Insect Apocalypse?

Statistics, dynamics, and asking the right questions

Eighdi Aung, Jessica Cunningham, Jeremy Draghi, Benjamin Jantzen, Caitlin Miller

Virginia Tech and the Fralin Biomedical Research Institute

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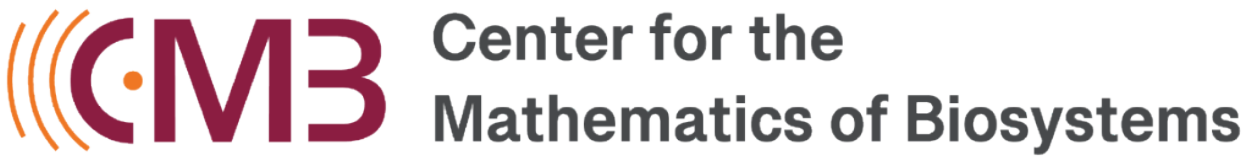

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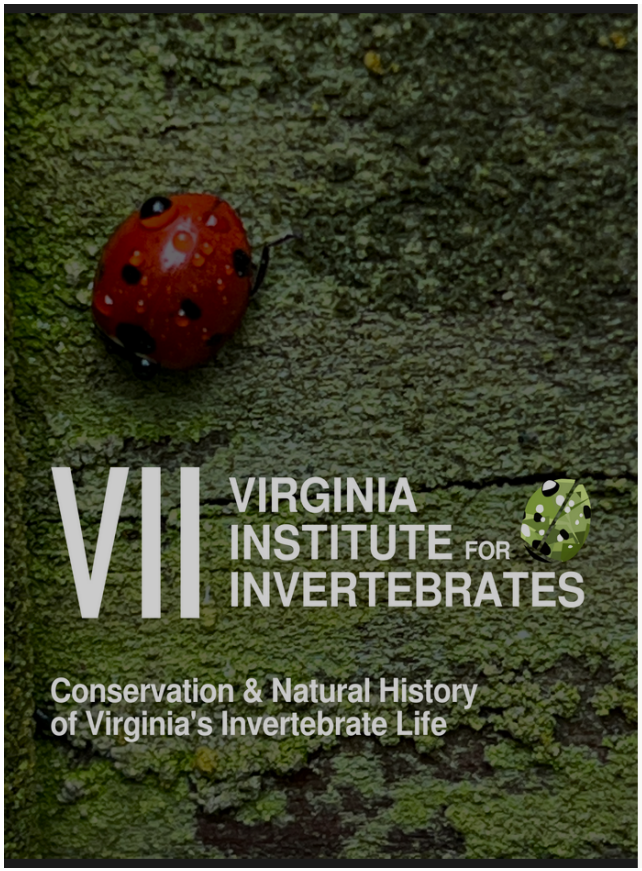


Our Mission

Monitoring

We know how important invertebrates are in the ecosystems of Virginia, but we don't know how the changing landscape is impacting their populations. VII will build and maintain the only network of insect population monitoring sites in the state, collecting valuable long-term data that will guide our conservation strategy and support scientific research.

Witnessing

We know very little about how even the common invertebrates in our backyards make a living. As habitat changes and species vanish, we risk losing the chance to learn about the incredible richness of life's diversity. By funding field research in natural history, we will serve as witness to life's grand pageant.

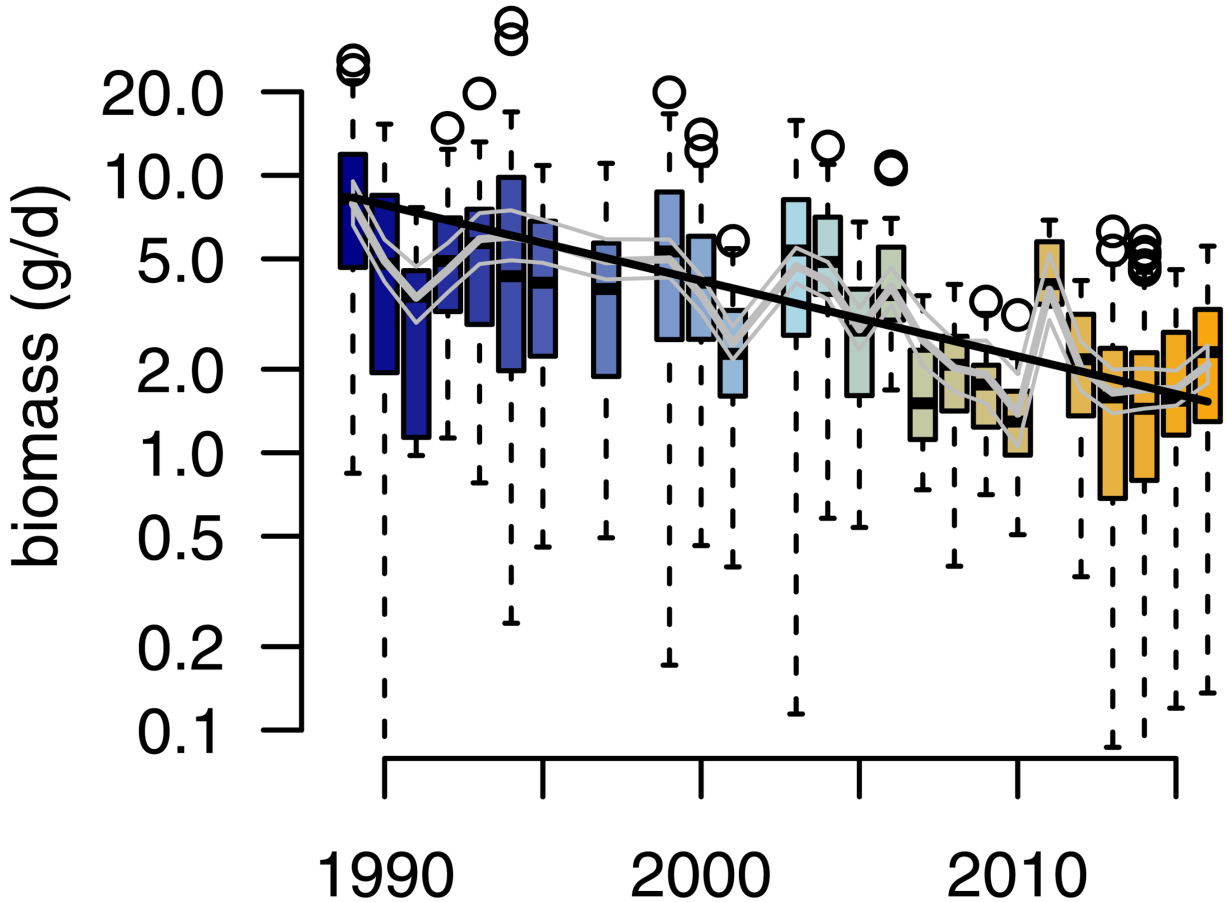
Conserving

Through the judicious use of land acquisitions and easements,VII is creating the first network of miniature conservation corridors in the state. This network will connect the remaining patches of prime habitat for native Virginia terrestrial and aquatic invertebrates, helping maintain dwindling populations of our most diverse animal groups.

Motivation

The 27 year trend in flying insect biomass over 63 nature protection areas in Germany.

Hallmann, C. A. et al. *PLOS ONE* 12, e0185809 (2017).



Contradictory evidence?

Insect biomass decline scaled to species diversity: General patterns derived from a hoverfly community

Caspar A. Hallmann[a,1], Axel Ssymank[b], Martin Sorg[c], Hans de Kroon[a], and Eelke Jongejans[a]

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SPECIAL FEATURE

Insect Conservation and Diversity (2009) **2**, 251–260 doi: 10.1111/j.1752-4598.2009.00062.x

Long-term changes in the abundance of flying insects

CHRIS R. SHORTALL, ALISON MOORE, EMMA SMITH, MIKE J. HALL, IAN P. WOIWOD and RICHARD HARRINGTON Plant and Invertebrate Ecology
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RESEARCH ARTICLE

Ecology and Evolution WILEY

No recovery in the biomass of flying insects over the last decade in German nature protected areas

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Abstract

Five years after a German study on insect biomass described a multi-decade decline in nature protected habitats, the DINA (Diversity of Insects in Nature protected Areas) project has investigated the status of insects in 21 selected nature reserves across Germany in the years 2020 and 2021. We used the same methods and protocols for trapping and measuring the biomass of flying insects as in the earlier study. Across two vegetation periods, we accumulated a comprehensive data set of 1621 data points of two-week emptying intervals to evaluate the insect biomass along gradients from arable land into nature reserves through transects of Malaise traps. On average, we observed an increase in maximum insect biomass per day along the transect from the edge to the centre of the nature reserve. Overall, the measured insect biomass remained at low levels, consistent with previous findings from the years 2007–2016. There were no significant regional differences. The results show that protected habitats have higher insect biomass compared to farmland and are therefore essential for insects but are unlikely to be sufficient to sustain insect biodiversity. Further measures need to be taken for better protection and sustainment of insects, which fulfil key functions in all terrestrial ecosystems.

KEYWORDS
agriculture, biodiversity loss, insect biomass, insect decline, malaise traps, natura 2000, nature conservation

TAXONOMY CLASSIFICATION
Applied ecology, Biodiversity ecology, Conservation ecology, Entomology

1 | INTRODUCTION

In the past few decades, alarming declines of insects have been observed in many places all over the world (Burner et al., 2021; Powney et al., 2019; Seibold et al., 2019). The study of Hallmann et al. (2017) illustrated the decline of insect biomass in nature protected areas in Germany over 27 years. The discussions this study generated made a significant contribution to raising public and political awareness of the problem of insect decline. Since then, several studies provided evidence that insect biomass decline involves a loss in diversity (Hallmann, Ssymank, Sorg, de Kroon, & Jongejans, 2021; Hallmann, Ssymank, Sorg, Kroon, & Jongejans, 2021; Hausmann et al., 2022). In

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Revealing uncertainty in the status of biodiversity change

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Global change biology

More winners than losers over 12 years of monitoring tiger moths (Erebidae: Arctiinae) on Barro Colorado Island, Panama

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No net insect abundance and diversity declines across US Long Term Ecological Research sites

Michael S. Crossley[1✉], Amanda R. Meier[1], Emily M. Baldwin[2], Lauren L. Berry[2], Leah C. Crenshaw[2], Glen L. Hartman[3], Doris Lagos-Kutz[3], David H. Nichols[2], Krishna Patel[2], Sofia Varriano[2], William E. Snyder[1] and Matthew D. Moran[2]

Recent reports of dramatic declines in insect abundance suggest grave consequences for global ecosystems and human society. Most evidence comes from Europe, however, leaving uncertainty about insect population trends worldwide. We used >5,300 time series for insects and other arthropods, collected over 4–36 years at monitoring sites representing 68 different natural and managed areas, to search for evidence of declines across the United States. Some taxa and sites showed decreases in abundance and diversity while others increased or were unchanged, yielding net abundance and biodiversity trends generally indistinguishable from zero. This lack of overall increase or decline was consistent across arthropod feeding groups and was similar for heavily disturbed versus relatively natural sites. The apparent robustness of US arthropod populations is reassuring. Yet, this result does not diminish the need for continued monitoring and could mask subtler changes in species composition that nonetheless endanger insect-provided ecosystem services.

Insects and other arthropods provide critical ecosystem services including pollination, natural pest control and decomposition, while influencing plant community structure and providing food to humans and other vertebrates[1]. Indeed, declines in populations of bumble bees and other pollinators endanger the production of an array of crops and reveal how dependent human society is on insects[2–5]. Thus, recent reports of sudden, dramatic drops in insect numbers[6–10] have triggered understandable fear that human-induced harm to the environment has reached a crisis point. Much evidence for what has been dubbed the 'insect apocalypse' comes from Europe[11–14], where humans have intensively managed landscapes for centuries and human population densities are particularly high. Indeed, insect declines there sometimes seem to be most rapid in the landscapes most heavily altered by human activity[15]. Other proposed drivers include relatively localized factors such as changing insecticide use patterns and artificial light pollution, and globally important factors such as climate change, nutrient dilution and increasing nitrification that presumably would reach even the most remote natural area[10,14,17]. So, depending on the underlying cause, insect decline might variously be predicted to be limited to heavily degraded landscapes (for example, ref. [13]) or reach into natural areas designated as nature preserves (for example, ref. [9]).

However, considerable scepticism has also emerged about the likelihood of the collapse of insect populations[18–20]. Critics note counter-examples where insects are relatively stable or increasing, even at sites heavily influenced by humans[20,21]. Others report apparent population rebounds through time[22]. Sometimes, sites in relatively human-disturbed areas exhibit insect populations with greater apparent stability than those in less disturbed landscapes[23], and climate change correlates with apparent declines in some cases[5] but not in others[8]. Clearly, before concluding that global insect populations are broadly in danger, we will need evidence from diverse communities of arthropods, across physically and ecologically dispersed sites that span both relatively natural and relatively human-managed landscapes, and outside of Europe[24]. This knowledge gap reflects a larger debate about what constitutes convincing evidence for global degradation of plant and animal biodiversity in the Anthropocene[25–27].

Here we utilized a geographically and taxonomically broad suite of relatively long-term datasets to search for evidence of insect decline in the United States. The US National Science Foundation initiated the establishment of a network of Long-Term Ecological Research (LTER) sites in 1980, and these now encompass a web of 25 monitoring locations across each of the country's major ecoregions (Fig. 1). Sites were chosen to reflect a diversity of habitat types in the United States and, critically, to span a range of human influence from urban (for example, within the US cities of Baltimore and Phoenix) or farmed regions (for example, the Midwest farmland aphid suction-sampling network) to those that are quite remote (for example, Arctic tundra in Alaska and Sevilleta desert/grassland in New Mexico) (Table 1). Arthropod data have been systematically collected from at least 12 different LTERs (Fig. 1) using a variety of approaches (but in a consistent way over time within each dataset; Supplementary Table 1), with some reporting multiple, separate datasets based on the taxa considered and/or method used for sampling ('Methods'). Types of arthropod data include grasshoppers per sweep in Konza Prairie (Kansas), ground arthropods per pitfall trap in Sevilleta desert/grassland (New Mexico), mosquito larvae per ovitrap in Baltimore (Maryland), pelagic macroinvertebrates per tow and crayfish per fyke net in North Temperate Lakes (Wisconsin), aphids per suction trap sample in the Midwestern United States, crab burrows per quadrat in Georgia Coastal Ecosystems, ticks per person/hour in Harvard Forest (Massachusetts), caterpillars per plot in Hubbard Brook (New Hampshire), arthropods per pitfall trap and sweep net in Phoenix metro area (Arizona) and stream insects per rock scrub in the Arctic (Alaska) (Table 1). When collecting these data, we did not discriminate based on taxa, type of

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Two conflicting approaches: Estimating aggregate trends

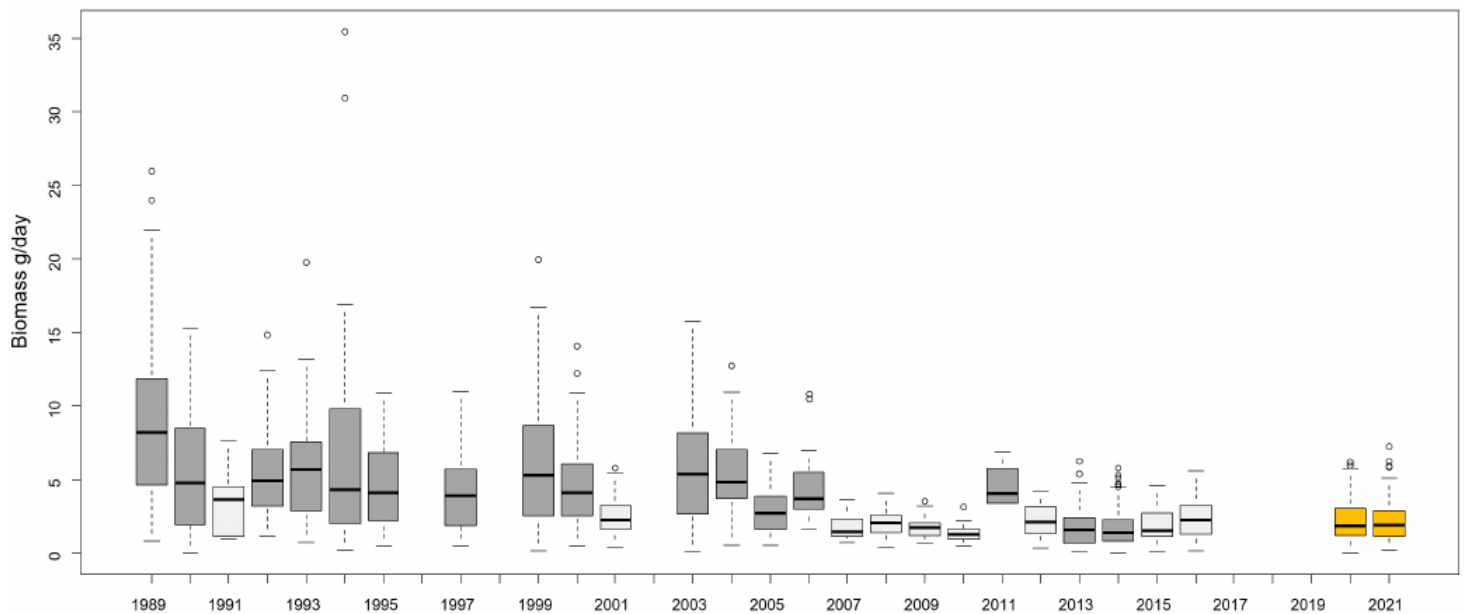
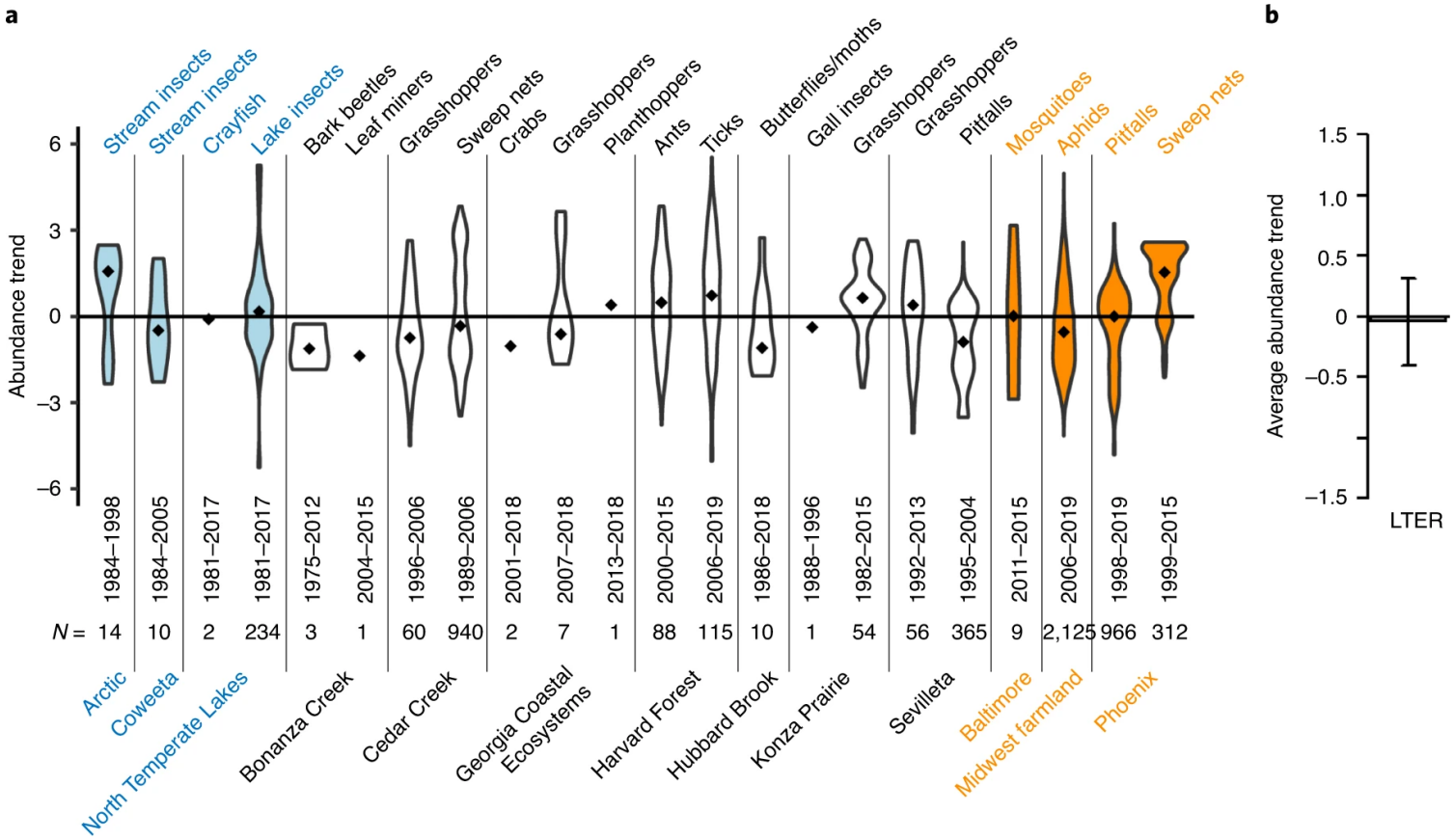


FIGURE 5 Daily insect biomasses in gram in German nature protected areas (NPA) of a 27-year timeseries published in Hallmann et al. (2017) (dark grey = significantly different to 2020 and 2021; light grey = no significant difference to 2020 and 2021, Mann–Whitney *U* test) compared to our data (mean daily biomass of MT3–MT5) from 2020 to 2021 (orange). Some years had small numbers of samples (1991 $n = 10$, 2011 $n = 4$ and 2015 $n = 10$).

Mühlethaler, R. et al. *Ecol Evol* 14, e11182 (2024).

Two conflicting approaches: Estimating the typical trend



Crossley, M. S. et al. *Nat Ecol Evol* 4, 1368–1376 (2020).

Estimating trends vs. Estimating aggregate trends

Aggregate effects

Is the total abundance or total diversity of insects declining, regardless of which specific taxa are increasing or decreasing? Note that if all and only the most abundant taxa are declining the answer can still be affirmative.

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Typical trends

Is the typical insect taxon showing a decline? Note that if half are declining and half increasing in abundance, the answer would be no.

Research question

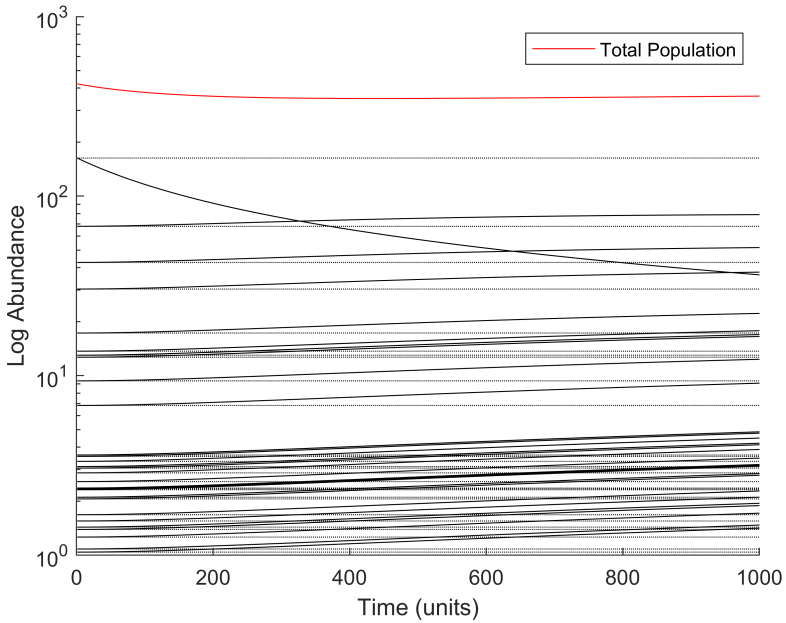
Can one build a dynamical system with realistic interaction strengths and connectivity in which the most abundant species (variable of the greatest value) is preferentially diminished such that the overall population (sum of variables) trends to 0 and yet the statistical tests commonly applied indicate the typical species is increasing?

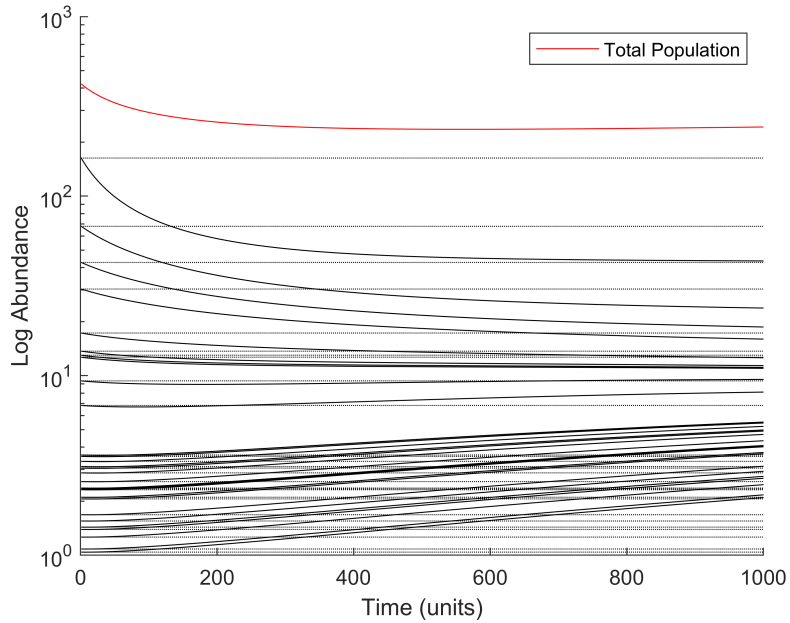
Model

$$\frac{dN_i}{dt}\frac{1}{N_i} = b_i(1 - \sum_{j=1}^{s} \alpha_{i,j} N_j) - (d_i + v_i * N_i)$$

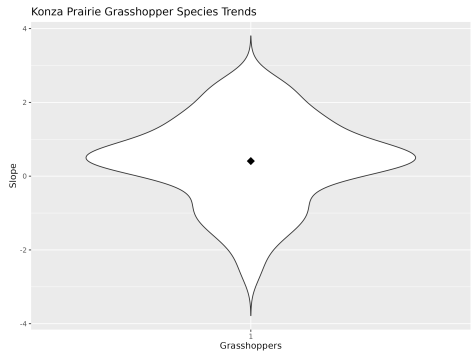
N_i	Abundance of species i
b_i	Maximum birth rate of i
d_i	Density-independent death rate of i
$\alpha_{i,j}$	Competitive effect of species j on i
v_i	Anthropogenic death rate of i
s	Number of species

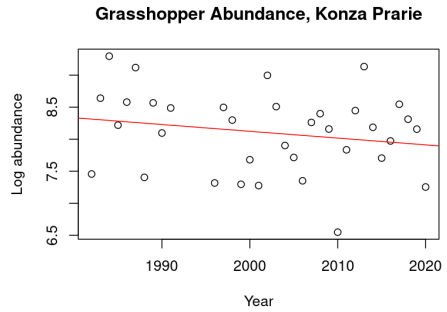
Model behavior

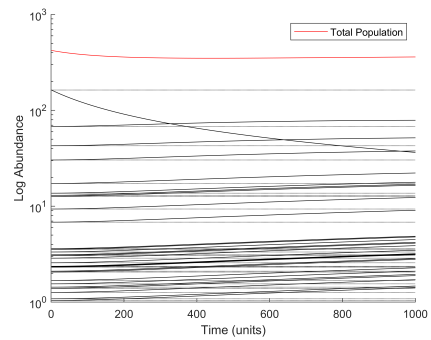


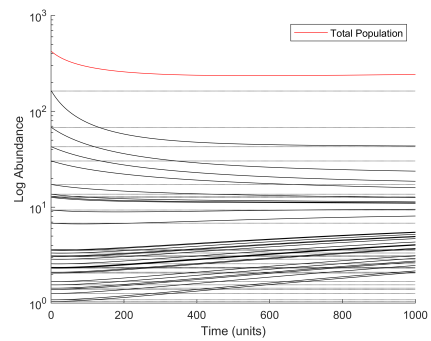


Divergent judgments









Takeaways

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3. The biggest impediment is a lack of data.
4. If you're interested in new initiatives to collect such data, go to virginiainvertebrates.org

Thank you.