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Systematic Map Protocol

Title
What are the spatial patterns in predicting vegetation range shift under global and local change drivers?

Citation:
Emma Underwood, Nigel Walford, Kerry Brown, Mark Mulligan. What are the spatial patterns in predicting vegetation range shift under global and local change drivers?: a Systematic Map Protocol. PROCEED-23-00072 Available from:
https://proceedevidence.info/protocol/view-result?id=72
https://doi.org/10.57808/proceed.2023.7

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Keywords
range shift, climate change adaptation, niche shift, vegetation, evidence atlas

Background
The last 30 years of range shift research have led to an accumulation of studies showing species have, and are likely to continue to alter their distributions globally in response to climate change (Klausmeyer and Shaw, 2009, Kuhn et al., 2016, Malcolm et al., 2006, Wróblewska and Mirski, 2018). Globally, plant distributions are changing, with general trends of poleward and upward (altitudinal) shifts (Parmesan and Yohe, 2003, Root et al., 2005, Root et al., 2003, Rosenzweig et al., 2008), but with a few studies showing exceptions to this general trend (Cannone and Pignatti, 2014). Many of the previous reviews of range shift studies have been meta-analyses which have explored a particular detail of range shift, for example, highlighting climate change as an important influence (Root et al., 2003), showing how biotic interactions may influence shifts using case studies (Hillerislambers et al., 2013), or exploring individual traits used in parameterising models (Maclean and Beissinger, 2017). Systematic reviews to date have incorporated multiple taxa including birds, mammals, fish and plants (Lenoir and Svenning, 2015, Root et al., 2003) as well as identifying shortfalls in which future research should address; but none appear to have focussed specifically on terrestrial plant range shift, nor has the systematic mapping approach been used. Comparatively fewer studies have been performed on vegetation range shift relative to those on animals. Moreover, there are few empirical studies documenting anthropogenically driven climate range shifts for long-lived terrestrial plants with long generation times, likely because their responses to environmental change are only observable on time scales spanning millennia. These factors have led to historically fewer systematic reviews, resulting in a lack of consolidation of progress in this area of range shift research.

Theory of change or causal model
(Attached theory of change graphic)

Stakeholder engagement
N/A

Objectives and review question
Objective: To understand the state of knowledge surrounding how future range shifts in plants are

predicted. Review question 1. What are the knowledge gaps surrounding vegetation range shift studies? a. How do studies formulate their range shift predictions? b. What models and parameters are used? c. What metrics and calculations are used? Review question 2. What are the geographical gaps surrounding vegetation range shift studies? a. What areas of the globe have (and have not) had range shift research published? b. Does range shift research focus in areas of Protected Areas or Biodiversity Hotspots?

Definitions of the question components

Q1. KNOWLEDGE GAPS & CLUSTERS a. How do studies formulate their range shift predictions? i. Do studies use a correlative (statistical, top-down) or mechanistic (process-based, bottom-up) approach? b. What models and parameters are used? i. Do studies use Maxent, Bayesian, ensembles or an alternative? ii. Do studies use other parameters beyond bioclimatic variables (e.g., temperature, precipitation) for example, land-use/land-cover or dispersal? c. What metrics and calculations are used? i. habitat net change (the area difference between the current and future predicted ranges), ii. habitat direction change (the up/downslope travel for elevational shifting), iii. or rate of change, an index for assessing whether species may be able to track climate change velocity. Q2. GEOGRAPHICAL GAPS & CLUSTERS a. What areas of the globe have (and have not) had range shift research published? b. Does range shift research focus in areas of Protected Areas or Biodiversity Hotspots?

Search strategy

SEARCH DATABASES: Scopus ISI Web of Knowledge Science Direct (No grey literature included): Initial searches of grey literature during pilot study showed no directly relevant non-academic studies that could be included. We believe this could be due to the niche/specific nature of the research question and the unlikelihood this area of work is being pursued without any links or collaboration with academia. There was one example of grey literature here: https://www.usgs.gov/programs/climate-adaptation-science-centers/science/understanding-species-range-shifts-response but it was excluded due to it being a review and unavailable/unpublished. Language: Set to collate all languages. Date: 1990 - 2020 BOOLEAN OPERATOR: "OR" and "AND" used TEXT SEARCH: TITLE-ABS-KEY SEARCH TERMS & OPERATORS (Scopus): TITLE-ABS-KEY (range* AND climate* AND plant* AND(model* OR sdm*)) > 1989 TITLE-ABS-KEY (range* AND climate* AND plant* AND landscape* OR *connectivity) AND PUBYEAR > 1989 TITLE-ABS-KEY (niche* AND climate* AND plant* AND landscape* OR *connectivity) AND PUBYEAR > 1989 TITLE-ABS-KEY (niche* AND climate* AND plant* AND land* OR *cover) AND PUBYEAR > 1989 TITLE-ABS-KEY (niche* AND climate* AND plant* AND land* OR *use) AND PUBYEAR > 1989 TITLE-ABS-KEY (cambio de gama* OR las plantas* OR cambio de área de distribución de las plantas*) AND PUBYEAR > 1989

Bibliographic databases

Three scientific bibliographic databases were searched: Scopus: we chose scopus due to global breadth of titles to remove any geographical bias in searches. ISI Web of Knowledge: chosen for functionality to work with EndNote referencing software. Science Direct: chosen to wide number of open-access articles available - also covers humanities in case of overlap of range shift between ecology/geography. These three bibliographic databases were searched between December 2020 and November 2021. The aim for this systematic map was to include 30 years of range shift research between 1990-2020. There was no end date set to the search terms to make sure the authors were made aware of any newer/relevant articles beyond 2020, not for inclusion but for reference (search conducted in early 2021). Search strings within databases: there was slight variability between search databases queries due to different rules. Unable to write all search keywords from across all three databases due to character limits. However, see "8. Search strategy" for search keywords used in Scopus which was what Web of Science and Science Direct searches were aiming to copy. Web of

Science: Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=1990-2020. Left hand truncation was not permitted in advanced queries within Web of Science so search terms were not completely identical to Scopus. Science Direct: Wildcards were not supported in Science Direct database therefore fewer results were returned overall. All results were combined into a single database using a reference manager where duplicates gathered from across the three search databases were removed.

Web-based search engines
N/A

Organisational websites
This site was searched but was unusable:
https://www.usgs.gov/programs/climate-adaptation-science-centers/science/understanding-species-range-shifts-response - see 8. Search strategy for further explanation.

Comprehensiveness of the search
PILOT STUDY: Conducting a pilot study to assess the number and quality of results returned by certain search term combinations. Testing MetaGear (R package) coding process. Outputs from the pilot will inform and improve query search terms.

Search update
N/A

Screening strategy
All papers gathered into single database. Using EndNote, remove duplicate studies. Export "Title and Abstract" information into a csv file. Use Metagear R package to blind screen each study using a "Yes", "No" or "Maybe" approach to sort the data. 90% of studies reviewed by reviewer 1, and 10% reviewed by reviewer no.2. Any studies that were not sorted unanimously (i.e., reviewer one decided "Yes" and reviewer no.2 decided "No" - this was highlighted to review again. Any studies sorted as "Maybe" by either reviewer were screened a second time, with both reviewers present to make a final decision.

Eligibility criteria
RELEVANT SUBJECT: 1. Vegetation range shift only - studies focussing on animals or had both were removed. 2. Terrestrial plants only - marine studies removed as rate of range shift or adaptation is not comparable due to faster paced changes in oceans ecosystems. STUDY DESIGN: 3. Predictive studies that use models to predict future changes to vegetation ranges (not historical). 4. Study had to be an individual study (not a review so as not to duplicate). OTHER RESTRICTIONS: 5. Date range 1990-2020 inclusive to include a large temporal time span (the pilot study returned no studies prior to 1990).

Consistency checking
90% of studies reviewed by reviewer 1, and 10% of studies were reviewed by reviewer 2. Any studies where reviewers disagreed were highlighted to review again. Any studies sorted as "Maybe" by either reviewer were screened a second time, with both reviewers present to make a final decision.

Reporting screening outcomes
Flow diagram showing numbers of studies removed at each stage of the systematic map. Summary table of article information and reason for inclusion/exclusion.

Study validity assessment

The study validity assessment was a combined approach during screening and coding stages, meaning we had double the opportunity to check a study was correct and eligible for this systematic map. It was important for us to include as many studies as possible that fit the criteria to understand the geographical breadth of who/what/where with regards to range shift studies on plants globally. However, if a study fit our inclusion criteria but was only available as an "abstract-only" paper, there was not enough information to categorise/code from, and therefore did not warrant inclusion to the next stage. These papers were separated from the main systematic map database and not included in the final map.

Consistency checking
Study is repeatable by anyone who has access and download capability of search engines and databases. As much as possible we chose open-source methods (e.g., Metagear in R for screening, and EviAtlas for visualising).

Data coding strategy
Our data coding strategy was a large, multi-column spreadsheet where where each row was an individual study. In separate columns, we collected information on each study such as reference type, journal name, publication year, language and access type. We also collected specific information on each study such as: Study scale (local - international), Geographic region, Study within a Protected Area or Biodiversity Hotspot, Study type - predictive only, or enhanced (with observed or empirical field data), Plant major group, Number of species included, Type of species records (presence-absence, etc.), Number of climate scenarios used, Furthest year of all predictions, Model type - Bayesian, ensemble, Maxent etc., Statistical type - correlative, mechanistic, combination, Parameters - which parameters used (bioclimatic, land cover, topography, edaphic, genetics etc.), Spatial resolution of study (km), Type of shift measured (upslope/latitudinal/general shift - geographically), Whether range shift velocity was measured, Range shift measurement metric (habitat change, field survey, rate of change), Range expansion/contraction/stasis - % of studies in study whose range is predicted to expand, contract or remain constant, Whether landscape connectivity - was measured or included, Was dispersal measured and how (dynamic, limited, not measured), Were biotic factors measured or used.

Meta-data to be coded
EXTRACTED FROM DATABASE: RefType - type of publication SourceName - Journal name PubYear - Year of publication Lang - Language Access - Open-access or not The rest of the codes (listed in 10. study validity assessment) were coded manually.

Consistency checking
Reviewer 1 assessed 90% Reviewer 2 assessed 10% Any studies that were not coded identically were highlighted for a re-review where both reviewers were present.

Type of mapping
Evidence atlas using EviAtlas which will include all codes mentioned. Hotspot mapping using GIS which highlight certain aspects of geography, scale and certain categorical variables to test for clustered relationships.

Narrative synthesis methods
Descriptive plots - EviAtlas

Knowledge gap identification strategy
Analysis of descriptive plots. Use of pivot tables on the fully-coded database to study change of variables over time and space (publication year, geography).

Demonstrating procedural independence
N/A

Competing interests
N/A

Funding information
Kingston University studentship.

Author’s contributions
ELU was reviewer 1 and KAB was reviewer 2 during systematic map screening and coding. Both ELU and KAB contributed to the planning and development of the systematic map and met regularly to discuss progress, validity and outcomes. ELU conducted interpretation of data. KAB, NW and MM supplied feedback on figures and iterations of writing. All authors read and approved the final manuscript.

Acknowledgements
Neal Haddaway provided support and guidance on converting the EviAtlas evidence atlas html file into github to produce an open-source web map of the systematic map.

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Submitted: Jan 19, 2023 | Published: Apr 27, 2023