). These scenarios are detailed in the food web modules: the grey circles represent species that go extinct and the black circles represent species that persist.

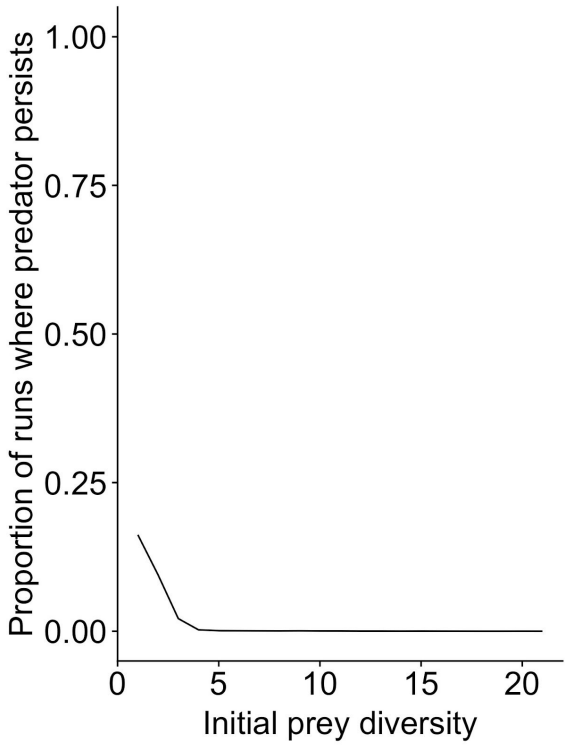

Figure SA10: Prey diversity decreases predator persistence.

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