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Comment on "Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances"

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Van Klink *et al.* (Reports, 24 April 2020, p. 417) argue for a more nuanced view of insect decline, and of human responsibility for this decline, than previously suggested. However, shortcomings in data selection and methodology raise questions about their conclusions on trends and drivers. We call for more rigorous methodology to be applied in meta-analyses of ecological data.

Recent evidence has emerged on insect decline and on the loss of insects' crucial ecological services (*1*, *2*), but the magnitude and causes of this decline are debated (*3*, *4*). In their meta-analysis, van Klink *et al.* (*5*) estimated a 9% decline in abundance per decade for terrestrial insects, and an 11% increase for freshwater insects. We argue that problems in data selection and in the methodology of the meta-analysis undermine the main conclusions of their report. In particular, we argue that the evidence for freshwater insect increases is seriously flawed.

We thoroughly examined the 166 studies included in their analysis, paying particular attention to the 14 studies identified as outliers, on which their estimated positive trend for freshwater insects was based. We identify problems in the data processing of 113 studies, including all outliers.

Fifty-seven studies, including five outliers (identified in the meta-analysis by numbers 313, 1261, 1364, 1408, and 1427), were field or natural experiments (*6*) examining experimental conditions likely to have an impact on insect communities. However, the effect of these experiments was not considered. Outlier 1364 included 172 experimental plots in a seven-hectare field. Outlier 1427 compared streams affected, or not, by a wildfire in a natural experiment. Both the wildfire and the crop experiments carried out in each plot introduced strong site heterogeneity that was not considered in the meta-analysis.

No attempt was made to weight studies according to their representativeness in terms of geographic location, anthropogenic impact (including farming methods and pesticide use), protected status, or insect assemblages. Twelve studies dealt with exceptional circumstances that cannot be extrapolated, such as the area around Chernobyl or the creation of a polder or a reservoir. They included outliers that addressed restoration activities in freshwaters designed to mitigate the impacts of historical mining (1423) and salinity (1503), as well as an outlier that considered high-flying migrant insects without accounting for the major impact of wind on their local abundance (1493).

Studies were also heterogeneous in terms of number of years with data (only 2 years for 21 studies), site sizes (ranging from one tree branch to a whole country), and distances among sites within a study (from 3.5 m to 1760 km). Although the identification of differences across geographical regions was a main purpose of the meta-analysis, the geographical coverage of the database was very uneven, with 76% of studies focused on the United States and Europe. A single dataset from Sweden accounted for 43% of freshwater sites.

Heterogeneous taxonomic levels were considered in the dataset. Among the 63 freshwater assemblages, 27 contained crustaceans, mollusks, or worms, including outliers 1423, 1427, and 1503. Because insects represented a highly variable proportion of these assemblages, insect trends cannot be inferred from overall invertebrate trends. In 90 of the 166 studies, only one taxonomic order was considered. Stress-tolerant or invasive taxa were overrepresented relative to those known to be susceptible to environmental change. For example, in the 13 studies on dipterans, nine pertained to mosquitoes, often invasive in temperate countries (*7*), or chironomids, often stress-tolerant (*8*). By contrast, bees, which are particularly threatened by intensive agricultural practices, were represented in only two of nine studies pertaining to hymenopterans. For wider assemblages, increases in abundance and biomass sometimes reflected the proliferation of such opportunistic taxa while hiding diversity losses. Finally, in five instances, the meta-analysis considered fewer insect taxa than were available in the original datasets.

Other types of problems were found for 37 studies. Outlier 70 presented a temporal skew due to undermapping of common species in an earlier period (*9*). The original dataset of outlier 1006 included 81 missing values coded as "101," mistaken as abundances of 101. Outliers 1476, 1477, and 1478 were overweighted by separating their common dataset into three studies and including more sites than in the original publications. Ten studies, including outlier 1409, inconsistently included five to eight abundance or biomass data per month, whereas the model considered the week as the finest time resolution.

Overall, we identified data processing problems in approximately two-thirds of terrestrial studies and three-quarters of freshwater studies (Fig. 1 and Table 1).

As for statistical methods, the model included random site effects assuming that site effects were independently and identically distributed, but this assumption was not met, notably because the inclusion of experimental sites implied nonrandom effects and there was a geographical dependency among sites in some studies. Moreover, the meta-analysis did not follow the usual standards, which consist of selecting the best model among several models of abundance or biomass trends and checking its validity, while also considering within-year temporal autocorrelation, regional and scale effects, taxa effects, differences in abundance and biomass trends, nonlinear dynamics, and changepoints.

The analysis of drivers also shows methodological shortcomings. Possible drivers of insect trends were analyzed by matching study data with external databases according to geographical coordinates, but this methodology is prone to numerous errors. The European Space Agency Climate Change Initiative database has a 300 m × 300 m resolution that allows only a rough assessment of local land use; when processing satellite images, this low resolution may easily lead to misclassified croplands and grasslands because of their similar spectral signatures (*10*, *11*). The meta-analysis considered that 48 terrestrial studies had at least one site with some local cropland cover. Actually, from corresponding publications or satellite images, we find that cropland cover was inadequately assessed in 31 of these studies.

In freshwaters, pollutants are carried by water throughout the watershed. Therefore, drivers of insect population change should examine land use upstream (*12*) and not only around the sampling site. The trophic status of water, reported in almost all studies, would have allowed a better assessment of anthropogenic pressures.

These issues call into question the conclusion that insect abundance trends are positively associated with crop cover at the local scale in both terrestrial and freshwater ecosystems. Overall, we argue that these methodological problems invalidate the estimates of the meta-analysis of van Klink *et al.* To avoid replicating such issues, ecologists must apply rigorous standards for systematic literature reviews and meta-analyses (*13*), as is becoming the rule, for example, in environmental health (*14*).

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Table 1. Types of problems encountered. The references of the studies numbered with the identifiers indicated in the table are available in the supplementary materials of van Klink *et al*. (*5*), in table S1 and in the References and Notes section. Outliers are in bold.

Problem type	Number of studies	Study identifiers
Field or natural experiment, experimental conditions not considered	57	63, 294, 300, 301, **313**, **1261**, 1335, 1339, 1357, **1364**, 1365, 1367, 1376, 1384, 1385, 1387, 1388, 1391, 1393, 1396, 1398, 1407, **1408**, 1410, 1411, 1413, 1415, 1417, 1419, 1421, 1424, 1426, **1427**, 1430, 1431, 1433, 1437, 1439, 1441, 1465, 1468, 1473, 1479, 1484, 1485, 1487, 1494, 1497, 1502, 1504, 1505, 1506, 1513, 1516, 1519, 1521, 1527
Non-insects (and non-arachnids*) included in the assemblage	31	1395, 1396, 1402, 1421, **1423**, 1424, 1425, **1427**, 1428, 1432, 1435, 1448, 1449, 1451, 1452, 1454, 1455, 1456, 1458, 1466, 1473, 1498, 1500, **1503**, 1504, 1506, 1507, 1509, 1511, 1513, 1521
Only 2 years with data	21	1335, 1365, 1376, 1384, 1385, 1402, 1411, 1415, 1419, 1421, 1425, 1435, 1439, 1465, 1468, 1480, 1502, 1508, 1513, 1515, 1521
Split studies (several studies from one dataset or one geographical location)	18	79, 380, **1006**, 1263, 1266, 1267, 1345, 1347, 1353, 1357, 1424, **1476**, **1477**, **1478**, 1485, 1487, 1495, 1496
Exceptional situation	12	478, 1324, 1395, 1422, **1423**, 1451, 1456, 1464, **1493**, 1498, **1503**, 1517
More than 4 data per month	10	249, 294, 301, 1263, 1351, **1409**, **1476**, **1477**, 1481, 1501
Change in site number	9	**70**, **1006**, 1102, 1263, 1266, 1267, 1388, **1476**, **1477**
Error in insect count	6	**1006**, 1393, 1431, 1448, 1457, 1509
Data exist for other taxa	5	**70**, 502, 1393, 1480, 1494
Data exist for a longer period	3	502, 1263, 1494
Time bias in data	2	**70**, 465
Very unbalanced data	1	1475
No identified problem	53	375, 1310, 1312, 1328, 1340, 1346, 1349, 1361, 1377, 1378, 1379, 1381, 1382, 1392, 1394, 1397, 1400, 1401, 1403, 1404, 1405, 1406, 1412, 1414, 1416, 1418, 1429, 1434, 1440, 1444, 1445, 1446, 1453, 1459, 1460, 1461, 1462, 1467, 1470, 1471, 1472, 1474, 1488, 1491, 1510, 1512, 1518, 1520, 1524, 1525, 1526

*Arachnids were considered as insects in the meta-analysis.

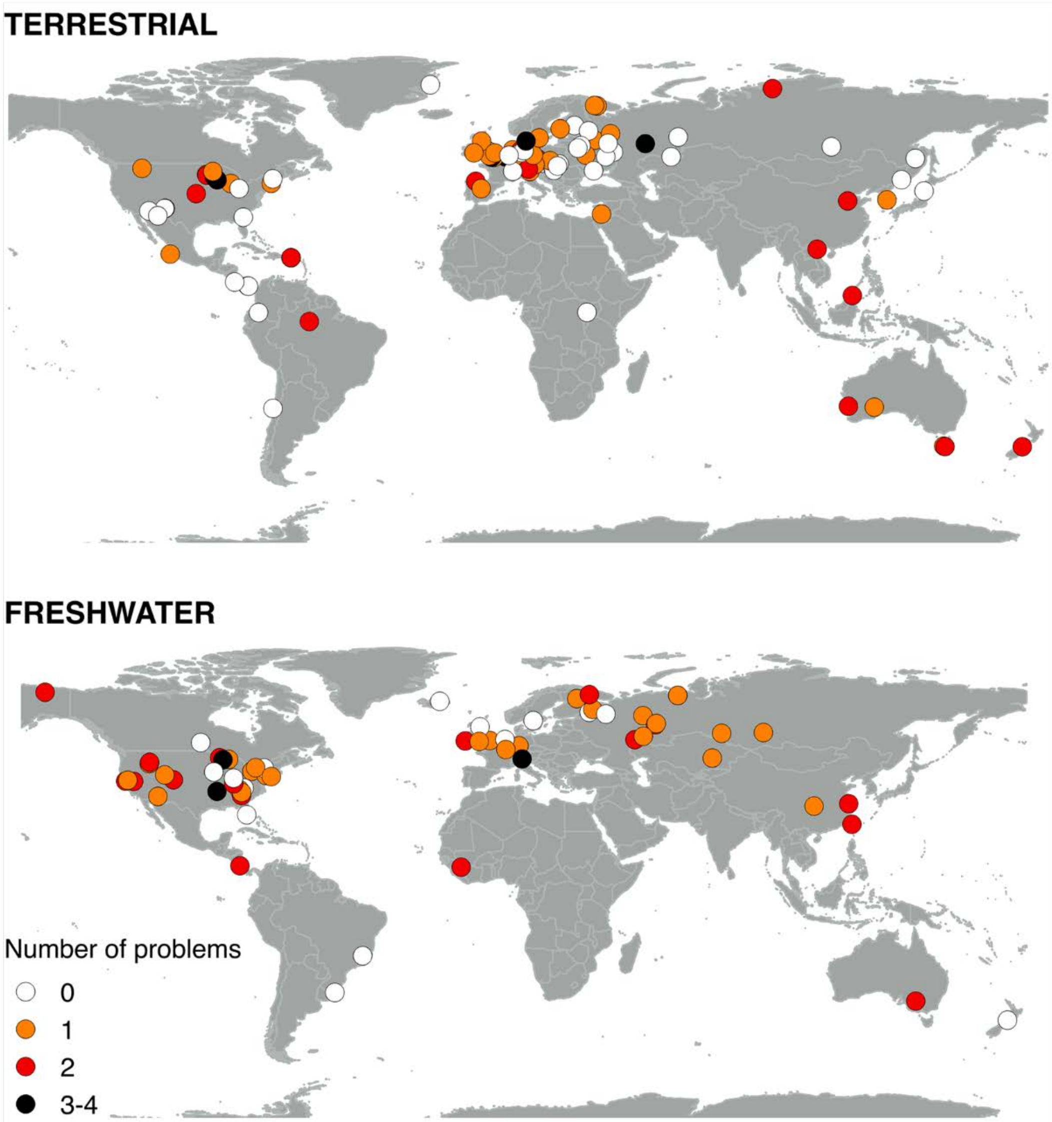

Fig. 1. Geographical distribution of studies giving rise to data processing concerns.

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