Peer Community In
Ecology

Rethinking Biomass Scaling in Predators-Preys ecosystems

Samir Simon Suweis *based on peer reviews by* ***Samraat Pawar*** *and 1 anonymous reviewer*

Onofrio Mazzarisi, Matthieu Barbier, Matteo Smerlak (2024) General mechanisms for a top-down origin of the predator-prey power law. bioRxiv, ver. 2, peer-reviewed and recommended by Peer Community in Ecology.
https://doi.org/10.1101/2024.04.04.588057

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The study titled "General mechanisms for a top-down origin of the predator-prey power law" provides a fresh perspective on the classic predator-prey biomass relationship often observed in ecological communities. Traditionally, predator-prey dynamics have been examined through a bottom-up lens, where prey biomass and energy availability dictate predator populations. However, this study, which instead explores the possibility of a top-down origin for predator-prey power laws, offers a new dimension to our understanding of ecosystem regulation and raises questions about how predator-driven interactions might influence biomass scaling laws independently of prey abundance.

Ecologists have long noted that ecosystems often exhibit sublinear scaling between predator and prey biomasses. This pattern implies that predator biomass does not increase proportionally with prey biomass but at a slower rate, leading to a power-law relationship. Traditional explanations, such as those discussed by Peters (1983) and McGill (2006), have linked this to bottom-up processes, suggesting that increases in prey availability support, but do not fully translate to, larger predator populations due to energy losses in the trophic cascade. However, these explanations assume prey abundance as the principal driver. This new work raises an intriguing question: could density-dependent predator interactions, such as competition and interference, be equally or more important in creating this observed power law?

The authors hypothesized that density-dependent predator interactions might independently control predator biomass, even when prey is abundant. To test this, they combined predator and prey biomass dynamics equation based on a modified Lotka-Volterra model with agent-based models (ABMs) on a spatial grid, simulating predator-prey populations under varying environmental gradients and density-dependent conditions.

These models allowed them to incorporate predator-specific factors, such as intraspecific competition (predator self-regulation) and predation interference, offering a quantitative framework to observe whether these top-down dynamics could indeed explain the observed biomass scaling independently of prey population changes.

Their results show that density-dependent predator dynamics, particularly at high predator densities, can yield sublinear scaling in predator-prey biomass relationships. This aligns well with empirical data, such as African mammalian ecosystems where predators seem to self-regulate under high prey availability by competing amongst themselves rather than expanding in direct proportion to prey biomass. Such findings support a shift from bottom-up perspectives to a model where top-down processes drive population regulation and biomass scaling.

I think that the work by Mazzarisi and collaborators (2024) offers a thought-provoking twist on predator-prey dynamics and suggests that our traditional frameworks may benefit from a broader, more predator-centered focus.

References:

1. Onofrio Mazzarisi, Matthieu Barbier, Matteo Smerlak (2024) General mechanisms for a top-down origin of the predator-prey power law. bioRxiv, ver.2 peer-reviewed and recommended by PCI Ecology https://doi.org/10.1101/2024.04.04.588057

2. Peters, R. H. (1986). The ecological implications of body size (Vol. 2). Cambridge university press.

3. McGill, B. J. (2006). "A renaissance in the study of abundance." Science, 314(5801), 770-772. https://doi.org/10.1126/science.1134920

Reviews

Evaluation round #1

DOI or URL of the preprint: https://doi.org/10.1101/2024.04.04.588057
Version of the preprint: 1

Authors' reply, 16 October 2024

Download author's reply

Decision by Samir Simon Suweis, posted 16 June 2024, validated 17 June 2024

The preprint merits a revision

Dear authors, you can find the reviewers comment of your manuscript "Top-down origins of the predator-prey power law?"

As you can see, both reviewers appreciate your work and I think they give positive and constructive criticism to further improve it. I thus suggest a mild revision before reccomending the preprint. I also personally suggest to avoid the question mark in the title. Prefer more direct and informative titles, e.g., "Different mechanisms can explain predator-prey power law", or "Alternative explainations to top-down origins of the predator-prey power law".

Thanks and best
Samir

Download the review

Reviewed by anonymous reviewer 1, 05 June 2024

This work by Mazzarisi et al. is a clean, concise exploration of a biological scaling relationship between predator and prey biomass densities. They use two complementary theoretical approaches to consider an alternative explanation for this relationship (top-down regulation) than used in previous literature (bottom-up regulation). The piece is well written, with clear and informative figures and easily accessible code (though it appears the data was removed from the current repository at some point). Overall, I enjoyed reading this work, but was left with several areas of confusion that could be ameliorated by improved explanations in the text.

One source of confusion when reading the text was the authors' implicit conceptions of ”top-down” vs. ”bottom-up”. These terms could use a more explicit treatment in the text. For instance, it makes sense to me that sublinear prey production is ”bottom-up,” that is, the consequences for the predator densities derive from prey dynamics (independent of the predator-prey interaction) (though see my next point for some further confusion on this topic). Likewise, density-dependent self-regulation of the predator and predation interference seem fairly intuitively ”top-down,” that is, the effect on predator densities is driven by the dynamics of the predators themselves, either explicitly in the context of the predator-prey interaction or not. Yet, prey saturation seems more like the former than the latter (despite being listed as a ”top-down” effect. Finally, the authors state they are working from the assumption of ”prey productivity as the primary driver for the biomass density gradient across ecosystems” (p 10), this assumption seems explicitly ”bottom-up”.

With respect to ”sublinear prey production” in particular, the discussion in section 3 suggests two pathways for this: changes in r (prey growth rates; what I envisioned when discussing prey production) or changes in q (predator consumption rates; something that feels like it could also be described as a ”top-down” effect). Moreover, as the authors point out, when r is the parameter of interest, it actually has no effect on equilibrium prey densities, raising the question of whether ”sublinear prey production” is actually even an accurate description of this situation. On this topic, the figure depicting this case is confusing to me: are the little blue dots meant to represent reproduction? If so, I guess the ”sub-linearity” is that not all four blue dots have offspring in the right subplot? I think it would make more sense if from the beginning not all points reproduced. And how is this functionally different from prey saturation, where there is also a depiction of slower prey growth? Regardless, the legend or caption needs to explain all symbols/colors used in this figure.

By the end of the piece, I was left confused what the take-home message was. It seems the authors want to demonstrate the existence of alternative dynamical explanations for an observed phenomenon (a fair and admirable goal). And I particularly appreciated the second-to-last paragraph, in which the biological implications were explored. Yet, they also write that the previous explanation is ”realistic and parsimonious” (p 6) and ”more appropriate to capture the general dynamics” (p 11), and that, of the ”range of [possible] explanations ... they are all top-down” (p 3).

Finally, while I understand the authors' arguments for the consideration of single-parameter explanations for the empirical pattern, I think they could do more to explain why they might think this to be the case biologically outside of the argument for parsimoniousness. It seems that one of the primary explanations for a sublinear relationship is a discrepancy between two growth rates, which need not be governed by the same underlying parameter. For instance, on p 4, the authors state ”We want to explore how dynamical, density-dependent effects can be relevant for the scaling. Therefore, we use as a working assumption that only one environmental parameter, possibly different in other datasets, is responsible for the gradient.” Yet, this second sentence is a non sequitur. As I said, I think the authors do a good job in the introduction talking about this, but I would have liked them to be more comprehensive in other sections and, in particular, to come back to this possibility in the discussion as well, as it is a strong assumption underlying the work.

Minor Points

Please add line numbers to facilitate revision in the future.

p 3 – the emphasis on ”phenotypic” for sigma feels strange here since rho can likewise be a phenotypic difference

There are several cases of the authors introducing a term with specific biological relevance to a system and without definition. This is particularly striking when most of the text is system agnostic. Examples: ”catch” (p 4), ”grass” (p 8)

Figure 5 (and the ABM in general)

– the parameter δ does not appear in the model explanation, only in the parameter list

– why is there no energy change listed under ”engages pred.” or ”engages prey”?

– why is the model run on such a small grid?

– did the authors do any sensitivity analysis considering the other parameters of the ABM (i.e. ξ, $\omega1$, $\omega2$, δ, η, μ?)

Core Questions

Title and abstract

Does the title clearly reflect the content of the article? Yes, though could be more descriptive

Does the abstract present the main findings of the study? Yes

Introduction

Are the research questions/hypotheses/predictions clearly presented? Yes

Does the introduction build on relevant research in the field? Yes

Materials and methods

Are the methods and analyses sufficiently detailed to allow replication by other researchers? Yes

Are the methods and statistical analyses appropriate and well described? Yes

Results

In the case of negative results, is there a statistical power analysis (or an adequate Bayesian analysis or equivalence testing)? NA

Are the results described and interpreted correctly? Yes

Discussion

Have the authors appropriately emphasized the strengths and limitations of their study/theory/methods/argument? Yes

Are the conclusions adequately supported by the results (without overstating the implications of the findings)? Yes