

## Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

### Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

- |                                     |                                                                                                                                                                                                                                                                                                |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| n/a                                 | Confirmed                                                                                                                                                                                                                                                                                      |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> The exact sample size ( $n$ ) for each experimental group/condition, given as a discrete number and unit of measurement                                                                                                                                    |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly                                                                                                                                    |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> The statistical test(s) used AND whether they are one- or two-sided<br><i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>                                                               |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A description of all covariates tested                                                                                                                                                                                                                     |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons                                                                                                                                        |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> For null hypothesis testing, the test statistic (e.g. $F$ , $t$ , $r$ ) with confidence intervals, effect sizes, degrees of freedom and $P$ value noted<br><i>Give <math>P</math> values as exact values whenever suitable.</i>                            |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings                                                                                                                                                                      |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes                                                                                                                                     |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> Estimates of effect sizes (e.g. Cohen's $d$ , Pearson's $r$ ), indicating how they were calculated                                                                                                                                                                    |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

### Software and code

Policy information about [availability of computer code](#)

- |                 |                                                                                                                                                         |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Data collection | We conducted a coordinated experiment spanning seven locations across Central and South America (18°N to 29°S) using tank bromeliads as a model system. |
| Data analysis   | All the analyses were conducted using the free R software and language.                                                                                 |

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

### Data

Policy information about [availability of data](#)

- All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:
- Accession codes, unique identifiers, or web links for publicly available datasets
  - A description of any restrictions on data availability
  - For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The data supporting the findings of this study are available via figshare at <https://doi.org/10.6084/m9.figshare.33307629>. The R code that supports the findings of this study is available at <https://doi.org/10.6084/m9.figshare.33307629>.

## Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender No humans were used in this study.

Reporting on race, ethnicity, or other socially relevant groupings No humans were used in this study.

Population characteristics No humans were used in this study.

Recruitment No humans were used in this study.

Ethics oversight No humans were used in this study.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

## Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://nature.com/documents/nr-reporting-summary-flat.pdf)

## Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description We conducted a coordinated experiment across Central and South America (18°N–29°S) using 210 freshwater microcosms to test how shifts in rainfall regimes and ecosystem size influence food-web structure and functioning (energy flux).

Research sample We used natural, detritus-based microcosms (bromeliad phytotelmata) as model systems due to their widespread distribution and ease of manipulation. Bromeliad aquatic ecosystems are inhabited by a diverse fauna of macroinvertebrates (insects, crustaceans), comprising top predators, mesopredators, and detritivores.

Sampling strategy At the end of the experiment (60th day), we dissected each bromeliad by removing and washing each leaf separately in running water and then filtered this water through 125 and 850  $\mu$ m sieves. We recorded the morphospecies and abundance of all aquatic macroinvertebrates (body size larger than 0.5 mm). We determined the body size and trophic interactions of each species. Trophic interactions were estimated through stomach content analysis based on morphological identifications of prey remains, together with field observations, feeding trials, and the literature. To calculate invertebrate body mass, we used allometric equations between the body length and dry mass, or mean of dry mass for very small insects.

Data collection After 60 days each bromeliad was dissected and washed, and its contents were removed entirely and separated into organisms and organic matter. Organisms were preserved in 70% ethanol and later counted, measured and identified to the lowest possible taxonomic level. Ecosystem size was the maximum water-holding capacity (plant filled to the point of overflowing). Trophic interactions were inferred from stomach-content analysis (morphological identification of prey remains), field observations, feeding trials and the literature, combined with predator–prey identity, body-size ratios and traits; "forbidden links" were excluded. Energy fluxes were modelled with fluxweb, not measured directly.

Timing and spatial scale The field experiments lasted 60 days. We replicated the experiment in seven sites across the Neotropics (18°N–29°S).

Data exclusions No data were excluded from the analyses.

Reproducibility We evaluated the effects of two main rainfall components: (i) the mean daily amount of rainfall,  $\mu$ ; and (ii) distribution of rainfall events around this mean through time,  $k$  (i.e., a measure of rainfall frequency). Sites with many dry days and infrequent rainfall resulted in low  $\mu$  and low  $k$  respectively. Ambient levels of the rainfall components were first determined using recent meteorological data from each site (see Methods). We applied a negative binomial distribution to these data to estimate the parameters  $\mu$  and  $k$ . We randomly applied ten levels of  $\mu$  (ranging from 0.1 to 3.0) and three levels of  $k$  ranging from 0.5 to 2.0 in a fully factorial experimental design at each of our seven sites for a total of  $10 \times 3 \times 7 = 210$  food webs in individual bromeliads. This allowed us to compare ambient, baseline conditions ( $\mu = 1$ ,  $k = 1$ ) and extreme fluctuations of rainfall quantity (10–300%) and frequency (50–200%) to average historical levels of daily variability for each site.

Randomization In each site, we randomly selected thirty bromeliads of the most abundant species and with the most common size. We used bromeliads that had more than 100 ml of tank capacity and thus can be colonized by the large predators. To remove any residual invertebrates, we hung the bromeliads upside down, and let them dry for seven days. For each site we homogenized detritus and

invertebrates collected from these bromeliads, then used equal aliquots of the mixture to initiate the community assembly in the experimental ecosystems

## Blinding

Each experiment was replicated seven times across the Neotropics. The PIs and their research groups conducted the experiment in these different sites following a standardized protocol. Typically the researchers cannot see what organisms are living into the bromeliad wells before dessicating them in the laboratory. Also, samples were allocated alphanumeric codes, which helped to avoid any observer bias during sample processing.

Did the study involve field work? ☒ Yes ☐ No

## Field work, collection and transport

### Field conditions

Each field site presented particular environmental conditions. These variations were controlled in our experiments.

### Location

We replicated the experiment at seven sites across Central and South America (from 29°S to 18°N), including Las Gamas (Argentina), Cardoso and Macae (Brazil), Colombia, Pitilla (Costa Rica), French Guiana, and Puerto Rico.

### Access & import/export

All the experiments were conducted following the rules and laws of the related countries.

### Disturbance

No significant disturbance was caused by manipulating small freshwater ecosystems

## Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

### Materials & experimental systems

### Methods

- n/a Involved in the study
- ☒ ☐ Antibodies
  - ☒ ☐ Eukaryotic cell lines
  - ☒ ☐ Palaeontology and archaeology
  - ☐ ☒ Animals and other organisms
  - ☒ ☐ Clinical data
  - ☒ ☐ Dual use research of concern
  - ☐ ☒ Plants

- n/a Involved in the study
- ☒ ☐ ChIP-seq
  - ☒ ☐ Flow cytometry
  - ☒ ☐ MRI-based neuroimaging

## Animals and other research organisms

Policy information about [studies involving animals](#); [ARRIVE guidelines](#) recommended for reporting animal research, and [Sex and Gender in Research](#)

### Laboratory animals

The study did not involve laboratory animals.

### Wild animals

While the taxonomic compositions of macroinvertebrate communities are site specific, all taxa can be assigned to three trophic levels: detritivores, mesopredators, and top-predators. The detritivores are typically represented by larvae of Diptera (Chironomidae (except Tanypodinae), Culicidae (except Toxorhynchites), Syrphidae, Tipulidae) and Coleoptera (Sciuridae). The largest top predators are represented by larvae of damselfly (Coenagrionidae), horsefly (Tabanidae), adult Coleoptera (Dytiscidae), and leeches (Hirudinea). The mesopredators often include larvae of Ceratopogonidae (Bezzia spp.), Corethrellidae, Toxorhynchites and Tanypodinae.

### Reporting on sex

We did not distinguish the sex of organisms, as sex-specific differences are not expected to influence the food-web metrics or ecological processes examined here, and therefore are not relevant to the objectives of this study.

### Field-collected samples

Experiments were performed in situ. No live field-collected animals were housed or maintained in the laboratory; after the experiment, preserved samples (70% ethanol) were processed in the laboratory for identification, counting and body-size measurement.

### Ethics oversight

No ethical approval or guidance was required because the experiment involved only invertebrates. And the countries where we conducted the experiments apparently have no specific laws that limit invertebrate manipulations.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

## Plants

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Seed stocks

Not applicable.

Novel plant genotypes

Not applicable.

Authentication

Not applicable.