Ecography

ECOG-04985
Erős, T., Comte, L., Filipe, A. F., Ruhi, A., Tedesco, P. A., Brose, U., Fortin, M.-J., Giam, X., Irving, K., Jacquet, C., Larsen, S., Sharma, S. and Olden, J. D. 2020. Effects of nonnative species on the stability of riverine fish communities. – Ecography doi: 10.1111/ecog.04985

Supplementary material

Appendix 1

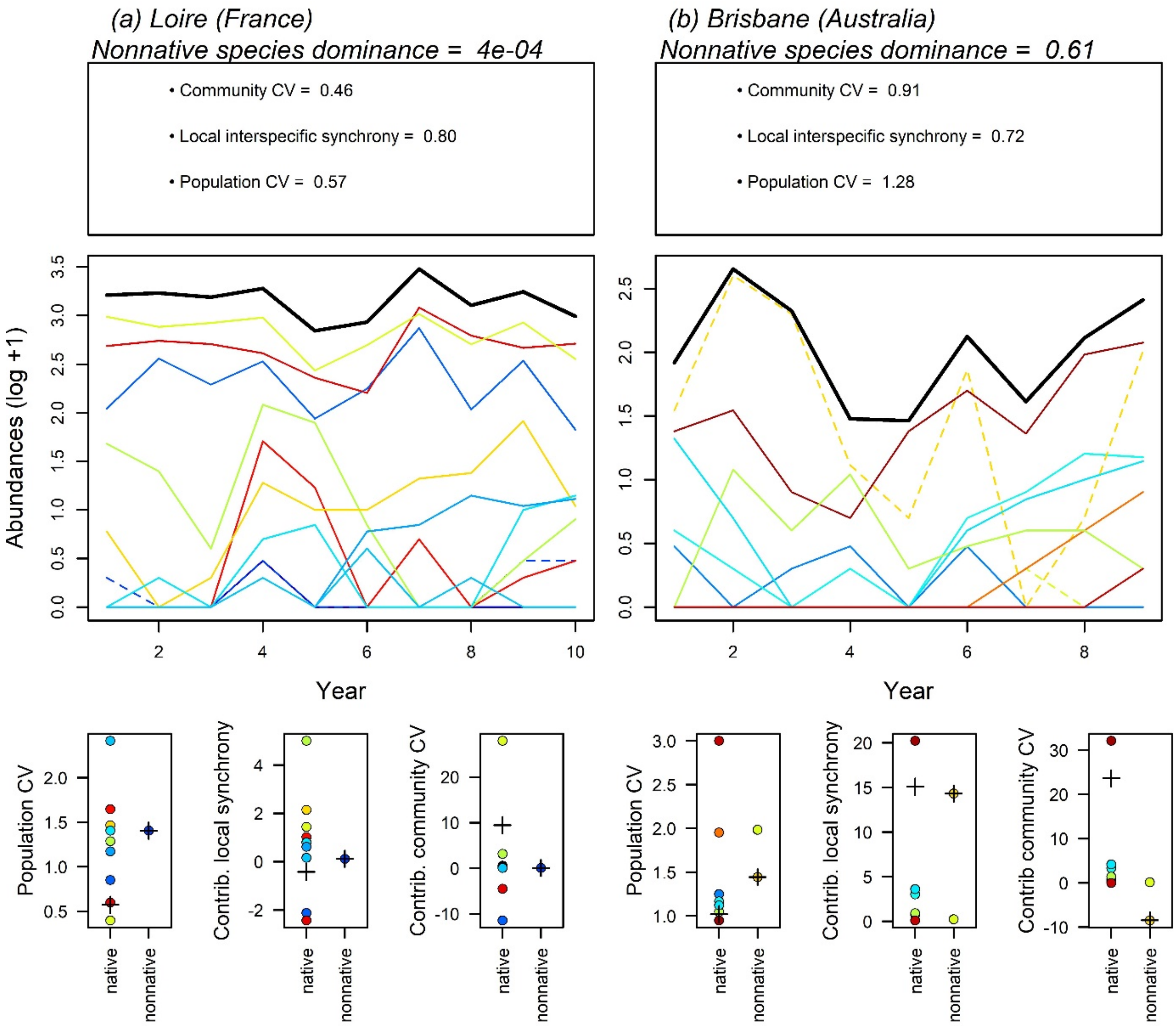

Figure A1. Population and community dynamics in two exemplar sites under a relatively (a) low [Loire, France] and (b) high [Brisbane, Australia] nonnative species dominance at the site level. The upper panels illustrate the population CV, local interspecific synchrony and community CV calculated at the site level. The middle panels illustrate the temporal fluctuations in abundance (log + 1) where each color represents a different population with solid and dotted lines for native and nonnative species, respectively; the thick black lines show the fluctuations in total community abundance. The bottom panels illustrate species-specific population CV, contributions of individual species to local interspecific synchrony and contribution of individual species to community CV where each colored dot represents a population (same color code as before) and the crosses the weighted average values for native and nonnative species separately.

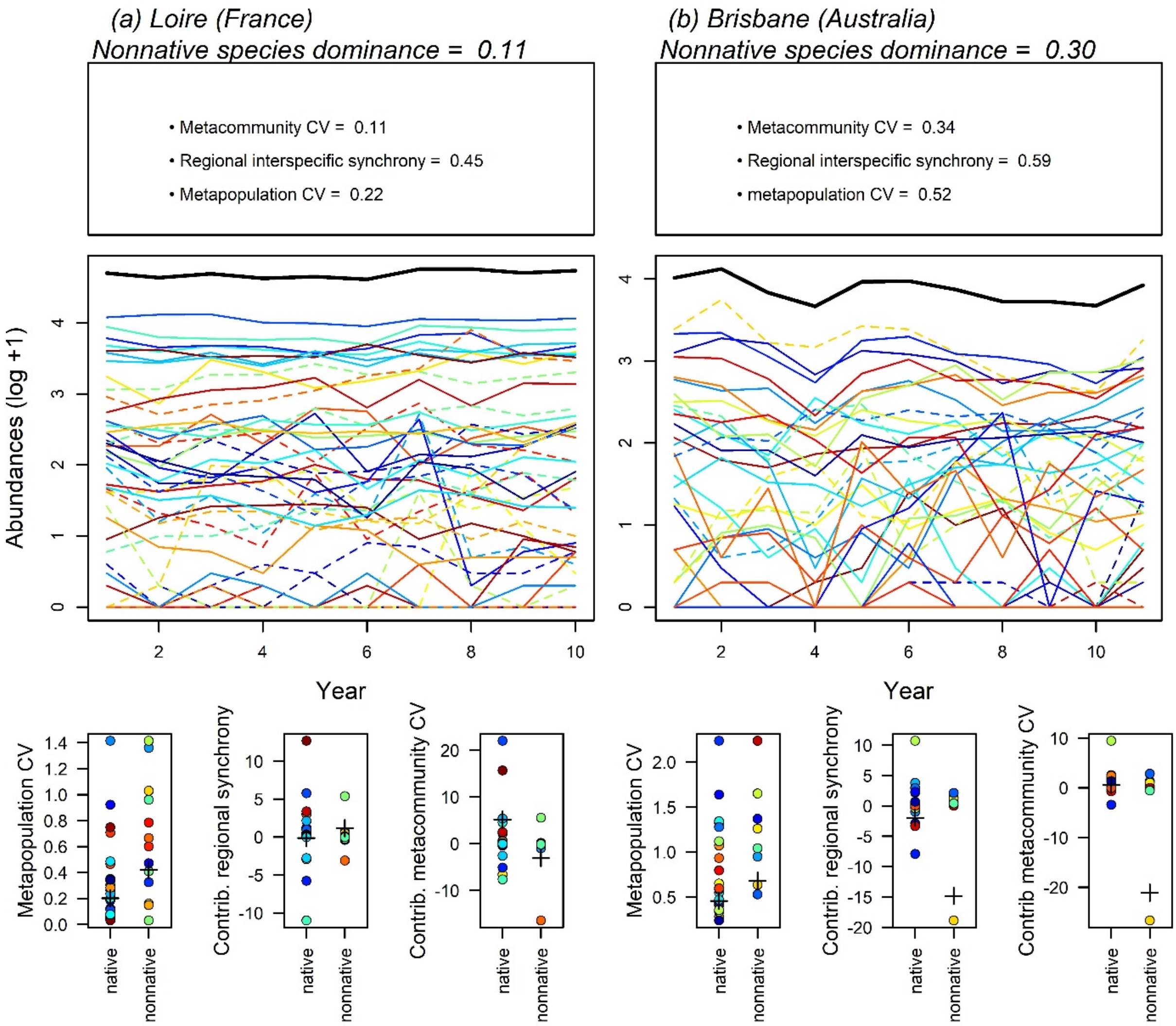

Figure A2. Metapopulation and metacommunity dynamics in two exemplar basins: (a) Loire (France) and (b) Brisbane (Australia) with different degrees of nonnative species dominance at the basin level. The upper panels illustrate the metapopulation CV, regional interspecific synchrony and metacommunity CV calculated at the basin level. The middle panels illustrate the temporal fluctuations in abundance (log + 1) where each color represents a different metapopulation with solid and dotted lines for native and nonnative species, respectively; the thick black lines show the fluctuations in total metacommunity abundance. The bottom panels illustrate species-specific metapopulation CV, contributions of individual species to regional interspecific synchrony and contribution of individual species to metacommunity CV where each colored dot represents a metapopulation (same color code as before) and the crosses the weighted average values for native and nonnative species separately.

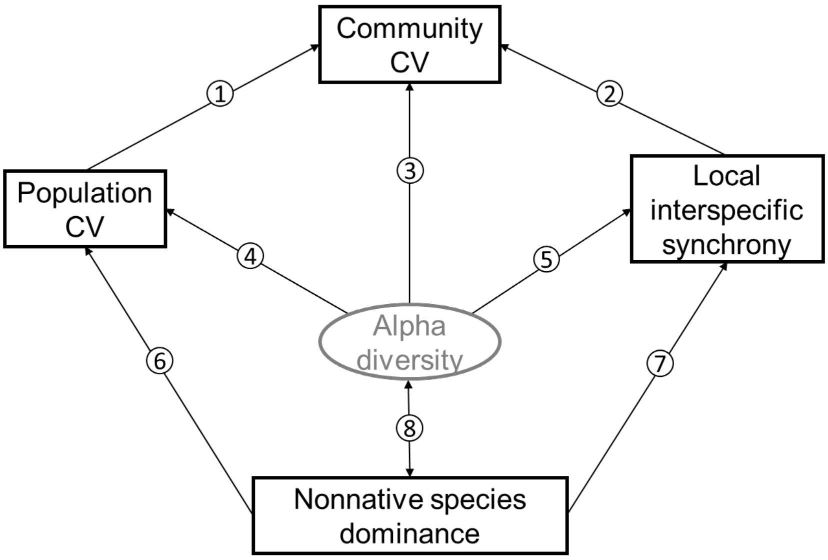

Figure A3. Conceptual figure illustrating the potential effects of nonnative species dominance on temporal variability and synchrony at the site scale. The contribution of population CV and local interspecific synchrony to community CV are well understood (paths 1-2; Loreau and de Mazancourt 2008, Wang and Loreau 2014). Less well understood are the effects of nonnative species dominance on community CV. We hypothesized that nonnative species increase native population CV through competitive or predation interactions (path 6; Gozlan et al. 2010, Cucherousset and Olden 2011). We also hypothesized that these effects scale up to the community level (through path 1), leading to higher community CV with increasing nonnative species dominance. Alternatively, we expected compensatory asynchronous population dynamics in native species in response to nonnative species to increase local interspecific synchrony (path 7; Gonzalez and Loreau 2009). In turn, we expected these effects to act as an opposite force so that community CV decreases with increasing nonnative species dominance (through path 2; Micheli et al. 1999). Alpha diversity is also expected to decrease community CV directly (path 3) or through increase/decrease in population CV and decrease in local interspecific synchrony (paths 4-5; Wang et al. 2019). Nonnative species dominance may thus influence community CV if it is correlated with alpha diversity, although the causal direction of this correlation is unclear (path 8).

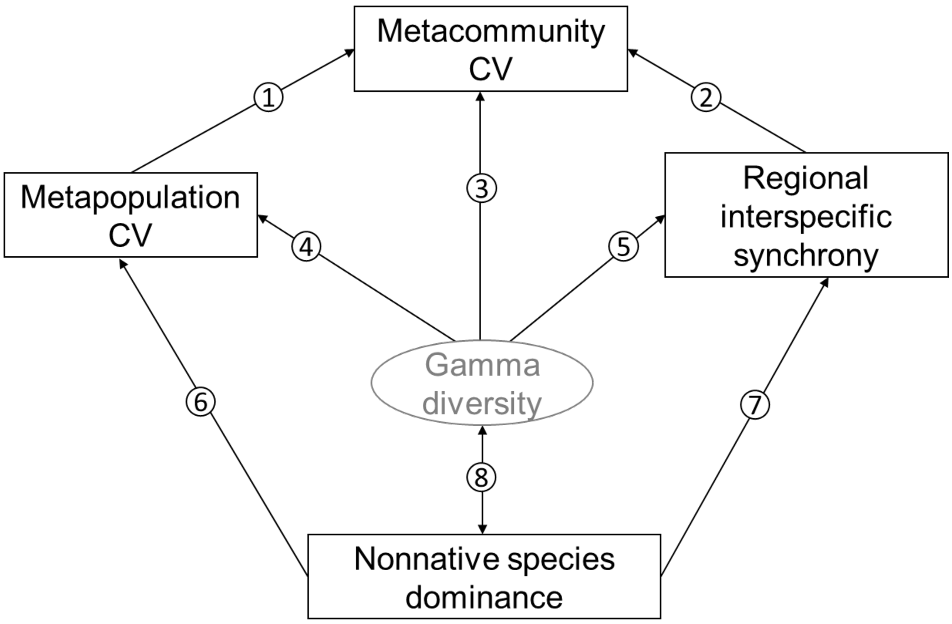

Figure A4. Conceptual figure illustrating the potential effects of nonnative species dominance on temporal variability and synchrony at the basin scale. Similarly to the site-scale analysis, we examined whether nonnative species dominance may affect metapopulation CV (positive effect expected; path 6) and regional interspecific synchrony (positive effect expected; path 7) and how these effects may scale up to metacommunity CV (through paths 1-2). Our modelling approach also accounts for the effects of gamma diversity on metacommunity CV (negative effect expected; path 3), metapopulation CV (positive or negative effect expected; path 4) and regional interspecific synchrony (negative effect expected; path 5) (Wilcox et al. 2017, Wang et al. 2019). As before, species dominance is also expected to influence metacommunity CV indirectly through its covariation with gamma diversity (path 8).

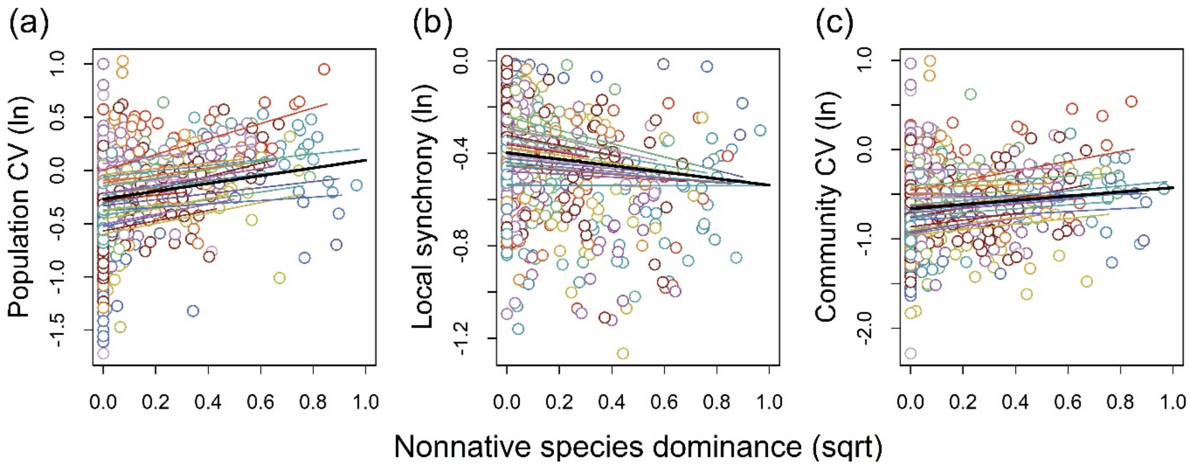

Figure A5. Effect of nonnative species dominance within communities (i.e. the mean ratio of total nonnative abundance to total community abundance) on: (a) population CV, (b) local interspecific synchrony, (c) community CV. Relationships are shown overall (fixed effects, black lines) and for individual basins (random effects, colored lines) after accounting for variations in alpha diversity (all $P < 0.05$; Table S2) by setting species richness to its mean value across communities. Each dot represents a site where the color represents a basin. The relationships are shown for the entire community (both native and nonnative species pools). See Figure 4 for the results including the native species pool only.

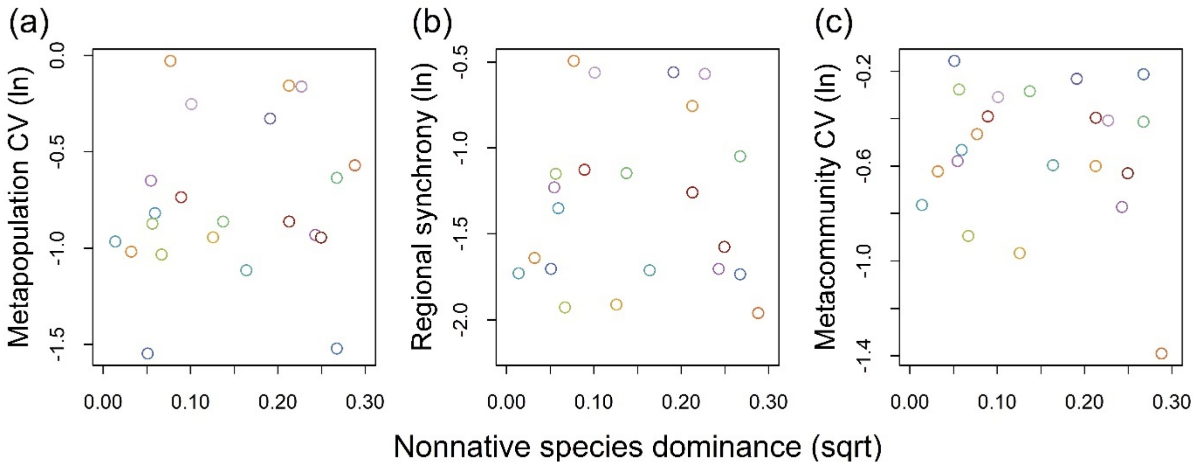

Figure A6. Effect of nonnative species dominance within metacommunities (i.e. the mean ratio of total nonnative abundance to total metacommunity abundance) on: (a) metapopulation CV, (b) regional interspecific synchrony, and (c) metacommunity CV. Relationships are shown after accounting for variations in gamma diversity (all $P \geq 0.05$; Table S2) by setting species richness to its mean value across metacommunities. Each dot represents a basin using the same color legend than in Fig. S5. The relationships are shown for the entire metacommunity (both native and nonnative species pools). See Figure 6 for the results including the native species pool only.

Table A1. Origin and characteristics of the monitoring datasets used in this study. Species richness (SR) and nonnative species dominance are given at the site (range of values for each basin) and basin (in brackets) scale. SR is defined as the mean number of species recorded through time at a given site or basin and nonnative species dominance as the mean ratio of total nonnative abundance to total community (site-scale) or metacommunity (basin-scale) abundance.

HydroBASIN ID[1]	Country	Basin name	N_{sites}	Sampling protocol	Time span	SR	Nonnative species dominance	Source
2080008490	Hungary	Danube	38	Electrofishing	2008-2017	1.20-13.00 (30.50)	0.00-0.71 (0.14)	Erős et al. 2014[2] & Erős et al. Unpublished
2080016510	France	Rhone	27	Electrofishing	2006-2015	1.00-20.10 (38.40)	0.00-0.24 (0.06)	French national monitoring program[3]
2080017150	Spain	Ebro	18	Electrofishing	2007-2016	1.00-9.30 (14.90)	0.00-0.32 (0.05)	Pais Vasco monitoring program[4]
2080020330	France	Adour	12	Electrofishing	1995-2004	1.20-12.30 (20.10)	0.00-0.06 (0.004)	French national monitoring program[3]
2080020590	France	Garonne	48	Electrofishing	1995-2004	1.00-16.10 (35.80)	0.00-0.56 (0.03)	French national monitoring program[3]
2080020620	France	Dordogne	16	Electrofishing	1995-2004	1.70-12.60 (24.10)	0.00-0.21 (0.02)	French national monitoring program[3]
2080021030	France	Loire	63	Electrofishing	1997-2006	1.00-20.00 (37.50)	0.00-0.55 (0.11)	French national monitoring program[3]
2080022150	France	Seine	48	Electrofishing	1995-2004	3.10-18.70 (34.30)	0.00-0.17 (0.02)	French national monitoring program[3]
2080022970	France	Meuse	10	Electrofishing	1996-2005	2.10-19.30 (27.10)	0.00-0.79 (0.04)	French national monitoring program[3]
2080023010	France	Rhine	34	Electrofishing	1994-2003	1.00-14.80 (32.80)	0.00-0.09 (0.01)	French national monitoring program[3]
2080031060	Sweden	Angermanalven	28	Electrofishing	2007-2016	0.90-4.30 (8.90)	0.00-0.03 (0.001)	Swedish Electrofishing RegiSter[5]
2080031160	Sweden	Indalsalven	20	Electrofishing	2007-2016	0.90-3.50 (7.20)	0.00-0.05 (0.003)	Swedish Electrofishing RegiSter[5]
2080031490	Sweden	Dalalven	36	Electrofishing	2007-2016	0.80-4.20 (8.90)	0.00-0.81 (0.07)	Swedish Electrofishing RegiSter[5]
2080033010	Sweden	Lagan	15	Electrofishing	2003-2012	1.70-4.10 (8.20)	0.00-0.17 (0.01)	Swedish Electrofishing RegiSter[5]
2080048980	UK	Avon	10	Electrofishing+seining	2004-2013	2.00-6.30 (11.90)	0.00-0.28 (0.08)	National Fish Populations Database[6]
2080049120	UK	Exe	10	Electrofishing+seining	2002-2016	1.93-2.80 (4.40)	0.00-0.001 (0.0002)	National Fish Populations Database[6]
2080053100	UK	Tees	17	Electrofishing+seining	2002-2011	1.00-8.80 (11.30)	0.00-0.27 (0.05)	National Fish Populations Database[6]
2080053240	UK	Derwent	60	Electrofishing+seining	2002-2011	0.90-9.50 (19.00)	0.00-0.45 (0.06)	National Fish Populations Database[6]
2080053260	UK	Trent	15	Electrofishing+seining	2002-2011	1.70-11.60 (17.70)	0.00-0.02 (0.004)	National Fish Populations Database[6]
2080053720	UK	Chelmer	10	Electrofishing+seining	2001-2010	6.90-10.60 (15.70)	0.00-0.01 (0.003)	National Fish Populations Database[6]
2080053790	UK	Thames	58	Electrofishing+seining	2003-2012	3.60-9.70 (20.90)	0.00-0.07 (0.003)	National Fish Populations Database[6]
5080070390	Australia	Brisbane	35	Electrofishing+seining	2004-2014	3.82-12.82 (27.73)	0.00-0.93 (0.30)	Ecosystem Health Monitoring Program (EHMP) Queensland[7]
5080070440	Australia	Logan	16	Electrofishing+seining	2005-2014	3.30-12.30 (24.70)	0.00-0.73 (0.23)	Ecosystem Health Monitoring Program (EHMP) Queensland[7]
7080008710	US	Colorado	12	Electrofishing+seining	1994-2003	3.00-7.80 (15.70)	0.00-0.62 (0.07)	Ruhi et al. 2016[8]

7080041400	US	Potomac	17	Electrofishing	1998-2007	5.10-22.60 (29.70)	0.00-0.18 (0.05)	Montgomery county monitoring program[9]
7080047060	US	Mississippi	11	Electrofishing+poisoning	2004-2014	13.60-22.60 (45.40)	0.001-0.01 (0.01)	Ohio statewide monitoring program[10]
7080049270	US	Rio Grande	12	Electrofishing+seining	2002-2011	6.80-10.70 (19.00)	0.16-0.41 (0.24)	Ruhi et al. 2016[8]

[1] Lehner, B., Verdin, K., Jarvis, A. (2008) New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89: 93-94.
[2] Erős, T., Sály, P., Takács, P., Higgins, C.L., Bíró, P., Schmera, D. (2014) Quantifying temporal variability in the metacommunity structure of stream fishes: the influence of non-native species and environmental drivers. Hydrobiologia 722: 31-43.
[3] available at http://www.naiades.eaufrance.fr/acces-donnees#/hydrobiologie
[4] available at http://www.euskadi.eus/sistema-de-informacion-de-la-naturaleza-de-euskadi/web01-a2ingdib/es/
[5] available at https://www.slu.se/en/departments/aquatic-resources1/databases1/database-for-testfishing-in-streams/
[6] available at https://data.gov.uk/dataset/d129b21c-9e59-4913-91d2-82faef1862dd/nfpd-freshwater-fish-survey-relational-datasets
[7] available upon request at https://acef.tern.org.au/geonetwork/srv/eng/metadata.show?uuid=1876ed37-3503-434e-82c3-0f81fa4eb64f
[8] Ruhi, A. et al. 2016. Declining streamflow induces collapse and replacement of native fish in the American Southwest. - Front. Ecol. Environ. 14: 465–472.
[9] available upon request at https://www.montgomerycountymd.gov/water/streams/data.html
[10] available at http://www.orsanco.org/data/

Table A2. Results of the multiple regressions revealing the effects of nonnative species dominance on (a) population CV, (b) local interspecific synchrony, (c) community CV, (d) metapopulation CV, (e) regional interspecific synchrony, and (f) metacommunity CV, after accounting for variations in species diversity among (meta)communities. Nonnative species dominance was defined as the mean ratio of total nonnative abundance to total (meta)community abundance. Alpha and gamma diversity, together with variability and synchrony metrics were *ln* transformed prior to model fitting; nonnative species dominance was *root-squared* transformed. The models were developed based on the entire community/metacommunity (both native and nonnative species pools). See Table 1 for the results including the native species pool only.

Fixed effects	Estimate	Standard error	df	*t*-value	*P*
(a) population CV					
Alpha diversity	0.24	0.03	667	7.78	<0.001
Nonnative species dominance	0.36	0.09	667	4.01	<0.001
(b) local interspecific synchrony					
Alpha diversity	-0.13	0.03	667	-4.31	<0.001
Nonnative species dominance	-0.14	0.05	667	-2.96	0.003
(c) community CV					
Alpha diversity	0.09	0.03	667	2.58	0.010
Nonnative species dominance	0.23	0.10	667	2.25	0.025
(d) metapopulation CV					
gamma diversity	0.07	0.14	24	-2.67	0.621
nonnative species dominance	0.33	0.56	24	0.59	0.559
(e) regional interspecific synchrony					
gamma diversity	-0.01	0.05	24	-0.23	0.821
nonnative species dominance	-0.35	0.21	24	-1.64	0.115
(f) metacommunity CV					
gamma diversity	0.07	0.18	24	0.42	0.678
nonnative species dominance	-0.41	0.71	24	-0.58	0.564

Supplementary references

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