



HAL
open science

A comprehensive formula for decomposing change in community similarity into introduction and extinction events

Xianping Li, Céline Bellard, Feng Hu, Huixin Li

► **To cite this version:**

Xianping Li, Céline Bellard, Feng Hu, Huixin Li. A comprehensive formula for decomposing change in community similarity into introduction and extinction events. *Ecography*, 2019, 42 (10), pp.1714-1716. 10.1111/ecog.04613 . hal-03252885

HAL Id: hal-03252885

<https://hal.science/hal-03252885>

Submitted on 8 Jun 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

A comprehensive formula for decomposing change in community similarity into introduction and extinction events

Xianping Li, Céline Bellard, Feng Hu and Huixin Li

X. Li (<https://orcid.org/0000-0003-4892-5953>), F. Hu and H. Li (<https://orcid.org/0000-0003-1058-7610>) (huixinli@njau.edu.cn), College of Resources and Environmental Sciences, Nanjing Agricultural Univ., CN-210095 Nanjing, PR China. – C. Bellard (<https://orcid.org/0000-0003-2012-1160>), Laboratoire Ecologie, Systématique et Evolution, Univ. Paris-Sud, CNRS, AgroParisTech, Univ. Paris-Saclay, Orsay Cedex, France.

Abstract

22 (Abstract)

23 The global phenomenon of biotic homogenization is threatening biodiversity worldwide. To explain
24 homogenization, multiple frameworks based on different classifications of introduction and
25 extinction events have been proposed. However, comprehensive and generalized approaches are
26 still lacking. Using mathematical derivation, we present a single comprehensive formula, which
27 demonstrates that similarity changes can be precisely determined by the frequencies of six event
28 types, initial similarity, and total number of species. The formula also shows that the effect
29 directions for all events are type-dependent, while their effect magnitudes generally covary with
30 initial similarity and decrease with increasing species numbers. We argue that future empirical
31 and/or predictive studies of biotic homogenization should pay more attention to these direct factors
32 for a deep understanding of community similarity changes.

33

34

35 Keywords: biotic homogenization, biological invasion, community similarity

36

37 **Introduction**

38 Biological invasion, climate change, and urbanization are presently altering species compositions
39 worldwide (McKinney and Lockwood 1999, McKinney 2006, Qian and Ricklefs 2006, Magurran et
40 al. 2015, Gossner et al. 2016, Newbold et al. 2018), while changes in community composition are
41 generally associated with higher community similarities and losses of community distinctiveness
42 (McKinney and Lockwood 1999, Olden et al. 2004). The underlying processes of homogenization
43 are still unclear and especially lack theoretical underpinnings (Olden and Poff 2003, Rosenblad and
44 Sax 2017). It was theoretically and empirically proposed that similarity changes are determined by
45 different events (Olden and Poff 2003, Villéger and Brosse 2012, Rosenblad and Sax 2017). For
46 example, the introduction of the same species to two sites would result in an increase in similarity,
47 while the extinction of same native species from two sites would lead to a decrease in similarity. In
48 complement to earlier works on the mathematical description of homogenization (Olden and Poff
49 2003, Villéger and Brosse 2012), Rosenblad and Sax (2017) provided a concise framework of six
50 types of introduction and extinction events with formula derivations to qualify the relative
51 importance of these events on changes in community similarity. They found that the effects of these
52 events vary according to event type and initial similarity. However, their conclusions mainly derive
53 from simplified assumptions of species richness and number of events, which prevent us from
54 understanding the precise relationships among initial similarity, different event types, and total
55 number of species. Through mathematical derivation (see below) and simulations (Fig. 1), we thus
56 aim to: 1) combine previously identified determinants of change in similarity into a single
57 comprehensive formula; 2) illustrate how these determinants interact with each other; and 3)
58 highlight the important role of gradient in species richness in affecting the magnitude of similarity

59 changes.

60 With this aim, and as documented by Rosenblad and Sax (2017) and Longman et al. (2018), the
61 types of introductions and extinctions among assemblage pairs can be characterized into seven
62 classes, six of which (I01, I02, I12, E10, E20, and E21) influence change in similarity (Fig. 1). In
63 keeping with Rosenblad and Sax (2017), we use Jaccard's index to quantify community similarity, J
64 $= S / T$, where J is Jaccard's coefficient, S the number of species shared by communities, and T the
65 total number of species in the two communities. We use the subscripts "ini" and "cur" to indicate
66 the metrics for the initial and current assemblage pair, respectively: for example, J_{ini} is the initial
67 similarity, and J_{cur} the current similarity. n_i is the number of species affected by event type i . Based
68 on the definitions of event types, we know that $T_{cur} = T_{ini} + n_{I02} + n_{I01} - n_{E20} - n_{E10}$, and $S_{cur} = S_{ini} +$
69 $n_{I12} + n_{I02} - n_{E21} - n_{E20}$. Thus, the overall change in similarity is as follows:

$$\begin{aligned} 70 \quad \Delta J &= J_{cur} - J_{ini} \\ 71 \quad &= S_{cur}/T_{cur} - J_{ini} \\ 72 \quad &= (S_{ini} + n_{I12} + n_{I02} - n_{E21} - n_{E20})/T_{cur} - J_{ini} \\ 73 \quad &= (T_{ini} \times J_{ini} + n_{I12} + n_{I02} - n_{E21} - n_{E20})/T_{cur} - J_{ini} \\ 74 \quad &= [(T_{ini} \times J_{ini} + n_{I12} + n_{I02} - n_{E21} - n_{E20}) - J_{ini} \times T_{cur}]/T_{cur} \\ 75 \quad &= [(T_{ini} \times J_{ini} + n_{I12} + n_{I02} - n_{E21} - n_{E20}) - J_{ini} \times (T_{ini} + n_{I02} + n_{I01} - n_{E20} - n_{E10})]/T_{cur} \\ 76 \quad &= [n_{I12} + (1 - J_{ini}) \times n_{I02} - J_{ini} \times n_{I01} - n_{E21} - (1 - J_{ini}) \times n_{E20} + J_{ini} \times n_{E10}]/(T_{ini} + n_{I02} + n_{I01} - n_{E20} - \\ 77 \quad &n_{E10}) \end{aligned}$$

78 Our formula and simulation results rigorously confirm that: 1) more I12, I02, and E10 events
79 tend to lead to homogenization while more I01, E21, and E20 events tend to lead to differentiation
80 (Rosenblad and Sax 2017) (Fig. 1); and 2) for I02 and E20, the effect magnitude of similarity

81 negatively covaries with initial similarity, while the effect magnitudes of I01 and E10 positively
82 covary with initial similarity. Importantly, our results also reveal the crucial role of the total number
83 of species in determining the magnitude of similarity changes (Olden and Poff 2003) (Fig. 1).
84 Namely, the magnitude of change in similarity for all six events decrease with the increasing
85 number of initial species. We further demonstrate that the effects of I12 and E21 are mediated by
86 the initial similarity when Sørensen's index of similarity is adopted (Supplementary material
87 Appendix 1). Because the number of species that are initially shared or unique to different sites
88 influences the potential number of extinctions, some extinction or introduction events (e.g. E10,
89 E20, E21, I12) are ecologically constrained by initial similarity and total species richness (Fig. 1).

90 Using the formula, we demonstrate that the direction and magnitude of change in community
91 similarity are determined by the frequencies of six introduction and extinction event types, initial
92 similarity, and total species richness. The formula provides a unified theoretical framework for
93 understanding homogenization and differentiation processes, which are documented in numerous
94 empirical studies (Qian and Ricklefs 2006, Villéger et al. 2011, Toussaint et al. 2014, Magurran et al.
95 2015). We also provide an interactive web application for visualizing the simultaneous effects of
96 different factors on similarity changes (<https://similarity-changes.shinyapps.io/sim_app/>). Our
97 formula could potentially be used to predict future patterns of similarity changes based on current
98 community compositions and the estimated introduction and extinction rates under future global
99 change (Olden and Poff 2003, Rosenblad and Sax 2017, Longman et al. 2018). The formula could
100 also provide a useful framework in which to explore how other factors (such as spatial variation in
101 human activities) determine the frequencies of different event types, which in turn drive patterns of
102 change in similarity. Our work comprehensively and rigorously combines previously identified

103 determinants of change in similarity such as different event types and initial similarity. Further, our
104 results emphasize that total richness should be considered when predicting or explaining the
105 magnitude of change in similarity among assemblage pairs.

106

107 **Acknowledgements:** This project was funded by National Natural Science Foundation of China
108 (no. 41571244).

109 **Conflict of interest:** The authors declare no conflict of interest.

110

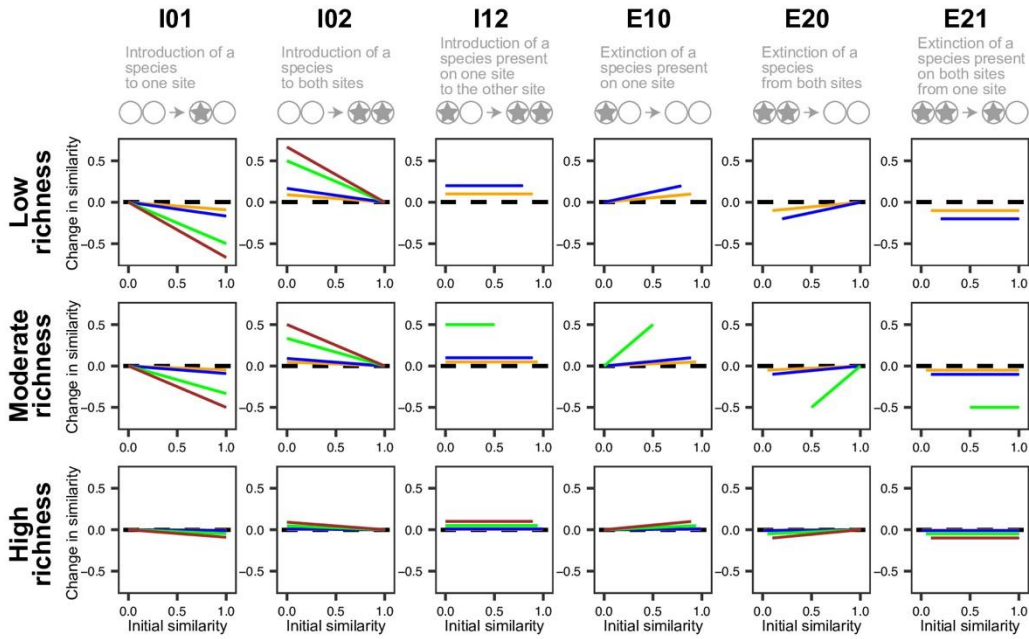
111 **References**

- 112 Gossner, M. M. et al. 2016. Land-use intensification causes multitrophic homogenization of
113 grassland communities. – *Nature* 540: 266-269.
- 114 Longman, E. K. et al. 2018. Extreme homogenization: The past, present and future of mammal
115 assemblages on islands. – *Global Ecol. Biogeogr.* 27: 77-95.
- 116 Magurran, A. E. et al. 2015. Rapid biotic homogenization of marine fish assemblages. – *Nature*
117 *Communications* 6: 8405.
- 118 McKinney, M. L. 2006. Urbanization as a major cause of biotic homogenization. – *Biol. Conserv.*
119 127: 247-260.
- 120 McKinney, M. L. and Lockwood, J. L. 1999. Biotic homogenization: a few winners replacing many
121 losers in the next mass extinction. – *Trends Ecol. Evol.* 14: 450-453.
- 122 Newbold, T. et al. 2018. Widespread winners and narrow-ranged losers: Land use homogenizes
123 biodiversity in local assemblages worldwide. – *PLoS Biol.* 16: e2006841.
- 124 Olden, J. D. et al. 2004. Ecological and evolutionary consequences of biotic homogenization. –
125 *Trends Ecol. Evol.* 19: 18-24.
- 126 Olden, J. D. and Poff, N. L. 2003. Toward a Mechanistic Understanding and Prediction of Biotic
127 Homogenization. – *The American Naturalist* 162: 442-460.
- 128 Qian, H. and Ricklefs, R. E. 2006. The role of exotic species in homogenizing the North American
129 flora. – *Ecol. Lett.* 9: 1293-1298.
- 130 Rosenblad, K. C. and Sax, D. F. 2017. A new framework for investigating biotic homogenization
131 and exploring future trajectories: oceanic island plant and bird assemblages as a case study. –
132 *Ecography* 40: 1040-1049.
- 133 Toussaint, A. et al. 2014. Historical assemblage distinctiveness and the introduction of widespread
134 non-native species explain worldwide changes in freshwater fish taxonomic dissimilarity. –
135 *Global Ecol. Biogeogr.* 23: 574-584.
- 136 Villéger, S. et al. 2011. Homogenization patterns of the world's freshwater fish faunas. – *Proc. Natl.*
137 *Acad. Sci.* 108: 18003-18008.
- 138 Villéger, S. and Brosse, S. 2012. Measuring changes in taxonomic dissimilarity following species
139 introductions and extirpations. – *Ecol. Indicators* 18: 552-558.

140

141

142



143

144 **Figure 1.** Relationship between initial similarity and change in similarity for each
 145 event type under different initial richness scenarios based on the Jaccard-derived
 146 formula. The top diagrams illustrating the events are adopted from Longman et al.
 147 (2018); circles indicate communities, and stars the introduced or extinct species. Low,
 148 moderate, and high richness were set at 50, 100, and 1000, respectively. For a given
 149 event type, four instances (orange line for 5 events, blue for 10, green for 50, and
 150 brown for 100) were used to demonstrate the effects of event frequency on the
 151 relationship, with the numbers of other event types kept as zero.

152

153