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InsectChange: Comment

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Abstract

The InsectChange database (van Klink et al. 2021) underlying the meta-analysis by van Klink et al. (2020a) compiles worldwide time series of abundance and biomass of invertebrates reported as insects and arachnids, as well as ecological data likely to influence their change. Based on a comprehensive review of the original publications and datasets, we highlight numerous issues in this database, such as errors in insect counts, sampling biases, inclusion of non-insects driving assemblage trends, omission of internal drivers investigated in the original studies and inaccurate assessment of local cropland cover. We argue that in its current state this database does not allow to study the temporal trends of insects or their drivers. Our in-depth analysis therefore calls for major changes and extreme vigilance in its use. It precisely details each problem identified and makes numerous suggestions for improvement in the supplementary information, which can be used as a basis for corrections.

Keywords: Insects, Terrestrial invertebrates, Freshwater invertebrates, Insect abundance change, Insect decline, Time-series analysis, Methodological biases, Cropland cover assessment, Land cover analysis

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Introduction

Today experts agree that biodiversity is shrinking in the face of global changes characterizing the Anthropocene era. However, as regards insects, which provide invaluable ecosystem services, decline rates are still debated, largely because their assessment is hampered by lack of data and subsequent analytical weaknesses. There is also no consensus on the main drivers of their change, including land use (urbanization/agriculture), climate, pesticides, pollution and invasive species, mostly because these drivers are not easily disentangled or may act in synergy (Wagner et al. 2021). While many authors have warned on insect extinctions worldwide (Cardoso et al. 2020), van Klink et al. (2020a) added to the debate by estimating a smaller decline in the abundance of terrestrial insects than reported by these authors and an increase in freshwater insects. They found that cropland was not involved in terrestrial insect decline and proposed improved water quality to be a driver of the freshwater insect increase. Yet their meta-analysis raised comments regarding their data selection and methodology (Desquilbet et al. 2020) leading to some corrections (van Klink et al. 2020b), the limitations of abundance and biomass as sole indicators of insect trends (Jähnig et al. 2021) and the heterogeneity in temporal coverage with a lack of old baselines (Duchenne et al. 2022). In the first place, however, the sensitive issue of insect trends and drivers requires the utmost rigor in databases intended to serve as references.

We present an in-depth study of the InsectChange database (van Klink et al. 2021) underlying the analysis by van Klink et al. (2020a). InsectChange compiles time series of abundance and biomass of invertebrates reported as insects and arachnids, as well as ecological data likely to influence their trends. Based on a comprehensive review of the original publications and datasets, we highlight numerous data limitations, whose accumulation also biases any assessment of insect change and drivers of change from this database.

1. The different issues in the InsectChange database

A first shortcoming is a lack of clear information on which invertebrate taxa are included in InsectChange. These are insects and arachnids according to the title and main text, but also entognaths, as indicated in the keywords and appendices. Considering entognaths within the scope of the data paper, we find that 17 types of problems pertaining to errors (240), inconsistencies (39), methodological issues (166) and information gaps (81) affect 154 of the 165 datasets totalizing 526 occurrences (Figure 1a), with more problem types per study in the freshwater realm (3.4 ± 1.5,

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n=62) than in the terrestrial realm (2.6 ± 1.7, n=103; T test for unequal variances, t(137)=3.2, P=0.002, n=165; Figure 1b, Appendix S1, *Problems.xlsx*).

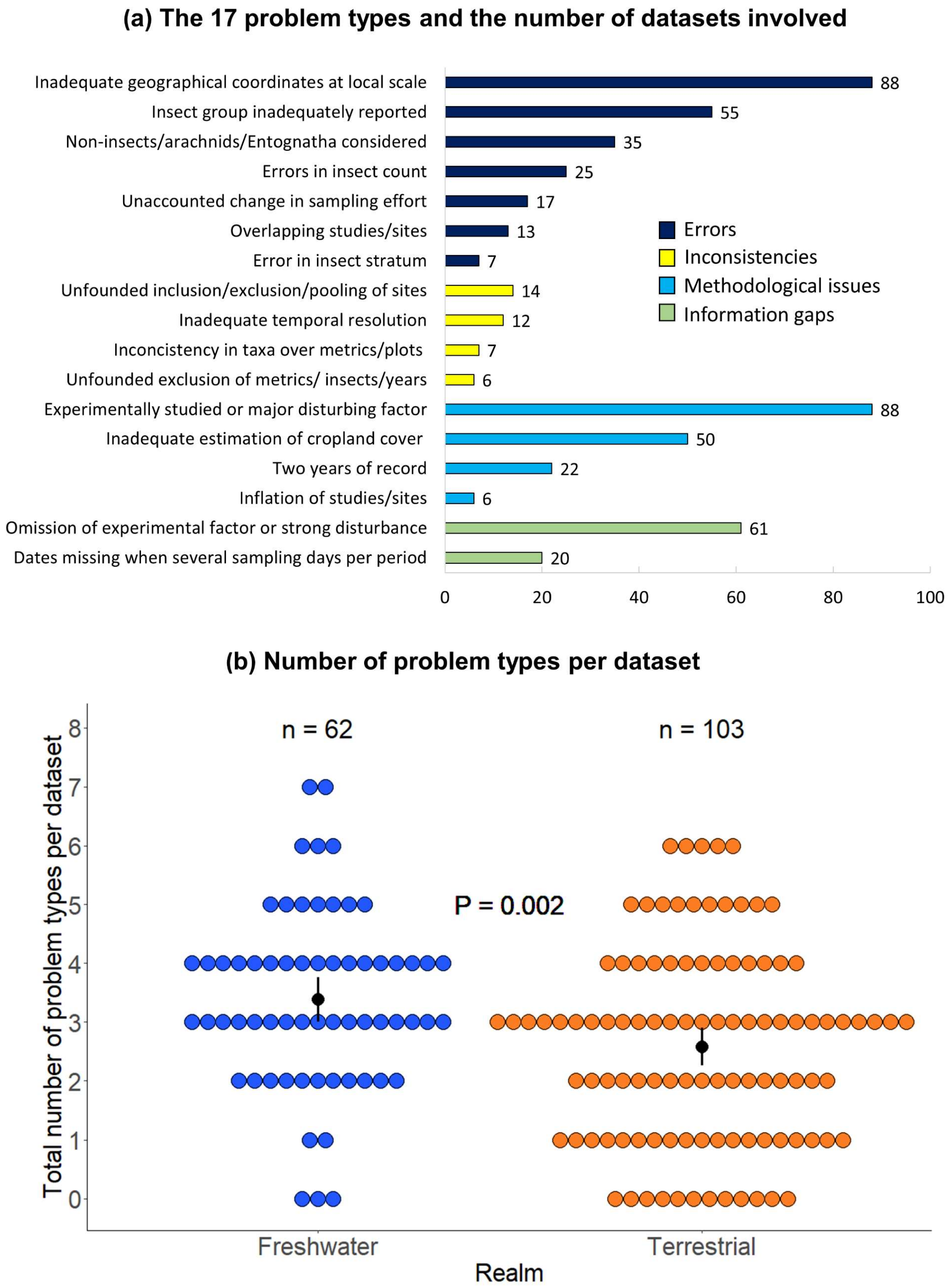

FIGURE 1 Problems encountered in the InsectChange database (*Problems.xlsx*). (a) The 17 types of problems and numbers of datasets involved. *Cropland cover assessment only for terrestrial studies. (b) Number of problem types per freshwater and terrestrial dataset (except those related to cropland cover assessed only for terrestrial studies) and associated means (± SE).

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Among the errors, 35 datasets considered taxa other than insects, arachnids or entognaths (hereafter collectively referred to as "insects" for brevity), most often including the entire invertebrate assemblage instead of insects only, sometimes biasing the trends to the point of reversal (Figure 2a). The composition of the invertebrate group selected from the source datasets was misreported in 55 datasets (e.g. Figure 2b). Insect numbers were misreported from source studies in 25 datasets because of calculation errors, inversion of numbers or species counted twice (e.g. Figures 2c and 2d). Variation in sampling effort was not accounted for in 17 datasets (e.g. Figure 2e). Some datasets or plots had overlapping data for all or part of the time period (13 datasets, e.g. Figure 2f). Finally, the geographic coordinates of the included plots were erroneous or not precise enough given the local scale objectives of the study in 88 datasets.

There were also a number of inconsistencies and information gaps. There were inconsistencies of taxa between plots of a same dataset (e.g. Figure 2e) or between metrics in a same plot (7 datasets, e.g. Figure 2g); but users cannot identify them because the insect group is not indicated at the plot level. Unfounded inclusion, exclusion (e.g. Figure 2h) or pooling of original sites concerned 14 datasets. There were unfounded exclusions of data regarding a metric (abundance or biomass), some insect groups or some time records (6 datasets, Figure 2i). A total of 12 datasets had an inadequate temporal resolution (Appendix S1, *Problems.xlsx*). Moreover, dates were not indicated when there were successive samplings per period, which may lead users to consider samples as interchangeable replicates, when they are time-dependent (20 datasets).

Regarding methodological issues, the inclusion of studies with experimental conditions or major disturbances and the estimation of the local cropland cover are the focus of sections 3 and 4. In addition, 22 datasets had only two years of data, while non-monotonic dynamics of insect populations call for more records. The number of sites and/or datasets was unduly inflated in 6 datasets compared to the original studies, leading to their overweighting.

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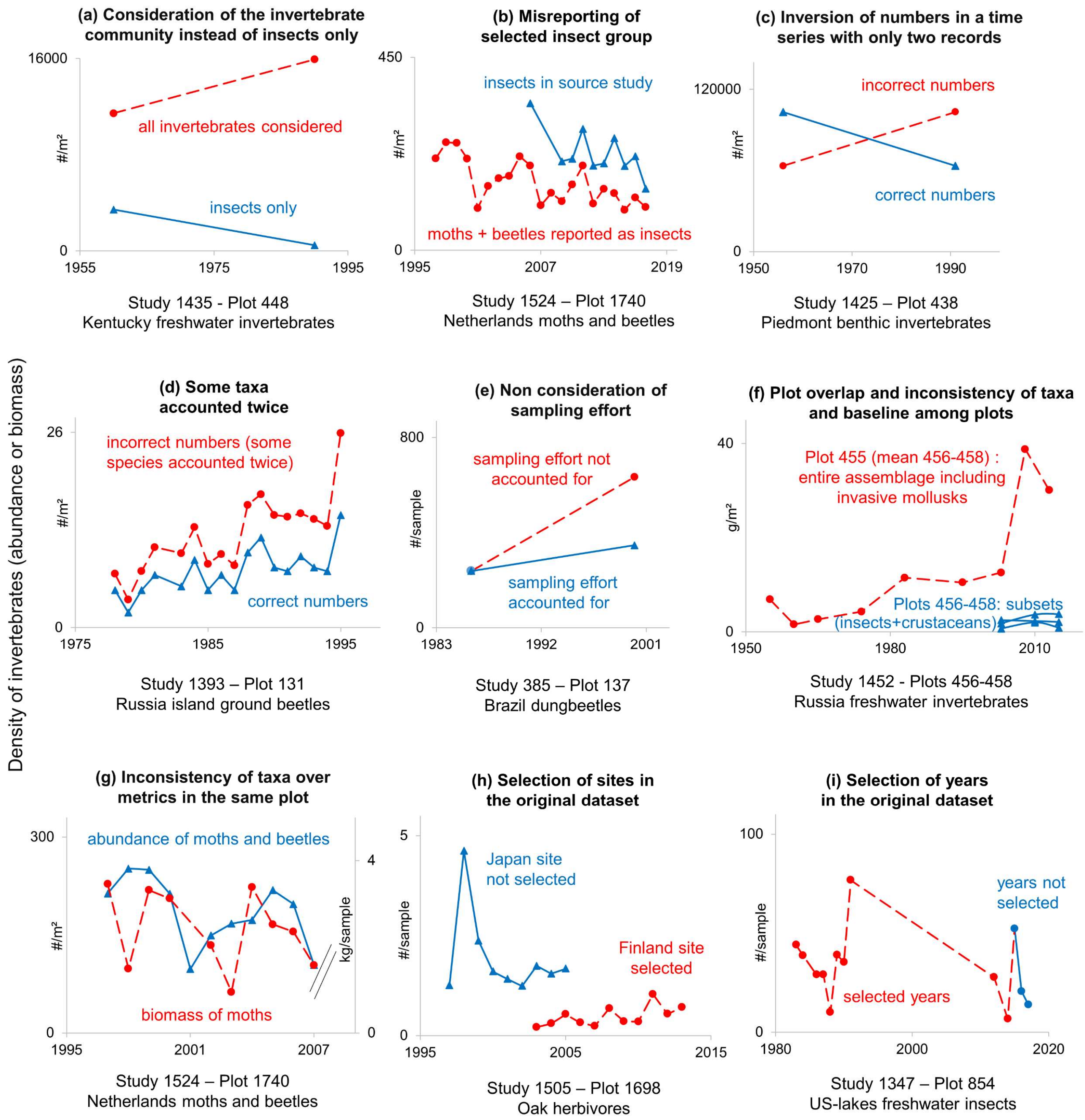

FIGURE 2 Errors and inconsistencies in data selection biasing insect change assessment (Appendix S1, *Problems.xlsx*, *Fig2and4.xlsx*). Examples of errors (a-e), inconsistencies regarding taxa over plots or metrics (f, g), inconsistencies regarding data selection (h, i).

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2. Focus on the problematic inclusion of clams, snails, worms, shrimps in freshwater data

In the freshwater realm, 80% (19 out of 24) of the biomass and 40% (21 out of 54) of the abundance datasets included invertebrates other than insects. They were related to 28 distinct datasets, 24 of which involved the entire freshwater invertebrate assemblage (Figure 3, Appendix S2: Table S1). The great majority of these 24 datasets included worms, mollusks and crustaceans, with notably Oligochaeta, Turbellaria and Amphipoda, often indicative of poor water quality (Appendix S2: Table S2). The inclusion of these datasets is not consistent with the purpose of the database, because the dynamics of insects cannot be inferred from those of invertebrate assemblages. This is illustrated by Figure 3a showing that insect and invertebrate assemblages can have contrasted trajectories (top), and that proliferating invasive mollusks can drive the trend of the invertebrate assemblage (bottom) (see also *FreshwaterNonInsects.xlsx*).

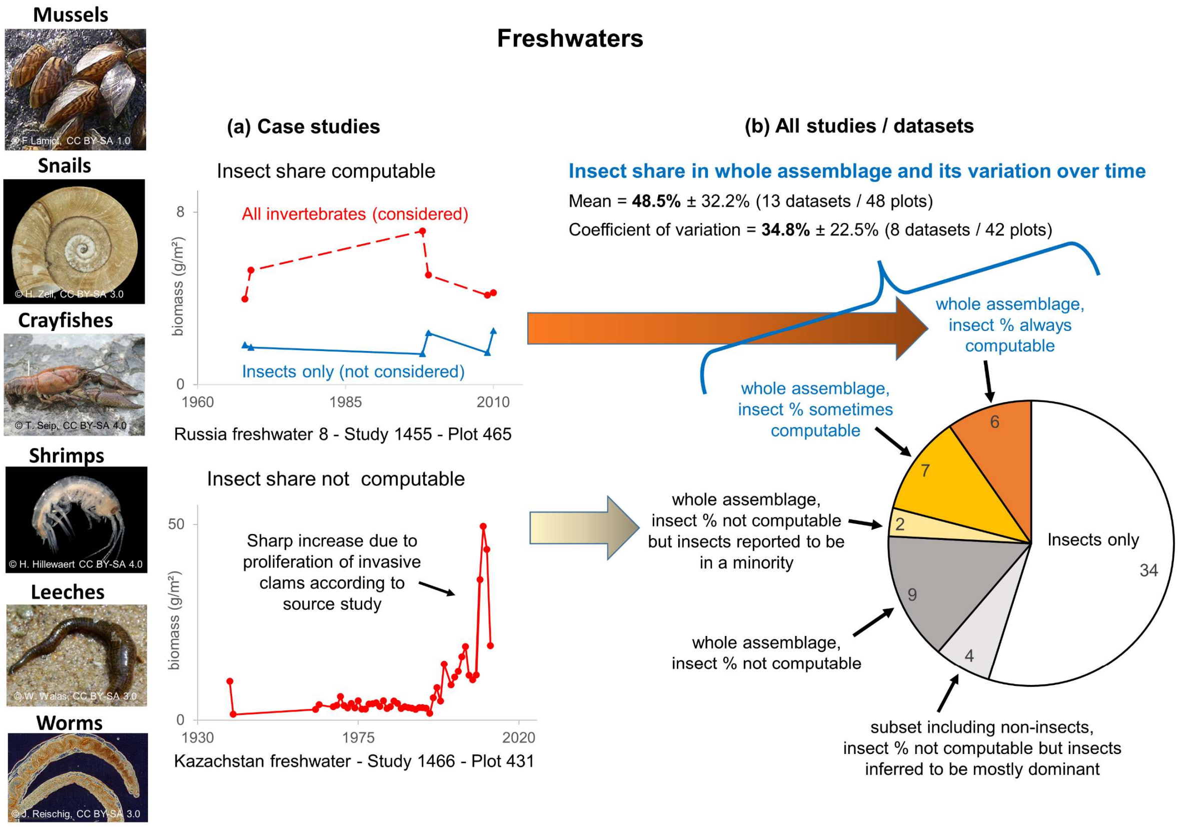

FIGURE 3 Freshwater time-series including non-insects while the insect share was often low and variable over time (Appendix S2, *FreshwaterNonInsects.xlsx*). (a) Case studies 1455 and 1466 (Appendix S1) illustrating (top) contrasted trajectories of the entire assemblage and insects only, and (bottom) invasive non-insects driving the trend. (b) The 62 freshwater datasets, 28 including non-insects (24 the entire assemblage). The insect share, extracted from 13 of these, averaged 48.5% with a ~35% CV. Photograph credits detailed in Appendix S2: Table S3.

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Beyond these examples, we calculated that on average insects made up 48.5% ± 32.2% of the entire assemblage in the 13 datasets (48 plots) with information on all or part of the time records (Figure 3b, *FreshwaterNonInsects.xlsx*). The insect share in the assemblage was also highly variable over time (Appendix S2: Figure S1) with a coefficient of variation averaging 34.8% ± 22.5% in the 8 datasets (42 plots) where information was available for more than one time record. Considering non-insects in the assemblage can therefore considerably alter the inferred 'insect' trend. Out of the 53 plots of 15 datasets with reported or inferred information on invertebrates driving the trend of the entire assemblage, non-insects (invasive mollusks, opportunistic oligochaetes and/or amphipods…) were found to drive the assemblage trend in half of the plots (25) and two-thirds of the datasets (10) (*FreshwaterNonInsects.xlsx*).

3. Inclusion of experimental or disturbed situations with internal drivers of insect change

A major limitation of the InsectChange database is that users are inclined to erroneously attribute insect changes to the ecological drivers extracted from external databases, when they more directly reflect habitat changes caused by –most often omitted– internal drivers investigated in the original studies. Indeed, 88 datasets were extracted from controlled or natural experiments or from strongly disturbed contexts. In addition, the factors originally investigated were not mentioned in 69% of these 88 datasets (*Problems.xlsx*). Among these 88 datasets, 14 controlled experiments tested the effect of one or several treatments in different plots (Figure 4a) and 53 natural experiments (Diamond 1983) investigated the effect of a natural disturbance by comparing insect abundance in more or less disturbed plots (Figure 4b) or before and after the disturbance in a plot (Figure 4c). In these experimental datasets, control plots, experimental plots or both control and experimental plots were inconsistently included in InsectChange. In the remaining 21 observational studies, a strong disturbance affected insect trends (Figure 4d).

Among the 88 datasets, the studied factor could be negative, such as a severe drought, fire or pesticide application, creating deleterious then recovery conditions for insects at the beginning, middle or end of the observation period, this timing strongly influencing insect trends (Appendix S3). The factor could also be positive, such as cessation of harmful activities, remediation measures (Figure 4e), active restoration or creation of new habitats such as ponds (Figure 4f), reservoirs or nesting sites, favoring insect recovery or colonization. Insects were also expected to increase in 6 studies on polluted and eutrophicated freshwaters (Appendix S3) because stress-tolerant

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chironomids were the selected insects or proliferating non-insects were considered such as oligochaetes, opportunists in polluted waters (Rosa et al. 2014), or invasive amphipods.

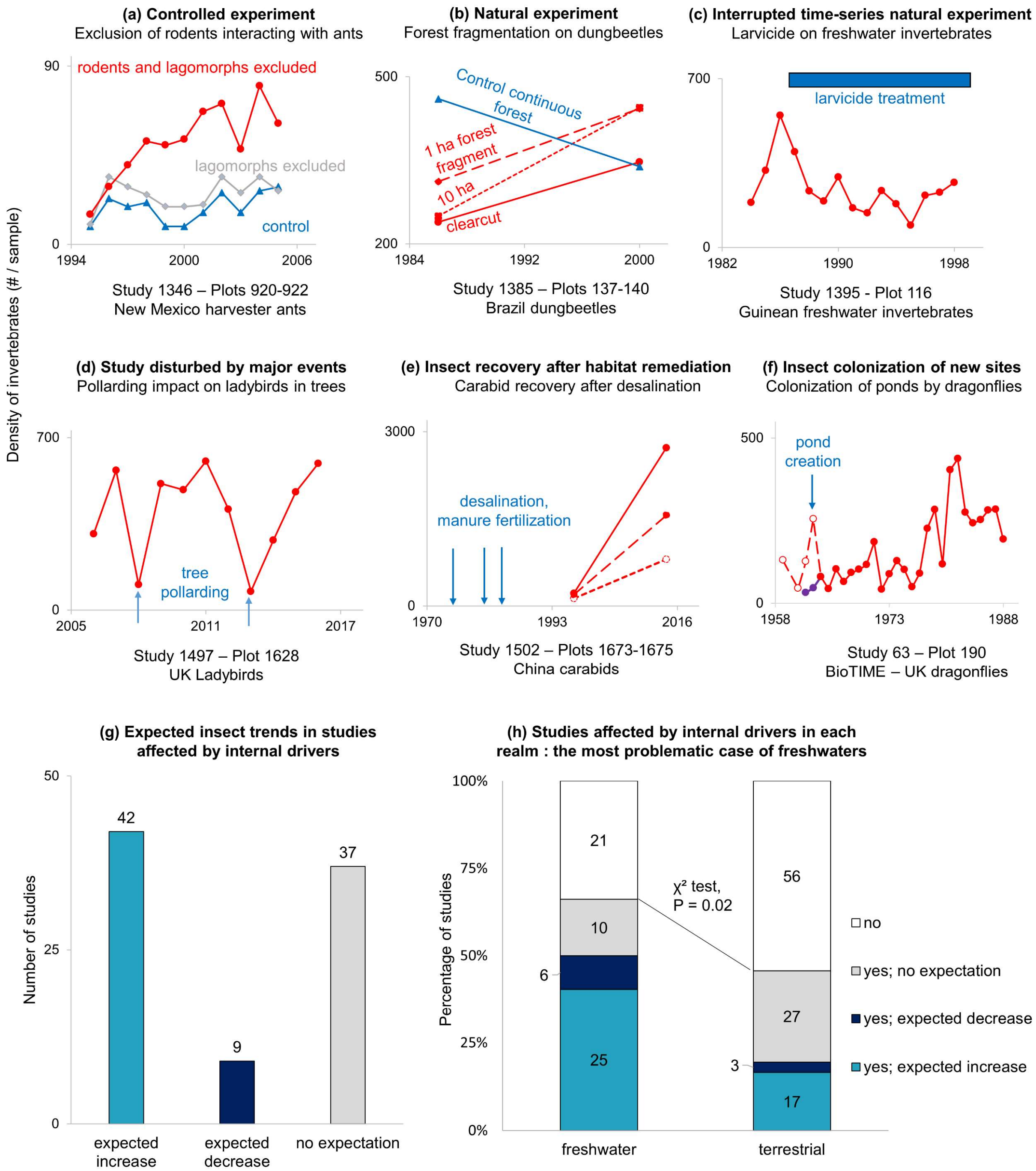

FIGURE 4 Inclusion of studies with specific internal drivers (Appendix S3, *Fig2and4.xlsx*). Examples of (a-c) controlled or natural experiments and (d-f) studies with major disturbances; in (f), dashed and purple curves respectively represent erroneous and actual data. (g) Insect trends expected under the internal drivers with (h) the most problematic case of freshwaters.

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Of these 88 datasets affected by specific internal drivers, there were almost five times more situations expected to favor an increase rather than a decrease in insects (Figure 4g, Appendix S3). Two-thirds of the freshwater datasets were affected by internal drivers, a proportion significantly higher than that (one half) of the terrestrial datasets (χ^2 = 5.7, P=0.02, Figure 4h). Of these two-thirds, insects were expected to increase in 61% of cases and decrease in only 15% of cases. We thus caution that InsectChange is unrepresentative of the habitat conditions and associated insect trends worldwide, particularly in freshwaters. In controlled experiments, it seems prudent to consider only control sites. Care should be taken regarding the representativeness of the situations investigated in natural experiments and of the overall studies in terms of sites without, under or post- disturbance (Cardinale et al. 2018).

4. Methodological issues resulting in a strong overestimation of the local cropland cover

Last, we found a strong overestimation of local cropland, a possible driver included in InsectChange by matching plots to land covers of the ESA CCI database (ESA 2017) via their geographic coordinates (GC). We found that the assessment of local cropland cover was inadequate for almost half (468 of 982) of the terrestrial plots, with a very uneven distribution of errors (Figure 5a, Appendix S4, *CroplandCover.xlsx*). Most plots assessed as having no surrounding crops were well assessed (451 of 486), while most plots assessed as having surrounding crops suffered from an overestimation of the crop cover (350 of 496), two-thirds (233) having no surrounding crops. We observed a similar picture when considering only plots with distinct GC (508) (Figure 5a). Because of this strong bias, we argue that InsectChange cannot provide a reliable analysis of the impact of local cropland cover on insect change and could incorrectly dismiss the impact of crops on insect decline.

The main reason for these errors was an inaccurate assessment of the local cropland cover from the interpretation of satellite images in the ESA-CCI database (Appendix S4), notably due to its limitation that grasslands may inaccurately be coded as croplands (Desquilbet et al. 2020) and its imprecise representation of land cover when used at a local scale composed of nine 300 m × 300 m squares with a rough cropland cover assigned to each of them (Figure 5b). Second, the GC were inadequate for estimating land cover at this scale for 228 of the 982 plots, mainly (212 plots) because the considered plots aggregated data from sampling points often several kilometers apart under the unique GC of their barycenter or of one of these points (Figure 5b).

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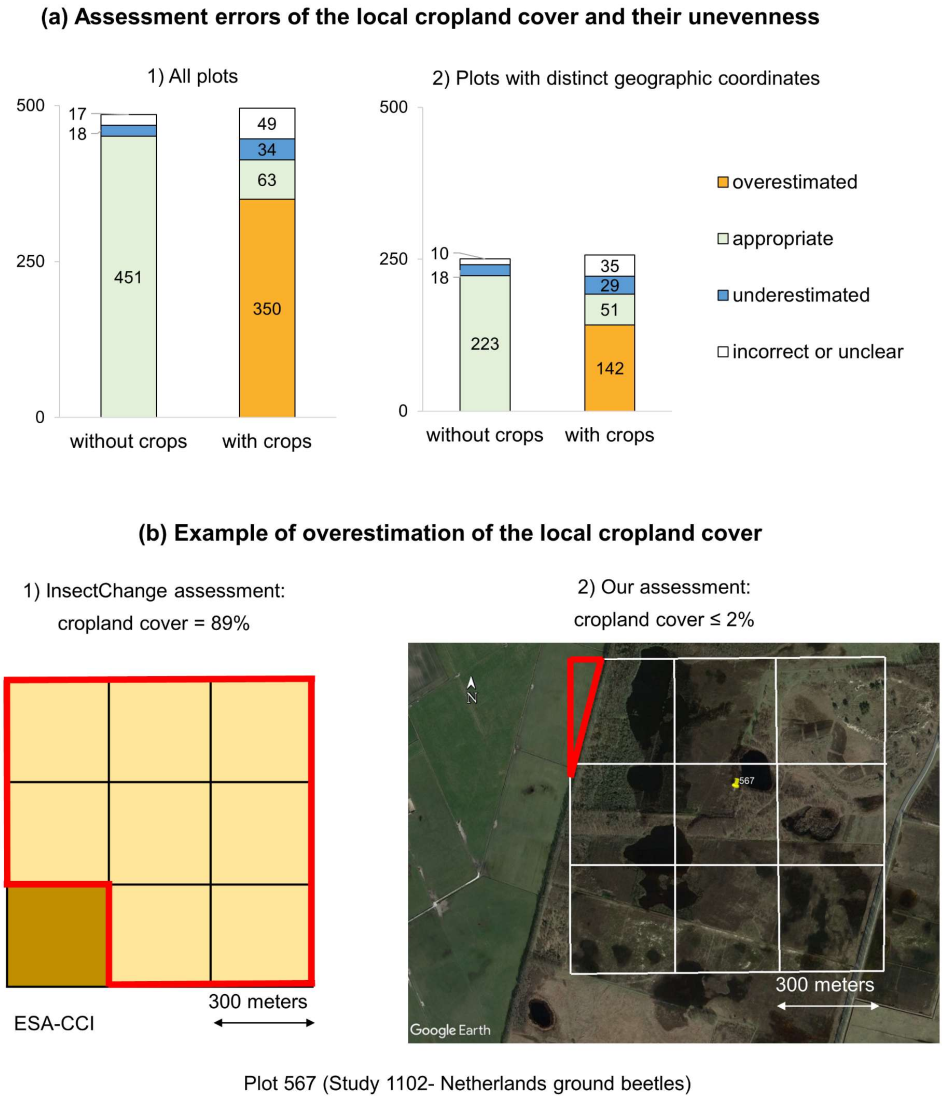

FIGURE 5 Overestimation of local cropland cover (Appendix S4, *CroplandCover.xlsx*). (a) Assessment errors of plot cropland cover and their unevenness. (b) Example of overestimation of the local cropland cover (Study 1102, Plot 567) outlined in red; 1) InsectChange assessment: cropland cover = (8×100%)/9 = 89% based on ESA-CCI; 2) our assessment: cropland cover ≤ 2% based on Google Earth and information from the source study.

Concerning freshwaters, the GC provided were inadequate for 108 of the 585 plots matched with ESA-CCI information and should be used with caution. We did not check local cropland cover estimates, as water quality at sampling points may be more dependent on upstream land use (Desquilbet et al. 2020). A quality check on the accuracy of estimates provided for other possible drivers of insect change is strongly recommended, notably local-scale drivers (urban cover and climate change) similarly affected by the inadequacy of GC.

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Conclusion

The numerous problems underlying InsectChange call for corrections and an extreme vigilance in its use. They fully undermine the results obtained so far from this database, in the first place those of van Klink et al. (2020a), widely covered by the media, which cast unsubstantiated doubt on insect decline (Kimbrough 2020, McGrath 2020). We argue that InsectChange, in its current state, does not allow to study insect trends worldwide, to analyze the influence of agriculture on insects or to suggest a positive effect of water protection policies on freshwater insects. More generally, this careful review illustrates the importance of contacting dataset owners to ensure their appropriate use. It calls for vigilance to avoid transferring errors across databases, as occurred for 11 datasets incorporated from the Global Population Dynamics Database (Prendergast et al. 2010) and/or Biotime (Dornelas et al. 2018) to InsectChange (Appendix S5). It underlines the need for relevant matching with external databases. Finally, our analysis highlights the attention that needs to be paid to the data and its meaning to ensure that large databases built from individual datasets participate in a cumulative knowledge process.

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Author contributions

M. Desquilbet and L. Gaume contributed equally to this work.

Conflict of interest statement

The authors declare no conflict of interest.

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Supplementary information

Five appendices (Appendix S1, Appendix S2, Appendix S3, Appendix, S4 and Appendix S5) and four datasheets (*Problems.xlsx*, *FreshwaterNonInsects.xlsx*, *CroplandCover.xlsx* and *Fig2and4.xlsx*) are available in the supplementary materials.

- Appendix S1 and *Problems.xlsx* describe and record the problems encountered in InsectChange.
- Appendix S2 summarizes the inclusions of freshwater non-insects in the InsectChange assemblages, while *FreshwaterNonInsects.xlsx* details the calculation of their parts in the assemblages and the problematic consequences on the inferred 'insect' trends.
- Appendix S3 shows the expected trends in the studies of InsectChange affected by internal drivers.
- Appendix S4 shows the assessment of the adequacy of geographic coordinates and local cropland cover, which are detailed in *CroplandCover.xlsx*.
- Appendix S5 details the errors transferred from other databases to InsectChange.
- *Fig2and4.xlsx* provides information supporting Figures 2 and 4 of this comment.

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