

OPINION



WILEY

Revisiting global trends in freshwater insect biodiversity

Sonja C. Jähnig^{1,2} | Viktor Baranov³ | Florian Altermatt^{4,5} |
 Peter Cranston⁶ | Martin Friedrichs-Manthey^{1,7} | Juergen Geist⁸ |
 Fengzhi He¹ | Jani Heino⁹ | Daniel Hering¹⁰ | Franz Hölker¹ |
 Jonas Jourdan¹¹ | Gregor Kalinkat¹ | Jens Kiesel¹ | Florian Leese¹² |
 Alain Maasri¹ | Michael T. Monaghan^{1,7} | Ralf B. Schäfer¹³ |
 Klement Tockner^{1,7,14} | Jonathan D. Tonkin¹⁵ | Sami Domisch¹

¹Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany

²Geography Department, Faculty of Mathematics and Natural Sciences, Humboldt-Universität zu Berlin, Berlin, Germany

³Department of Biology II, LMU Munich Biocenter, Martinsried, Germany

⁴Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zürich, Switzerland

⁵Department of Aquatic Ecology, Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland

⁶Australian National University, Canberra, Australian Capital Territory, Australia

⁷Institut für Biologie, Freie Universität Berlin, Berlin, Germany

⁸Aquatic Systems Biology, Technical University of Munich, TUM School of Life Sciences, Freising, Germany

⁹Freshwater Centre, Finnish Environment Institute, Oulu, Finland

¹⁰Aquatic Ecology, University of Duisburg-Essen, Essen, Germany

¹¹Department of Aquatic Ecotoxicology, Institute for Ecology, Evolution and Diversity, Goethe University Frankfurt am Main, Frankfurt am Main, Germany

¹²Aquatic Ecosystem Research, University of Duisburg-Essen, Essen, Germany

¹³Institute for Environmental Sciences, Quantitative Landscape Ecology, University of Koblenz-Landau, Landau, Germany

¹⁴Austrian Science Fund FWF, Vienna, Austria

¹⁵School of Biological Sciences, University of Canterbury, Christchurch, New Zealand

Correspondence

Sonja C. Jähnig, Leibniz Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany.
 Email: sonja.jaehnic@igb-berlin.de

Funding information

Federal Agency for Nature Conservation (BfN), Grant/Award Number: 3518685A08; NSF Macrosystems Biology Program, Grant/Award Number: 1442595; Leibniz-Gemeinschaft, Grant/Award Number: J45/2018

Abstract

A recent global meta-analysis reported a decrease in terrestrial but increase in freshwater insect abundance and biomass (van Klink et al., *Science* 368, p. 417). The authors suggested that water quality has been improving, thereby challenging recent reports documenting drastic global declines in freshwater biodiversity. We raise two major concerns with the meta-analysis and suggest that these account for the discrepancy with the declines reported elsewhere. First, total abundance and biomass alone are poor indicators of the status of freshwater insect assemblages, and the observed differences may well have been driven by the replacement of sensitive species with tolerant ones. Second, many of the datasets poorly represent global trends and reflect responses to local conditions or nonrandom site selection. We conclude that the results of

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2020 The Authors. *WIREs Water* published by Wiley Periodicals LLC.

the meta-analysis should not be considered indicative of an overall improvement in the condition of freshwater ecosystems.

This article is categorized under:

Water and Life > Conservation, Management, and Awareness

KEYWORDS

freshwater ecosystems, insect abundance, long-term research, threats

A recent global meta-analysis of insect abundance and biomass from 63 freshwater and 103 terrestrial datasets revealed diverging trends between the two realms, with a reported decrease of ~9% per decade in terrestrial insects but an increase of ~11% per decade in freshwater insects (van Klink et al., 2020). The decline in terrestrial insect abundance and biomass is consistent with several prominent recent studies (Hallmann et al., 2017; IPBES, 2019; Seibold et al., 2019). However, the increase in freshwater insect abundance needs to be evaluated cautiously in the context of (i) distinct and contrasting trends documented for a number of freshwater insect species (Baranov, Jourdan, Pilotto, Wagner, & Haase, 2020; Floury, Usseglio-Polatera, Ferreol, Delattre, & Souchon, 2013; Hallmann et al., 2020; Out-hwaite, Gregory, Chandler, Collen, & Isaac, 2020; Stepanian et al., 2020), (ii) increasing threats to, and disproportionate loss of, freshwater biodiversity at the global scale (Albert et al., 2020; Reid et al., 2019; WWF, 2020), and (iii) the existing degraded status of many freshwater ecosystems in Europe, North America, and Asia (Vörösmarty et al., 2010). We argue that this contrasting perspective arises from two key limitations of the study by van Klink et al. (2020). First, total abundance and biomass are, on their own, poor indicators of the ecological state of freshwater insect assemblages. Second, the compiled datasets are not representative of freshwater ecosystem trends due to spatial and temporal restrictions. Interest in long-term trends in insect distribution, abundance, and biodiversity has been growing among scientists, stakeholders, and policymakers. We therefore strongly caution against drawing general conclusions or formulating recommendations regarding freshwater habitats and insect assemblages based on the data and subsequent analyses of van Klink et al. (2020).

While changes in total abundance and biomass may reflect changes in environmental conditions (e.g., Hallmann et al., 2017), such changes do not necessarily indicate improved water quality. Freshwater insect assemblages often comprise hundreds of species, and any observed increase in total abundance or biomass can be driven by increasing numbers of a few tolerant and widespread taxa, which masks the simultaneous loss of sensitive taxa (Larsen, Chase, Durance, & Ormerod, 2018). Such changes have been reported in response to the stressors flow modification, pollution, and intensification of human land-use (Alvarez-Cabria, Barquin, & Juanes, 2011; Camargo, Alonso, & de la Puente, 2005; Kaelin & Altermatt, 2016). We argue that climate warming and eutrophication could lead to an increase in total abundance and biomass of freshwater insects as found by van Klink et al. (2020), and this may explain why abundance increases were stronger in unprotected areas and regions dominated by cropland. Species turnover from sensitive to tolerant taxa can be accompanied by alterations of ecosystem functions, such as carbon and nutrient cycling, which ultimately can lead to an erosion of services these ecosystems provide to people (Cao et al., 2018).

Uncovering trends in global insect abundance and biomass requires, of course, a set of globally representative samples. We argue that 28 of the 63 freshwater datasets used by van Klink et al. (2020) are of limited value for this task. In nine of the freshwater datasets, insect, and noninsect abundances and biomass were not separated in the original study. The increased abundances could therefore have been driven by noninsect taxa such as crustaceans, bivalves, or oligochaetes. Furthermore, 21 datasets encompass case studies that examined the response of the assemblages to stressor onset. Of these, 12 studies investigated the response of insects to an introduced anthropogenic stressor (e.g., succession after a dam was built, response to larvicide application), six examined the response to a decrease in or removal of a stressor (e.g., from organic pollution, mining, and heavy-metal pollutants), and three examined changes following natural extreme events (e.g., wildfire, extreme flood, and extreme drought events). While studies of responses to single (major) stressors could indeed be indicative of long-term global trends, care should be taken in any attempt to draw general conclusions from such studies. Undoubtedly, developments have taken place since the 1990s that have had positive effects on freshwater ecosystems, including the reduction of nitrogen and sulfur emissions from power stations and the increased investment in water treatment facilities. However, a specific geopolitical change like the collapse of the Soviet Union, as suggested by van Klink et al. (2020), is unlikely to govern the results, particularly while ongoing

severe and accelerating degradation from pollution, flow modification, and habitat transformation due to population growth, economic development, and poorly enforced environmental regulations are neglected. Although the poor representation of datasets from the Global South was acknowledged, we argue that a total of five datasets (covering 20 sites) reflect neither the diversity nor the current state of freshwater insect assemblages in Africa, South America, and large parts of Asia. Besides these spatial caveats, the temporal distribution of data origin may reflect a shifting baseline effect (Soga & Gaston, 2018), whereby interpretation of a trend is dependent on the available reference point. A large representation of the data originates from the European Union, with 1986 being the median year for the start of these time series. This time period reflects a period of widespread recovery of heavily degraded freshwater ecosystems in Europe. Furthermore, the length of many of the datasets are likely insufficient to overcome this shifting baseline effect and identify long-term trajectories; recent work indicates greater than 20 years may be necessary (the median length of studies used in van Klink et al. (2020)) (Baranov et al., 2020; Bell, Blumgart, & Shortall, 2020).

In summary, we raise two major concerns that, while not intrinsically invalidating the findings of van Klink et al. (2020), require a careful reconsideration of their conclusions regarding the global status and trends of freshwater insects. While we agree that an increase in insect abundance may reflect improved water quality sporadically, we argue that increasing abundance and biomass in nonrepresentative datasets do not reflect an overall improvement in freshwater ecosystem condition. In fact, we question whether current practices of restoration and management of freshwater ecosystems would be sufficient to result in a further improvement in insect abundance and biomass in many of these locations (Geist & Hawkins, 2016). Finally, unless it can be demonstrated that the datasets applied to the meta-analysis accurately reflect the global distribution and diversity of freshwaters, any inference is likely to result in severe biases including the overestimation of global trends. While we acknowledge the tremendous efforts in collating and analyzing the data by van Klink et al. (2020), we hope the discussion stimulates: (1) further research on trends in freshwater insect assemblages, (2) the mobilization of thus far unexplored data sources, and (3) the development of new, more representative monitoring schemes including enhanced long-term research programs and embracing new technologies (e.g., remote sensing, eDNA analysis) to allow robust inference about insect population trends. A more coherent picture on freshwater biodiversity conditions and trends will only emerge once data on multiple taxonomic groups, species diversity, population size, and habitat characteristics become available and fully accessible.

ACKNOWLEDGMENTS

FH and GK are supported through the project “Species protection through environmental friendly lighting” funded by the Federal Agency for Nature Conservation (BfN) within the framework of the Federal Programme for Biological Diversity with funds from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). AM acknowledges funding through US NSF Macrosystems Biology Program (grant no. 1442595), and SD by the Leibniz Competition (J45/2018). The authors are grateful to the reviewers and the editor for their comments, which helped improve the text. Open access funding enabled and organized by Projekt DEAL.

AUTHOR CONTRIBUTIONS

Sonja Jähnig, Viktor Baranov, Jonas Jourdan, Sami Domisch: Conceptualization; writing-original draft; writing-review and editing. **Florian Altermatt, Peter Cranston, Martin Friedrichs-Manthey, Juergen Geist, Fengzhi He, Jani Heino, Daniel Hering, Franz Hölker, Gregor Kalinkat, Jens Kiesel, Florian Leese, Alain Maasri, Michael Monaghan, Ralf Schäfer, Klement Tockner, Jonathan Tonkin:** Writing-original draft; writing-review and editing.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

ORCID

Sonja C. Jähnig  <https://orcid.org/0000-0002-6349-9561>

Viktor Baranov  <https://orcid.org/0000-0003-1893-3215>












Florian Altermatt  <https://orcid.org/0000-0002-4831-6958>

Peter Cranston  <https://orcid.org/0000-0001-7535-9809>

Martin Friedrichs-Manthey  <https://orcid.org/0000-0003-0644-7869>

Juergen Geist  <https://orcid.org/0000-0001-7698-3443>

Fengzhi He  <https://orcid.org/0000-0002-7594-8205>

Jani Heino  <https://orcid.org/0000-0003-1235-6613>
 Franz Hölker  <https://orcid.org/0000-0001-5932-266X>
 Jonas Jourdan  <https://orcid.org/0000-0002-2745-2520>
 Gregor Kalinkat  <https://orcid.org/0000-0003-3529-5681>
 Jens Kiesel  <https://orcid.org/0000-0002-4371-6434>
 Florian Leese  <https://orcid.org/0000-0002-5465-913X>
 Alain Maasri  <https://orcid.org/0000-0003-1236-8374>
 Michael T. Monaghan  <https://orcid.org/0000-0001-6200-2376>
 Ralf B. Schäfer  <https://orcid.org/0000-0003-3510-1701>
 Klement Tockner  <https://orcid.org/0000-0002-0038-8151>
 Jonathan D. Tonkin  <https://orcid.org/0000-0002-6053-291X>
 Sami Domisch  <https://orcid.org/0000-0002-8127-9335>

REFERENCES

- Albert, J. S., Destouni, G., Duke-Sylvester, S. M., Magurran, A. E., Oberdorff, T., Reis, R. E., ... Ripple, W. J. (2020). Scientists' warning to humanity on the freshwater biodiversity crisis. *Ambio*, *50*(1), 85–94. <https://doi.org/10.1007/s13280-020-01318-8>.
- Alvarez-Cabria, M., Barquin, J., & Juanes, J. A. (2011). Microdistribution patterns of macroinvertebrate communities upstream and downstream of organic effluents. *Water Research*, *45*(3), 1501–1511. <https://doi.org/10.1016/j.watres.2010.11.028>
- Baranov, V., Jourdan, J., Pilotto, F., Wagner, R., & Haase, P. (2020). Complex and nonlinear climate-driven changes in freshwater insect communities over 42 years. *Conservation Biology*, *34*, 1241–1251. <https://doi.org/10.1111/cobi.13477>
- Bell, J. R., Blumgart, D., & Shortall, C. R. (2020). Are insects declining and at what rate? An analysis of standardised, systematic catches of aphid and moth abundances across Great Britain. *Insect Conservation and Diversity*, *13*(2), 115–126. <https://doi.org/10.1111/icad.12412>
- Camargo, J. A., Alonso, A., & de la Puente, M. (2005). Eutrophication downstream from small reservoirs in mountain rivers of Central Spain. *Water Research*, *39*(14), 3376–3384. <https://doi.org/10.1016/j.watres.2005.05.048>
- Cao, X., Chai, L., Jiang, D., Wang, J., Liu, Y., & Huang, Y. (2018). Loss of biodiversity alters ecosystem function in freshwater streams: Potential evidence from benthic macroinvertebrates. *Ecosphere*, *9*(10), e02445. <https://doi.org/10.1002/ecs2.2445>
- Floury, M., Usseglio-Polatera, P., Ferreol, M., Delattre, C., & Souchon, Y. (2013). Global climate change in large European rivers: Long-term effects on macroinvertebrate communities and potential local confounding factors. *Global Change Biology*, *19*(4), 1085–1099. <https://doi.org/10.1111/gcb.12124>
- Geist, J., & Hawkins, S. J. (2016). Habitat recovery and restoration in aquatic ecosystems: Current progress and future challenges. *Aquatic Conservation-Marine and Freshwater Ecosystems*, *26*(5), 942–962. <https://doi.org/10.1002/aqc.2702>
- Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., ... de Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS One*, *12*(10), e0185809. <https://doi.org/10.1371/journal.pone.0185809>
- Hallmann, C. A., Zeegers, T., van Klink, R., Vermeulen, R., van Wielink, P., Spijkers, H., ... Jongejans, E. (2020). Declining abundance of beetles, moths and caddisflies in The Netherlands. *Insect Conservation and Diversity*, *13*(2), 127–139. <https://doi.org/10.1111/icad.12377>
- IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany: IPBES.
- Kaelin, K., & Altermatt, F. (2016). Landscape-level predictions of diversity in river networks reveal opposing patterns for different groups of macroinvertebrates. *Aquatic Ecology*, *50*(2), 283–295. <https://doi.org/10.1007/s10452-016-9576-1>
- Larsen, S., Chase, J. M., Durance, I., & Ormerod, S. J. (2018). Lifting the veil: Richness measurements fail to detect systematic biodiversity change over three decades. *Ecology*, *99*(6), 1316–1326. <https://doi.org/10.1002/ecy.2213>
- Outhwaite, C. L., Gregory, R. D., Chandler, R. E., Collen, B., & Isaac, N. J. B. (2020). Complex long-term biodiversity change among invertebrates, bryophytes and lichens. *Nature Ecology & Evolution*, *4*(3), 384–392. <https://doi.org/10.1038/s41559-020-1111-z>
- Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T. J., ... Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, *94*(3), 849–873. <https://doi.org/10.1111/brv.12480>
- Seibold, S., Gossner, M. M., Simons, N. K., Blüthgen, N., Müller, J., Ambarli, D., ... Weisser, W. W. (2019). Arthropod decline in grasslands and forests is associated with landscape-level drivers. *Nature*, *574*(7780), 671–674. <https://doi.org/10.1038/s41586-019-1684-3>
- Soga, M., & Gaston, K. J. (2018). Shifting baseline syndrome: Causes, consequences, and implications. *Frontiers in Ecology and the Environment*, *16*(4), 222–230. <https://doi.org/10.1002/fee.1794>
- Stepanian, P. M., Entekin, S. A., Wainwright, C. E., Mirkovic, D., Tank, J. L., & Kelly, J. F. (2020). Declines in an abundant aquatic insect, the burrowing mayfly, across major North American waterways. *Proceedings of the National Academy of Sciences, USA*, *117*(6), 2987–2992. <https://doi.org/10.1073/pnas.1913598117>
- van Klink, R., Bowler, D. E., Gongalsky, K. B., Swengel, A. B., Gentile, A., & Chase, J. M. (2020). Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances. *Science*, *368*(6489), 417–420. <https://doi.org/10.1126/science.aax9931>

Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., ... Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, *467*, 555–561. <https://doi.org/10.1038/nature09440>

WWF. (2020). *Living planet report 2020 - Bending the curve of biodiversity loss*. Gland, Switzerland: WWF.

How to cite this article: Jähnig SC, Baranov V, Altermatt F, et al. Revisiting global trends in freshwater insect biodiversity. *WIREs Water*. 2021;8:e1506. <https://doi.org/10.1002/wat2.1506>