



## How to evolve an alternative stable state

**Tim Coulson** based on reviews by Jean-François Arnoldi and 1 anonymous reviewer

A recommendation of:

Evolutionary emergence of alternative stable states in shallow lakes

Alice Ardichvili, Nicolas Loeuille, Vasilis Dakos (2022), *bioRxiv*, 2022.02.23.481597, ver. 3 peer-reviewed and recommended by Peer Community in Ecology  
<https://doi.org/10.1101/2022.02.23.481597>

Scripts used to obtain or analyze results

<https://doi.org/10.5281/zenodo.6606311>

Open Access

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### Recommendation

Alternative stable states describe ecosystems that can persist in more than one configuration. An ecosystem can shift between stable states following some form of perturbation. There has been much work on predicting when ecosystems will shift between stable states, but less work on why some ecosystems are able to exist in alternative stable states in the first place. The paper by Ardichvili, Loeuille, and Dakos (2022) addresses this question using a simple model of a shallow lake. Their model is based on a trade-off between access to light and nutrient availability in the water column, two essential resources for the macrophytes they model. They then identify conditions when the ancestral macrophyte will diversify resulting in macrophyte species living at new depths within the lake. The authors find a range of conditions where alternative stable states can evolve, but the range is narrow. Nonetheless, their model suggests that for alternative stable states to exist, one requirement is for there to be asymmetric competition between competing species, with one species being a better competitor on one limiting resource, with the other being a better competitor on a second limiting resource.

These results are interesting and add to growing literature on how asymmetric competition can aid species coexistence. Asymmetric competition may be widespread in nature, with closely related species often being superior competitors on different resources. Incorporating asymmetric competition, and its evolution, into models does complicate theoretical investigations, but Ardichvili, Loeuille, and Dakos' paper elegantly shows how substantial progress can be made with a model that is still (relatively) simple.

## References

Ardichvili A, Loeuille N, Dakos V (2022) Evolutionary emergence of alternative stable states in shallow lakes. bioRxiv, 2022.02.23.481597, ver. 3 peer-reviewed and recommended by Peer Community in Ecology. <https://doi.org/10.1101/2022.02.23.481597>

## Reviews

Toggle reviews

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### *Evaluation round #1*

DOI or URL of the preprint: <https://doi.org/10.1101/2022.02.23.481597>

Version of the preprint: 1

### *Author's Reply, None*

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*Decision by [Tim Coulson](#), 23 Apr 2022*

[Download recommender's annotations](#)

### *Reviewed by anonymous reviewer, 09 Apr 2022*

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### *Reviewed by [Jean-François Arnoldi](#), 22 Apr 2022*

Ardichvili, Loeuille and Dakos propose a modelling study of the evolution of macrophyte living-depth in shallow lakes. They look for the condition that lead to potential regime shifts, where a strategy may suddenly dominates, if nutrient enrichment varies.

This is seen as an example of a more general endeavour: to investigate the evolutionary underpinnings of ecological regime shifts.

The authors find that the modelling scenarios and parameters that lead to potential regime shifts are strictly nested within those that allow for sympatric diversification, and that the potentiality of regime shifts may change along the course of evolution. It should be noted that in the context considered, diversification is a prerequisite for regime shifts, since the latter require at least two competing strategies to coexist prior to the shift (see question 2-3 below). What is not obvious is that conditions leading to diversification can also allow for regime shifts. I suppose that it could have been the case that the two constraints would be mutually exclusive (but see question 1 below).

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I read the manuscript in depth and found it to be well conducted, with clear figures and rigorous numerical analysis of the model. I am confident that the reported findings are correct.

I do not have much to ask from the authors, the manuscript is probably publishable as is, but below I try to be a bit more critical in hope to help the authors improve the manuscript. Indeed, I think that some work is needed to make the message appealing to a wider audience than theoreticians interested in adaptive dynamics or regime shifts models.

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My major issue is that I have difficulties extracting a clear message that may be relevant beyond the specific modelling context considered. Because of that, I end up with many questions instead of a clear picture.

Questions:

1/Is it a coincidence that regime shifts and diversification emerge from similar mechanisms?

2/Are the strategies that coexist and allow for regime shifts resemble those found in shallow lakes? From the discussion I understood that this was not the case.

3/Is it really necessary to have sympatric speciation in order to find regime shifts of this kind in nature? Isn't it enough for populations to exhibit some plasticity or enough intraspecific phenotypic variation?

4/Since we are considering eco-evolutionary interplays, why not go one step further and allow strategies to evolve in response to nutrient enrichment?

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Suggestions:

A/The paper is very descriptive and quite long, I would suggest trying to make it more concise and focus on a clear message, simple and general enough to have a chance to be relevant in natural systems.

B/It would be good to first recall the scenarios and parameters that lead to regime shifts in the ecological model, so that we can see more clearly how constraining it is to ask for those conditions to be evolutionary stable.

Minor:

Fig.5 second line, please recall (e.g as a vertical line) the value  $N_0$  at which the evolution took place (5 mg/m<sup>2</sup> according to the table), so that we see the reference point from which the ecosystem is perturbed.

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