InsectChange: a global database of temporal changes in insect and arachnid assemblages

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Introduction

Insects and ecologically similar arthropod groups (e.g., arachnids), are the most ubiquitous and diverse group of eukaryotic organisms on Earth. Insects are a key component of functioning ecosystems, and deliver indispensable ecosystem services to humans, including crop pollination (Gallai et al. 2009), pest control (Huang et al. 2018), and human food (Ramos-Elorduy 2009, Van Huis et al. 2013). Some insect species also remain one of the most important current and future threats to food security in the form of agricultural (Oerke 2006, Deutsch et al. 2018) and silvicultural pests (van Lierop et al. 2015), and others are a major source of human mortality by acting as vectors for the transmission of infectious diseases (FAO 2017).

While insect monitoring schemes, and studies on insect-related ecosystem services and disservices, have been ongoing for decades, recent attention has focused on dramatic declines of many groups of insects as a harbinger of anthropogenic biodiversity decline (e.g. Thomas et al. 2004, Biesmeijer et al. 2006, Brooks et al. 2012, Forister et al. 2016, Hallmann et al. 2017, 2020, Lister and Garcia 2018, Harris et al. 2019, Macgregor et al. 2019, Seibold et al. 2019, Wepprich et al. 2019). However, studies on changes in insect populations and communities have largely been localized, as synthetic compilations of data have not heretofore been available. Hence, it has remained unclear whether studies showing dramatic declines are emblematic of broader trends, or rather part of a more nuanced and variable series of cases (Thomas et al. 2019, Didham et al. 2020, Saunders et al. 2020).

In a meta-analysis of 1668 openly accessible long-term (≥10 years) time series of terrestrial and freshwater insect and arachnid assemblages (Van Klink et al. 2020b), we demonstrated that trends in assemblage sizes (measured as biomass or summed abundance) were variable across space and time, but that terrestrial assemblage sizes were on average decreasing and freshwater assemblage sizes were on average increasing. The data underlying this analysis are presented here.

To compile this database, we searched the literature in Thomson Reuters Web of Knowledge and Elibrary.ru in English and Russian for reports on changes in insect assemblages meeting three criteria: insects and/or arachnids were (i) collected using consistent, standardized methods over time, (ii) were collected at the same location each time, and (iii) were, or could be, aggregated at the family level or higher taxonomic resolution (in one case subfamily level) to attain a measure of total assemblage size. Assemblage size was either reported (or could be calculated) as total biomass or total abundance (i.e., number of individuals). Worms, mollusks, crustaceans and myriapods were excluded from any data set when present and possible, to maintain consistency with recent case-studies. Additionally, we searched the data repositories of the LTER network and the Environmental Change Network, the Global Population Dynamics Database (Prendergast et al. 2010), BioTIME (Dornelas et al. 2018), VectorBase

(Giraldo-Calderón et al. 2015), LTREB awarded grants and the Knowledge Network Biocomplexity (KNB) for data meeting these criteria.

The compiled database contains the total abundance and/or biomass values for each plot per time point, as analyzed in Van Klink et al. (2020b). In all, we compiled data from 165 studies, 16 of which were previously unpublished (methods provided in Appendix S1). Within those studies, there were 1668 locations leading to a total of 68219 site × sampling event combinations (Table 1). The standardizations necessary for any data sets of which we obtained raw data are detailed in Appendix S2. We excluded three data sources (ID's 1339, 1404, 1416) used in Van Klink et al. (2020b) because their access licenses precluded publication of derived numbers, but their meta-data are included. These studies can be accessed from the source, and our methods of processing them are detailed in Appendix S2. The studies originated from all continents except Antarctica (Fig. 1), but were mostly from Europe (48%) and North America (29%). The data span the period from 1925 to 2018, and the monitoring time span for each site ranged between 9 and 81 years, albeit most were not continuous (Fig. 2). There were 103 studies with a total of 1053 plots from the terrestrial realm, and 62 studies with a total of 615 plots from the freshwater realm. About one-third (34%) of the plots were located inside protected reserves following the Global Database on Protected Areas (IUCN and UNEP-WCMC 2018). In the terrestrial realm, Lepidoptera were the most frequently sampled order, closely followed by Coleoptera and studies that sampled many groups of terrestrial taxa (Fig 3). In the freshwater realm, the majority of studies investigated three or more insect orders. The insects were collected using 34 different methods, of which barber pitfall traps were the most common method (27 studies) followed by light trapping (17) and transect counts (17). As metric of assemblage size, 129 studies reported the number of individuals encountered per sampling event, 13 studies reported the biomass of the assemblage, and 23 studies reported both abundance and biomass.

When using this database, or parts thereof, we ask that researchers respect the access licenses of the individual studies, and cite each appropriately, as well as this compilation.

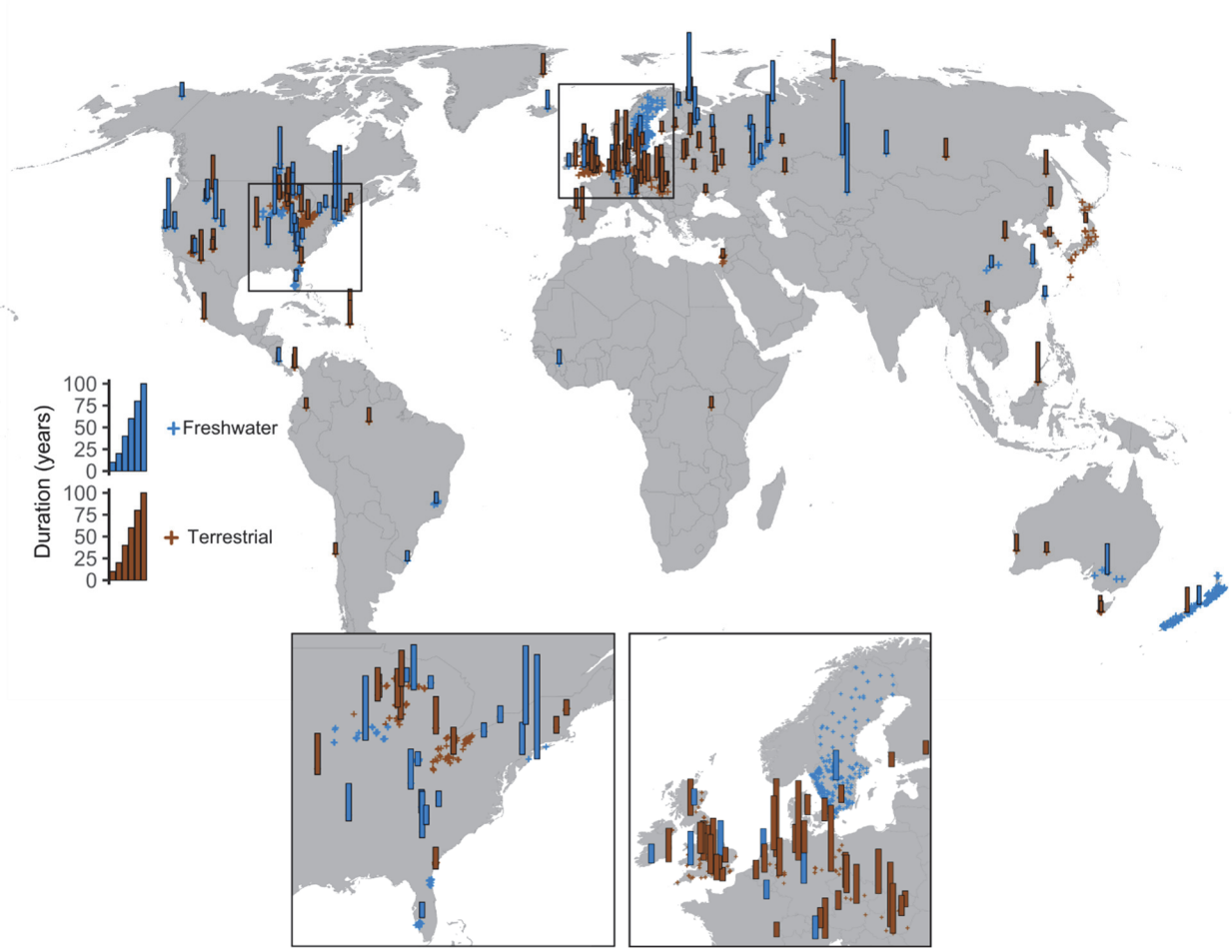

Fig 1. Duration of all data sets (height of the bars corresponds to study duration, centered on the central coordinates of each data set), and locations of all plots (+). For North-western Europe and Eastern North America, detailed images are provided to improve clarity.

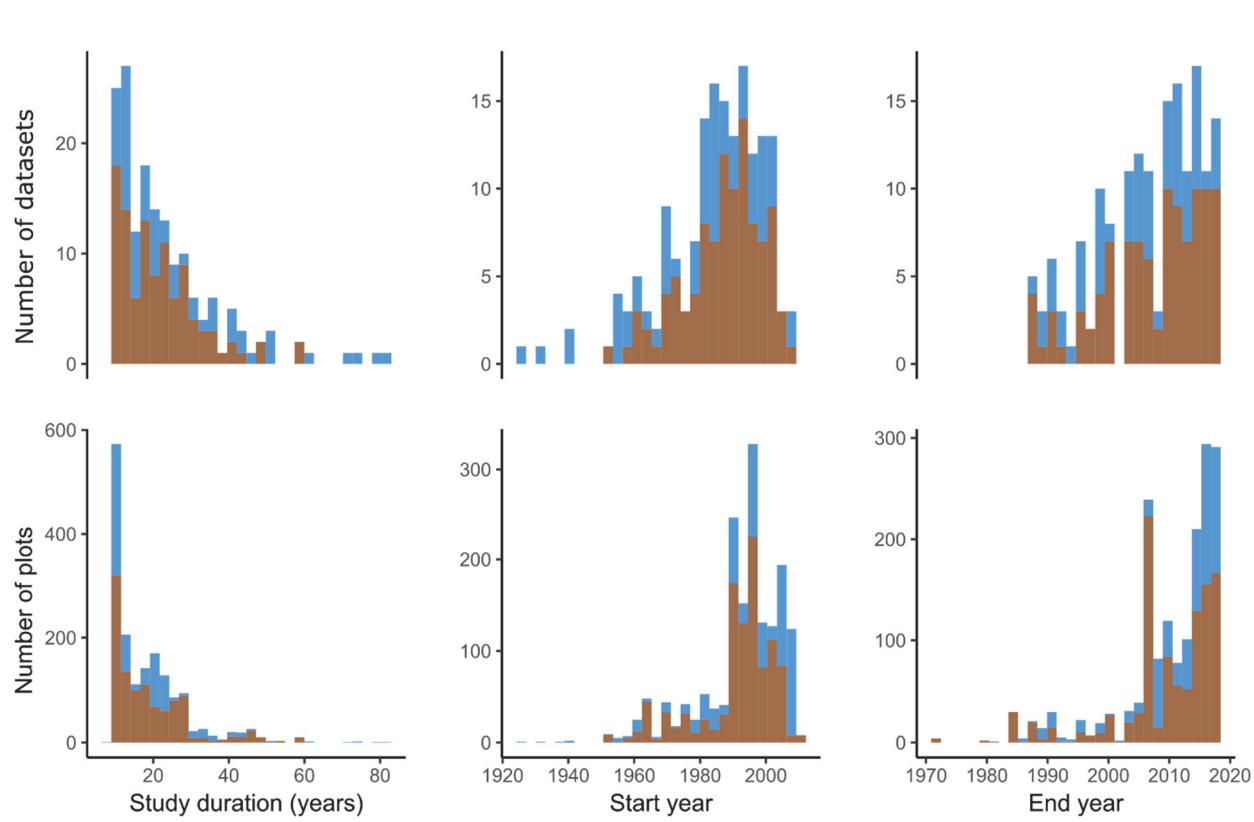

Fig 2. Stacked histograms of study duration, start year and end year of the data sets and plots in both realms. Brown are terrestrial data sets and blue are freshwater data sets.

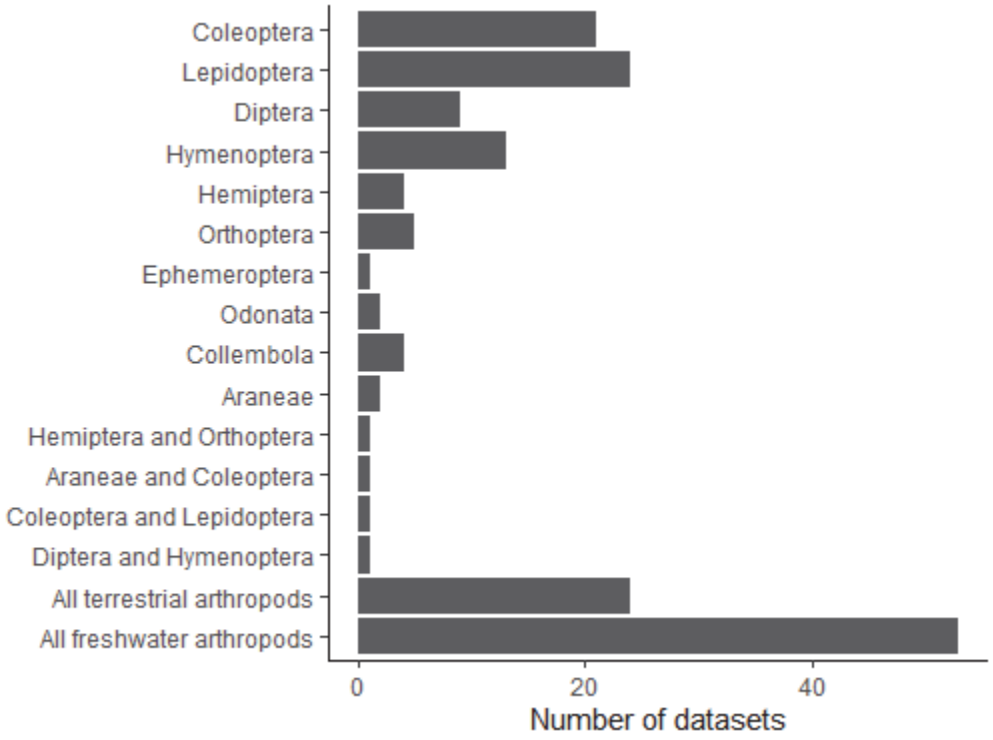

Fig 3. Focal taxa of the 165 data sets. Data sets focusing on more than two orders were classified under 'all arthropods' in their respective realms.

Table 1. Details on the datasets used in this study.

Open access licenses:
PD: public domain (all data extracted from papers),
OGL: Open Government License (UK),
CC-BY, CC0, CC-BY-NC, CC-BY-ND,
ODC: Open Data Commons
No share: data openly accessible, but no redistribution of data or derived products is allowed,

Link to data: URL's are provided to the source of the data points (repository or publication), unless there was no online version of the data available (NA).

Datasource ID	Place	Taxon	Abundance / Biomass	First year	Last year with data	Time span (yrs)	Nr yrs data	Nr of plots	Link to data	Conditions for use	Reference
63	England	Dragonflies	A	1959	1988	30	29	1	URL	CC-BY	(Moore 1991, Dornelas et al. 2018)
70	Belgium	Migratory Lepidoptera	A	1983	1996	14	14	1	URL	CC-BY	(Dornelas et al. 2018)
79	United Kingdom	Butterflies	A	1976	1985	10	10	22	URL	CC-BY	(Pollard et al. 1986, Prendergast et al. 2010)
249	Denmark	Coleoptera and Lepidoptera	A	1992	2009	17	17	1	URL	CC0	(Thomsen et al. 2016, Dornelas et al. 2018)
294	Vietnam	Butterflies	A	2003	2013	11	8	6	URL	CC-BY	(Vu 2009, Dornelas et al. 2018)
300	USA: Michigan	Insects	A	1989	2017	29	29	51	URL	CC-BY	(Landis 2018)
301	USA: Kansas	Grasshoppers	A	1982	2013	32	25	15	URL	CC-BY	(Joern 2016, Dornelas et al. 2018)
313	USA: Minnesota	Grasshoppers	A	1989	2006	18	18	20	URL	CC-BY	(Knops and Tilman 2006, Dornelas et al. 2018)
375	Japan	Beetles	AB	2004	2014	11	11	22	URL	CC-BY	(Monitoring Site 1000 Project, Biodiversity Center 2015, Dornelas et al. 2018)
380	England	Butterflies	A	1978	1987	10	10	1	URL	PD	(Pollard 1991, Prendergast et al. 2010)
465	Czech Republic	Moths	A	1967	1992	26	26	1	URL	PD	(Novak 1983, Prendergast et al. 2010)
478	Germany	Freshwater invertebrates	A	1969	2005	37	37	5	URL	CC-BY	(Wagner et al. 2011)
502	United Kingdom	Aphids	A	1969	1990	22	22	16	URL	PD	(Taylor et al. 1990, Prendergast et al. 2010)
1006	United Kingdom	Moths	A	1992	2015	24	24	13	URL	OGL	(Rennie et al. 2018a)
1102	Netherlands	Ground beetles	A	1959	2016	58	50	29	This paper	CC_BY	(Bowler et al. 2017, Van Klink et al. 2019)
1261	USA: Massachusetts	Ants	A	2003	2015	13	13	8	URL	CC-BY	(Ellison 2017)
1263	United Kingdom	Butterflies	A	1993	2012	20	20	13	URL	OGL	(Rennie et al. 2018b)
1266	United Kingdom	Froghoppers	A	1993	2015	23	23	16	URL	OGL	(Rennie et al. 2018c)
1267	United Kingdom	Ground beetles	A	1993	2015	23	23	36	URL	OGL	(Rennie et al. 2018d)
1310	Panama	Plant- and leafhoppers	A	1974	1987	14	14	1	URL	PD	(Wolda 1992)
1312	Czech Republic	Moths	A	1963	1991	29	29	3	URL	PD	(Wolda et al. 1994)
1319	USA: New Mexico	Grasshoppers	A	1992	2013	22	22	4	URL	CC-BY	(Lightfoot 2010a)
1324	Netherlands	Spiders and Ground beetles	A	1969	2008	40	39	4	NA	PD	(Meijer and Barendregt 2018)
1328	England	Hoverflies	A	1972	2001	30	30	1	This paper	CC-BY	(Hassall et al. 2017)

1335	Czech Republic	Ladybeetles	A	1983	2010	28	2	3	URL	PD	(Honek et al. 2014)
1339	USA: Montana	Grasshoppers	A	1981	2016	36	36	4	URL	No share	(Belovsky 2018)
1340	Hungary	Moths	A	1962	2009	48	46	7	URL	CC0	(Valtonen et al. 2017)
1345	USA: New Mexico	Ground dwelling arthropods	A	1992	2004	13	13	3	URL	CC-BY	(Lightfoot 2010b)
1346	USA: New Mexico	Ants	A	1995	2005	11	11	6	URL	CC-BY	(Lightfoot 2010c)
1347	USA: Wisconsin	Freshwater invertebrates	A	1981	2015	35	33	14	URL	CC-BY	(Magnuson et al. 2010)
1349	USA: Arizona	Ground dwelling arthropods	A	1998	2016	19	19	29	URL	CC-BY	(Grimm and Childers 2018)
1351	USA: Arizona	Freshwater invertebrates	A	1985	1999	15	10	1	URL	CC0	(Grimm et al. 2007)
1353	USA: Arizona	Ants	A	1988	2009	22	19	2	URL	CC0	(Ernest 2018)
1357	Puerto Rico	Arboreal arthropods	A	2004	2016	13	6	34	URL	CC-BY	(Schowalter 2011)
1361	USA: Georgia	Grasshoppers	A	2000	2016	17	17	7	URL	CC-BY	(Pennings 2016)
1364	USA: Minnesota	Herb layer arthropods	A	1996	2006	11	10	172	URL	CC-BY	(Tilman et al. 2006)
1365	USA: Minnesota	Ground beetles	A	1980	2005	26	2	3	URL	PD	(Gandhi et al. 2011)
1367	Italy	Ground beetles	A	1980	2009	30	4	6	URL	PD	(Pizzolotto et al. 2014)
1376	Taiwan	Freshwater invertebrates	A	1985	1995	11	2	4	URL	PD	(Shieh and Yang 2000)
1377	Panama	Orchid bees	A	1979	2000	22	20	1	URL	PD	(Roubik 2001)
1378	Costa Rica	Butterflies	A	2003	2012	10	10	1	URL	PD	(Grøtan et al. 2014)
1379	Ecuador	Butterflies	A	1994	2004	11	11	1	URL	PD	(Grøtan et al. 2012)
1381	Brazil: Rio Grande del Sul	Freshwater invertebrates	A	2000	2010	11	10	1	URL	PD	(Souza da Silva et al. 2015)
1382	Chile	All arthropods	AB	2003	2014	12	12	1	URL	PD	(Meserve et al. 2016)
1384	New Zealand	Moths	A	1962	1988	27	2	1	URL	PD	(White 1991)
1385	Brazil: Amazonas	Dung- and Carrion beetles	A	1986	2000	15	2	4	URL	PD	(Quintero and Roslin 2005)
1387	Australia: Western Australia	Spiders	A	1990	2000	11	7	1	URL	PD	(Langlands et al. 2006)
1388	USA: California	Freshwater invertebrates	A	1984	2003	20	20	4	URL	PD	(Bêche and Resh 2007, Resh 2018)
1391	Russia: Murmansk	Soil fauna	A	1986	2010	25	3	6	URL	PD	(Rybalov and Kamayev 2012)
1392	Slovakia	Butterflies	A	2001	2012	12	6	1	URL	PD	(Kočíková et al. 2014)
1393	Russia: Tatarstan	Insects	A	1978	1995	18	18	3	URL	PD	(Shafigullina 2009)
1394	Uganda	Butterflies	A	2000	2011	12	12	1	URL	PD	(Valtonen et al. 2013)

1395	Guinea	Freshwater invertebrates	A	1984	1998	15	15	1	URL	PD	(Crosa et al. 2001)
1396	Germany	Springtails	A	1980	2000	21	17	2	URL	PD	(Daghighi et al. 2017)
1397	Hungary	Ants (nests)	A	1981	2017	37	28	1	URL	PD	(Gallé 2017)
1398	Czech Republic	Beetles	A	1975	2007	33	7	3	URL	PD	(Hodecek et al. 2015)
1400	Russia: Buryatia	Ground beetles	A	1988	2007	20	20	4	URL	PD	(Ananin and Ananina 2011)
1401	Russia: Lipetsk Oblast	Beetles	A	1995	2011	17	17	4	URL	PD	(Tsurikov 2016)
1402	Russia: Krasnoyarsk Krai	Springtails	A	1969	2010	42	2	8	URL	PD	(Babenko 2013)
1403	Russia: Sverdlovsk Oblast	Parasitoid wasps	A	1994	2003	10	4	1	URL	PD	(Fedyunin 2008)
1404	Greenland	Arthropods	A	1996	2017	22	20	6	URL	No share	(Aarhus University 2018)
1405	Finland	Saproxylic beetles	A	1990	1999	10	10	2	URL	PD	(Martikainen and Kaila 2004)
1406	Russia: Orenburg Oblast	Ground dwelling arthropods	A	1990	2004	15	9	1	URL	PD	(Nemkov and Sapiga 2010)
1407	Russia: Tver Oblast	Ground beetles	A	1996	2012	17	17	2	URL	PD	(Korobov 2015)
1408	Finland	Freshwater invertebrates	A	2000	2013	14	14	23	URL	CC0	(Huttunen et al. 2017)
1409	Germany	Flying Insects	B	1989	2016	28	18	24	URL	PD	(Hallmann et al. 2017)
1410	Germany	Arthropods	A	1992	2005	14	8	1	URL	PD	(Karg et al. 2015)
1411	Austria	Soil fauna	AB	1998	2012	15	2	4	URL	PD	(Steinwandter et al. 2017)
1412	Netherlands	Freshwater invertebrates	A	1987	2007	21	5	1	URL	PD	(van dam 2009)
1413	South Korea	Soil fauna	A	1998	2007	10	10	8	URL	PD	(Kwon et al. 2016)
1414	Iceland	Midges and black flies	A	1977	1996	20	20	2	URL	PD	(Gardarsson et al. 2004)
1415	USA: Wisconsin	Mayflies	AB	2002	2012	11	2	1	URL	PD	(Brunk et al. 2014)
1416	USA: New Hampshire	Caterpillars	AB	1986	1997	12	12	4	URL	No share	(Holmes 2018)
1417	USA: Michigan	Freshwater invertebrates	B	1984	1993	10	10	2	URL	PD	(Stout and Rondinelli 1995)
1418	USA: Tennessee	Dragonflies	A	1978	1989	12	12	1	URL	PD	(Crowley and Johnson 1992)
1419	Western Australia	Ants	A	1980	1997	18	2	3	URL	PD	(Bisevac and Majer 1999)
1421	USA: Arkansas	Freshwater invertebrates	A	1971	1999	29	2	2	URL	PD	(Johnson and Harp 2005)
1422	USA: Tennessee	Freshwater invertebrates	A	1986	2003	18	18	4	URL	PD	(Smith et al. 2011)
1423	USA: Colorado	Freshwater invertebrates	A	1989	2006	18	18	4	URL	PD	(Clements et al. 2010)
1425	USA: Georgia	Freshwater invertebrates	AB	1956	1991	36	2	1	URL	PD	(Grubaugh and Wallace 1995)
1426	USA: Pennsylvania	Freshwater invertebrates	A	1980	1990	11	11	3	URL	PD	(McCreadie et al. 1994)

1427	USA: Idaho	Freshwater invertebrates	AB	1993	2005	13	13	6	URL	PD	(Rugenski and Minshall 2014)
1428	USA: Pennsylvania	Freshwater invertebrates	AB	1972	1996	25	7	1	URL	PD	(Bradt et al. 1999)
1429	USA: New York	Freshwater invertebrates	A	1956	2016	61	61	2	URL	ODC	(Rudstam 2018)
1430	USA: Utah	freshwater invertebrates	A	1958	1999	42	28	3	URL	PD	(Vinson 2001)
1431	USA: Alaska	Freshwater invertebrates	A	1984	1998	15	15	2	URL	PD	(Slavik et al. 2004)
1432	USA: North Carolina	Freshwater invertebrates	B	1992	2006	15	15	1	URL	PD	(Wallace et al. 2015)
1433	Belgium	Freshwater invertebrates	A	1998	2011	14	13	1	URL	PD	(Latli et al. 2017)
1434	Switzerland	Spiders	A	1994	2004	11	11	1	URL	PD	(Blandenier et al. 2014)
1435	USA: Kentucky	Freshwater invertebrates	A	1960	1990	31	2	12	URL	PD	(Johnson et al. 1994)
1437	USA: Idaho	Freshwater invertebrates	B	1979	1989	11	11	10	URL	PD	(Minshall et al. 2001)
1439	China: Jiangsu	Midges	A	1987	2007	21	2	4	URL	PD	(Cai et al. 2015)
1440	CA: Winnipeg	Freshwater invertebrates	A	1969	2013	45	12	3	URL	PD	(Hann et al. 2017)
1441	CA: Ontario	Freshwater invertebrates	A	1983	1995	13	3	2	URL	PD	(Haynes et al. 1999)
1444	New Zealand	Freshwater invertebrates	A	1989	2008	20	20	66	URL	CC_BY_NC	(Groker 2018)
1445	USA: Arizona	Ants (nests)	A	1977	2009	33	28	2	URL	CC0	(Ernest 2018)
1446	Russia: Kursk Oblast	Ground beetles	A	1983	1999	17	16	3	URL	PD	(Grechanichenko 2014)
1448	Russia: Nenets Okurg	Freshwater invertebrates	AB	1990	2000	11	2	1	URL	PD	(Baranovskaya 1976, Fefilova et al. 2014)
1449	Russia: Komi Republic	Freshwater invertebrates	A	2000	2014	15	5	2	URL	PD	(Baturina et al. 2017)
1451	Russia: Perm Krai	Freshwater invertebrates	B	1964	2014	51	12	1	URL	PD	(Aleksevnina and Presnova. 2017)
1452	Russia: Perm Krai	Freshwater invertebrates	B	2002	2015	14	6	6	URL	PD	(Istomina 2017)
1453	Russia: Karelia	Freshwater invertebrates	AB	1954	1993	40	16	1	URL	PD	(Pavlovsky 2014)
1454	Russia: Karelia	Freshwater invertebrates	B	2003	2015	13	13	1	URL	PD	(Petukhov et al. 2017)
1455	Russia: Nenets Okurg	Freshwater invertebrates	AB	1968	2010	43	6	1	URL	PD	(Baranovskaya 1976, Baturina et al. 2012)
1456	Russia: Saratov Oblast	Freshwater invertebrates	AB	1969	2011	43	6	3	URL	PD	(Nechvalenko 1973, Kurina et al. 2016)
1457	Russia: Samara Oblast	Freshwater invertebrates	AB	1991	2007	17	6	3	URL	PD	(Golovatyuk and Abrosimova 2015)
1458	Russia: Novgorod Oblast	Springtails	A	1981	1995	15	5	3	NA	PD	(Kuznetsova 2005)
1459	Russia: Moscow Oblast	Ground beetles	A	1974	1990	17	6	2	NA	PD	(Gryuntal 2008)
1460	Russia: Leningrad Oblast	Rove beetles	A	1983	2005	23	4	1	URL	PD	(Guseva 2017)

1461	Russia: Khabarovsk Krai	Hoverflies	A	1988	2013	26	5	1	URL	PD	(Mutin 2015)
1462	Russia: Primorsky Krai	Butterflies	A	1986	2005	20	20	1	URL	PD	(Sasova 2008)
1464	Belarus	Hymenoptera	A	1990	2000	11	11	1	URL	PD	(Shlyakhtenok 2007a)
1465	Malaysia	Moths	A	1965	2007	43	2	10	URL	PD	(Chen et al. 2011)
1466	Kazachstan	Freshwater invertebrates	B	1939	2012	74	48	1	URL	PD	(Krupa et al. 2013)
1467	Belarus	Hymenoptera	A	1986	2003	18	16	1	URL	PD	(Shlyakhtenok 2007b)
1468	Spain	Bumblebees	A	1988	2008	21	2	1	URL	PD	(Ploquin et al. 2013)
1470	Belarus	Hymenoptera	A	1985	2005	21	21	1	URL	PD	(Shlyakhtenok 2007c)
1471	Ukraine	Beetles	A	2003	2011	9	9	1	URL	PD	(Nitochko 2012)
1472	Hungary	Moths	A	1990	2004	15	8	1	URL	PD	(Szabó et al. 2007)
1473	USA: Idaho	Freshwater invertebrates	AB	1993	2013	21	19	11	URL	PD	(Mebane et al. 2015b, 2015a)
1474	Germany	Bugs and Grasshoppers	A	1951	2009	59	2	9	This paper	CC-BY	(Schuch 2011, Schuch et al. 2012a)
1475	Germany	Plant- and leafhoppers	A	1962	2010	49	9	27	This paper	CC-BY	(Schuch 2011, Schuch et al. 2012b)
1476	USA: Wisconsin	Butterflies	A	1987	2017	31	31	56	This paper	CC-BY	(Swengel and Swengel 2015a)
1477	USA: Wisconsin	Butterflies	A	1988	2017	30	30	47	This paper	CC-BY	(Swengel and Swengel 2015b, 2015a)
1478	USA: Wisconsin	Butterflies	A	1990	2017	28	28	35	This paper	CC-BY	(Swengel and Swengel 2015b)
1479	AUS: Tasmania	Ground and foliage dwelling arthropods	A	1999	2015	17	9	6	This paper	CC-BY	(Driessen 2016)
1480	AUS: Tasmania	Ground dwelling arthropods	A	2001	2012	12	4	14	This paper	CC-BY	(Doran et al. 2003)
1481	Israel	Butterflies	A	2009	2018	10	10	10	This paper	CC-BY	(Pe'er and Comay 2019)
1484	Mexico	Herb layer arthropods	B	1987	2014	28	3	1	URL	PD	(Lister and Garcia 2018)
1485	Puerto Rico	Herb layer arthropods	B	1976	2013	38	5	3	URL	PD	(Lister and Garcia 2018)
1487	Puerto Rico	Canopy arthropods	A	1991	2016	26	15	65	URL	PD	(Schowalter 2017)
1488	Sweden	Freshwater invertebrates	AB	1969	2017	22	22	264	URL	CC0	(SLU 2018)
1491	Brazil: Minas Gerais	Freshwater invertebrates	A	1999	2010	12	12	13	URL	CC-BY-NC	(Sistema de Informação sobre a Biodiversidade Brasileira - SiBBr 2018, Aguila et al. 2018)
1493	England	Flying Insects	AB	2000	2009	10	10	1	URL	PD	(Hu et al. 2016)

1494	England	Sawflies	A	1970	1988	19	19	5	URL	PD	(Aebischer 1990)
1495	United Kingdom	Flying Insects	B	1973	2001	29	29	4	URL	PD	(Shortall et al. 2009)
1496	Scotland	Flying Insects	A	1972	1997	27	27	1	URL	PD	(Benton et al. 2002)
1497	England	Ladybeetles	A	2006	2016	11	11	4	URL	PD	(Brown and Roy 2018)
1498	Ireland	Freshwater invertebrates	A	1985	1998	14	12	1	URL	PD	(Woodward et al. 2015)
1499	Scotland	Freshwater invertebrates	A	1983	1994	12	12	1	URL	PD	(Soulsby et al. 1995)
1500	Wales	Freshwater invertebrates	A	1981	2005	25	21	1	URL	PD	(Durance and Ormerod 2007)
1501	Ireland	Butterflies	A	1992	2016	25	17	2	URL	CC-BY	(Irish National Biodiversity Data Centre 2018)
1502	China: Hebei	Ground beetles	A	1997	2014	18	2	3	URL	PD	(Zhang et al. 2018)
1503	Australia: New South Wales	Freshwater invertebrates	A	1980	2012	33	32	6	URL	PD	(Paul et al. 2018)
1504	USA: California	Freshwater invertebrates	A	1998	2015	18	18	6	URL	PD	(Herbst et al. 2018)
1505	Finland	Mining and galling insects	AB	2003	2013	11	11	1	URL	CC0	(Blanchet et al. 2018b, 2018a)
1506	Costa Rica	Freshwater invertebrates	AB	1997	2011	15	15	2	URL	PD	(Gutiérrez-Fonseca et al. 2018)
1507	Russia: Orenburg Oblast	Freshwater invertebrates	AB	1981	2005	25	6	1	URL	PD	(Shulepina 2010)
1508	Russia: Murmansk Oblast	Freshwater invertebrates	AB	1992	2005	14	2	4	URL	PD	(Chernenkova et al. 1995, Tanasevitch et al. 2009)
1509	Russia: Murmansk Oblast	Freshwater invertebrates	AB	1939	2010	72	8	2	URL	PD	(Kashulin et al. 2012)
1510	Russia: Archangelsk Oblast	Freshwater invertebrates	AB	2003	2015	13	13	1	URL	PD	(Novoselov et al. 2017)
1511	Russia: Novosibirsk Oblast	Freshwater invertebrates	B	1925	2004	80	19	1	URL	PD	(Bezmaternykh et al. 2008)
1512	Germany	Ground beetles	B	1994	2017	24	24	1	URL	PD	(Homburg et al. 2019)
1513	Italy	Freshwater Insects	A	1997	2013	17	6	6	URL	PD	(Lencioni 2018)
1515	Spain	Dung beetles	A	1983	2017	35	2	1	URL	PD	(Cuesta and Lobo 2019)
1516	Sweden	Saproxylic beetles	A	2001	2013	13	3	1	URL	PD	(Gran and Götmark 2019)
1517	China: Chongqing & Hubei	Mosquitoes	A	1997	2009	13	13	6	URL	PD	(Guo et al. 2018)
1518	USA: Ohio	Butterflies	A	1996	2016	21	21	60	This paper	CC-BY	(Wepprich et al. 2019)
1519	USA: New York & New Jersey	Mosquitoes	A	1932	2012	81	81	2	This paper	CC-BY	(Rochlin et al. 2016)

1520	USA: Iowa	Mosquitoes	A	1969	2018	50	46	27	URL	CC-BY-NC	(Giraldo-Calderón et al. 2015, Iowa Mosquito Surveillance 2019, Field et al. 2019)
1521	Denmark	Springtails	A	1985	1999	15	8	2	URL	PD	(Petersen et al. 2004)
1524	Netherlands	Light-attracted insects	A	1997	2017	21	21	1	URL	PD	(Hallmann et al. 2020)
1525	USA: Indiana	Mosquitoes	A	2008	2018	11	11	13	URL	CC-BY	(Giraldo-Calderón et al. 2015)
1526	USA: Florida	Mosquitoes	A	2007	2018	12	12	32	URL	CC-BY	(Giraldo-Calderón et al. 2015)
1527	USA: California	Mosquitoes	A	1954	2005	52	52	1	This paper	CC-BY	(Rochlin et al. 2016)

METADATA

CLASS I. DATA SET DESCRIPTORS

A Data set identity

Title: *A global database of long-term changes in insect assemblages*

B. Data set identification code

The data are available at the Knowledge Network Biocomplexity: https://doi.org/10.5063/F11V5C9V

C. Data set description

1. Originators

Roel van Klink, Diana E. Bowler, Orr Comay, Michael M Driessen, S.K. Morgan Ernest, Alessandro Gentile, Francis Gilbert, Konstantin B. Gongalsky, Jennifer Owen, Guy Pe'er, Israel Pe'er, Vincent H. Resh, Ilia Rochlin, Sebastian Schuch, Ann E. Swengel, Scott R. Swengel, Thomas L. Valone, Rikjan Vermeulen, Tyson Wepprich, Jerome L. Wiedmann, Jonathan M. Chase

Contact: Roel.vanklink@gmail.com

For questions regarding specific data sets, please refer to the author(s) of each section in Appendix S1.

2. Abstract

Insects are the most ubiquitous and diverse group of eukaryotic organisms on Earth, forming a crucial link in terrestrial and freshwater food webs, but have recently made headlines because of observations of dramatic declines in some places. Although there are hundreds of long-term insect monitoring programs, a global database for long-term data on insect assemblages has so far remained unavailable. In order to facilitate synthetic analyses of insect abundance changes, we compiled a database of long-term (≥10 year) studies of assemblages of insects (many also including arachnids) in the terrestrial and freshwater realms. We searched the scientific literature and public repositories for data on insect and arachnid monitoring using standardized protocols over a time span of 10 years or longer, with at least two sampling events. We focused on studies that presented or allowed calculation of total community abundance or biomass. We extracted data from tables, figures and appendices, and, for data sets that provided raw data, we standardized trapping effort over space and time when necessary. For each site, we extracted provenance details (such as country, state and continent) as well as information on protection status, land-use, and climatic details from publicly available GIS sources. In all, the database contains 1668 plot-level time series sourced from 165 studies with samples collected between 1925 and 2018. Sixteen data sets

provided here were previously unpublished. Studies were separated into those collected in the terrestrial realm (103 studies with a total of 1053 plots) and those collected in the freshwater realm (62 studies with 615 plots). Most studies were from Europe (48%) and North America (29%), with 34% of the plots located in protected areas. The median monitoring time span was 19 years, with 12 sampling years. The number of individuals was reported in 129 studies, the total biomass was reported in 13 studies, and both abundance and biomass were reported in 23 studies. This data set is published under a CC-BY license, requiring attribution of the data source. Please cite this paper if the data are used in publications, and respect the licenses of the original sources when using (part of) their data as detailed in Table 1.

3. Data set description

The data consists of total abundances or biomass of whole insect or arachnid assemblages in the freshwater and terrestrial realms, sourced from 165 studies or monitoring programs in which the abundance or biomass of organisms were assessed using standardized methods over a time span of 10 years or more (9 years in 2 cases). This includes resampling studies with at least 10 years between the first and last samples. The original data were collected between 1925 and 2018. The data were extracted from figures, tables, appendices and repositories. These 165 studies comprised 1668 sites in 41 countries, with 62 studies on freshwater insects and 103 studies on terrestrial insects. The median time-span was 19 years, ranging between 9 and 81 years, and between 1 and 264 plots per data set. Three data sets precluded sharing of the derived numbers. For these, the links to the data sets, and to the code for processing are provided in section III.B.4.

The data in the data set are at a temporal resolution between weekly and yearly values. Hence, in data sets where sampling took place at a higher frequency (i.e. daily), these sampling events were summed or averaged, to produce one value per week or month (averaging was only done in cases of variable sampling effort, e.g. due to randomly missing samples). When data were presented as an average over several years, the mean of these years was used for input. In cases of multiple replicates per plot (e.g., multiple soil cores, traps or net sweeps), these were summed, or where necessary, averaged, to produce one value per plot per sampling event. In six data sets, a total of 16 plots were sampled more frequently than weekly (26 instances). We retained these original values in order not to have to make arbitrary decisions regarding their processing (e.g. removing samples in some months but not in others).

To obtain a metric as close as possible to the total size of the assemblage, the abundances or biomass values were aggregated at the highest possible taxonomic resolution per sampling event, typically family level or higher (order or class). In this data product, only the summed abundance or biomass is reported.

Future iterations of subsets of these data will also be broken down into abundances or biomass at lower taxonomic resolution, for more refined analyses of patterns of biodiversity and species composition.

The data are stored in four tables containing information at different organizational levels (study, plot level, sample level and the actual insect abundance/ biomass data). These tables are linked through the columns 'DataSource_ID' and 'Plot_ID'. In the table PlotData, the exact location and the climatic, land-use, and protection status data are provided. The table SampleData provides information on the sampling methods and the extraction of the data.

D. Key words

Arthropods, Insects; Arachnids; Spiders; Entognatha; Springtails; Long-term; Biomass; Abundance; Dynamics; Assemblage; Community; Monitoring; Insect decline

CLASS II. RESEARCH ORIGIN DESCRIPTORS

A. Overall project description

1. Identity:

This data product is derived from 165 studies of standardized monitoring of insect and arachnid assemblages. It contains additional metadata at the level of the studies used for this analysis, the locations (plots) where the insects were collected, the methods of capture, and the total abundance or biomass of the assemblages. Future tables will include taxonomic richness and abundance per taxonomic group.

2. Project initiators:

Roel van Klink & Jonathan M. Chase

3. Period of study

The searches for studies containing useful data were performed between December 2017 and April 2019. The last data were added in September 2019. The original data were collected between 1925 and 2018.

4. Objectives

The objective of the project was to investigate patterns of temporal changes in insect assemblages across the world, focusing first on temporal changes in total assemblage size (measured as total abundance or biomass).

5. Abstract

See above

6. Sources of funding

Table 2. Funding sources.

Granting Organization	Award Number
Deutsche Forschungsgemeinschaft	FZT118
Russian Foundation for Basic Research	19-05-25 00245
Yad HaNadiv	
National Science Foundation	NSF-0080529
National Science Foundation	NSF-0217774
National Science Foundation	NSF-8811906
National Science Foundation	NSF-9411976
National Science Foundation	DEB-0423704
National Science Foundation	DEB-0620652
National Science Foundation	DEB-0832652

National Science Foundation	DEB-0936498
National Science Foundation	DEB-1234162
National Science Foundation	DEB-1256696
National Science Foundation	DEB-1633026
National Science Foundation	DEB-1637685
National Science Foundation	DEB-1832016
National Science Foundation	NSF-06-20443
National Science Foundation	OCE-0620959
National Science Foundation	OCE-1237140
National Science Foundation	OCE-1832178
National Science Foundation	OCE-9982133

7. Methods

Data Acquisition

We searched for publications reporting on long term monitoring of invertebrate assemblages using Thomson-Reuters Web of Knowledge, by a topic search with the following search-terms: "insect*", "arthropod" and "invertebrate", “beetle*”, “butterfl*”, “moth*”, “*flies”, “bee*”, “grasshopper”, “herbivore”, “pollinator”, “mosquito”, in combination with “biomass”, "abundance", "dynamics", “temporal”, “trend”, “monitor*”, “dynamics” and “long”. The same search terms were used for the search in Russian using the elibrary.ru search engine and Google Scholar.

Topic search string: '(insect* OR invertebrate* OR arthropod* OR beetle* OR butterfl* OR moth* OR *flies OR grasshopper* OR bee OR pollinator* OR mosquito*) AND (monitor* OR dynamic* OR trend) AND (long) NOT (marine)'. From the search results, we excluded all non-ecological scientific fields. To check if any studies on biomass were missed, we did separate searches for ("insect abundance" OR "arthropod abundance" OR "invertebrate abundance") and for ("insect biomass" OR "arthropod biomass" OR "invertebrate biomass"), refined by 'long'.

This yielded ~5100 titles, which were first scanned by topic and the remaining papers by study duration, taxonomic scope, method consistency and assemblage metrics reported. We also searched for data meeting our criteria in the following data repositories: BioTIME (Dornelas et al. 2018), GPDD (Prendergast et al. 2010), the LTER repository (www.lternet.edu), Knowledge Network Biocomplexity (https://knb.ecoinformatics.org/), the LTREB database, the Global Biodiversity Information Facility (www.gbif.org), the environmental change network (http://www.ecn.ac.uk/), Environmental Data

Initiative (https://environmentaldatainitiative.org/) and VectorBase (Giraldo-Calderón et al. 2015). The searches were repeated in April and September 2019. Overall, the search yielded 165 studies with 1668 plots from which data could be extracted. Time series of abundance and biomass data were extracted from figures, tables, appendices and data repositories. Several authors provided original data or metadata upon our request. A full list of included studies can be found in Table 1.

We extracted environmental information for each of the 1668 plots as proxies for anthropogenic pressures: protection status, percentage cover of urban and cropland at local and landscape scales, and changes in temperature and precipitation at local and landscape scales over the sampling period.

Conservation status of each site was extracted from the World Database on Protected Areas (IUCN and UNEP-WCMC 2018), a database listing all protected reserves in the world. Although the WDPA provides some level of detail on whether a reserve is protected at international, national or sub-national level, these classifications are poorly transferable between countries, and do not provide any information on the quality of the management, or any contrast to the surrounding not-protected lands. Therefore, we only used a binary classification: protected (for all sites included in the WDPA), or not protected (for all other sites).

We extracted data on the percentages urban and cropland cover at and surrounding the sampling sites. We chose these land use types over the also available forest and grassland cover, as they are clearly anthropogenic, whereas forest and grassland can range from natural or anthropogenic with various levels of management intensity. We extracted the percentages of urban and cropland cover at the start and end of sampling for each plot from two public databases: the land-use harmonization (LUH2) database (Hurtt et al. 2018) at 0.25°×0.25° resolution for all years at the landscape-scale, and the ESA CCI (ESA 2017) database (900 × 900 m resolution, only available for 1992–2015) for the local scale. At the landscape scale, we present the cover percentages at the end of the sampling period, and calculated the change in urban and crop cover between the first and last year of sampling. For the local scale, we only present the cover percentages at the end of the sampling period (± 5 years, in case the sampling ended before 1992 or after 2015). We do not present local scale land-use change over the sampling period, since change was marginal: the land use code of less than 5% of cells changed during the period 1992-2015, and per five-year period only 1.5% of our cells changed, justifying the use of available data for years 5 years before or after. For details on the data processing see Appendix S2.

To calculate the anthropogenic climate change at each site, we extracted data on mean monthly temperature and precipitation at regional scales from the CRU database (Harris et al. 2014) (0.5° × 0.5° resolution for all years), and at local scales from the CHELSA database (Karger et al. 2017) (1 km^2

resolution for 1979-2013, 669 plots - for data sets starting before 1979 or ending after 2013 we calculated no slope). From these monthly values, we calculated climate change as the slope of a regression against year over the sampling period per site. Details on data processing are provided in Appendix S2.

Data harmonization

Harmonization of the data extracted from different sources was necessary within plots (in time and space) and across data sets.

1) Harmonization across data sets:

Many data sets contained multiple plots, and these sometimes varied in sampling period or design. Plots were sometimes spatially clustered within study areas, for this we added a grouping factor (column 'Location'). In some cases, it was necessary to account for variation in sampling protocols (e.g. the different tree species sampled in Luquillo forest LTER site, Puerto Rico (Schowalter 2017)). Comparability among data sets is specifically targeted for the temporal slopes, but not for the intercepts, as sampling effort differed strongly among studies.

2) Harmonization within plots:

Within the plots, sampling was not always temporally or spatially homogeneous. That is, the number of samples taken per year or the number of sampling units (e.g., traps) per sampling period sometimes varied. This was particularly true for raw data downloaded from repositories, where, for example, samples were occasionally missing for a given sampling event due to trap malfunctions or damage. We accounted for such missing values by taking the mean of all functioning traps per time point. In this data product, all sampling events within a plot have the same sampling effort. For details on standardization done for each of these data sets, see Appendix S2.

Some data sets reported multiple data points within each year (days, weeks, months or seasons). To account for this, we maintained 'week' as the finest temporal grain, hence, data in data sets with a finer temporal grain than week were aggregated per week or larger temporal unit (e.g. daily samples were summed or averaged to form a week or month).

Sources of data

See Table 1 and the list of literature cited.

8. Acknowledgements

We thank Nina Naderi for help with the digitization of data sets, and Inês Martins and Petr Keil for help with the maps. We thank all collectors of the original data for their work that made this compilation possible; we specifically thank Aaron Ellison, Lars Rudstam, Nick Haddad, Peter Brown, Brad Lister, and Paul Giller for their help in understanding their data sets, and Brenda Hann, Petri Martikainen, Elaheh Daghighi, Warren Paul for providing metadata. We acknowledge funding of iDiv via the German Research Foundation (DFG FZT 118), including funding through sDiv, the Synthesis Centre of iDiv.

B1. Subproject descriptions

Sixteen data sets included in this database were previously only available upon request. Details on their environmental conditions, collection methods and post processing are overviewed in Appendix S1. All other data sets were described in their original source.

Datasource_ID	Taxon	Scientific name	Country or state	Details
1102	Ground beetles	Coleoptera: Carabidae	The Netherlands	
1328	Hoverflies	Diptera: Syrphidae	England	
1353	Ants	Hymenoptera: Formicidae	USA: Arizona	Bait piles
1388	Freshwater invertebrates	Arthropoda*	USA: California	
1445	Ants	Hymenoptera: Formicidae	USA: Arizona	Nests
1474	Grasshoppers, True bugs, Plant and leafhoppers	Orthoptera, Hemiptera: Heteroptera, Hemiptera: Auchenorrhyncha	Germany	
1475	Plant- and leafhoppers	Hemiptera: Auchenorrhyncha	Germany	
1476, 1477, 1478	Butterflies	Lepidoptera: Rhopalocera	USA: Wisconsin	
1479	All arthropods	Arthropoda*	AUS: Tasmania	Moorland
1480	All arthropods	Arthropoda*	AUS: Tasmania	Warra /Mt Weld
1481	Butterflies	Lepidoptera: Rhopalocera	Israel	
1518	Butterflies	Lepidoptera: Rhopalocera	USA: Ohio	
1519, 1527	Mosquitoes	(Diptera: Culicidae)	USA: New York, New Jersey, California	

* The data included in this data product exclude crustaceans and myriapods

C. Data limitations and potential enhancements

Limitations:

Our database presently only reports the abundance and/or biomass of entire species assemblages. It is therefore not possible to perform species-specific analyses, and analyses at the higher taxonomic level (family level or higher) should be done with caution.

Because of the disparate sampling methods and various spatial and temporal scales used to collect the original data, this data set is most relevant for studying temporal trends (differences in slopes). We strongly caution against direct comparisons of standing insect abundance/biomass among locations (differences in intercept) since the sampling efforts, sometimes even among plots within one data set, may not be not comparable.

The data were taken only from published papers or repositories, and, therefore, proprietary data were not included. We are aware of many monitoring schemes that are not included here because of access rights. This includes most large-scale butterfly monitoring schemes (but see Irish National Biodiversity Data Centre 2018), , many mosquito monitoring programs (but see Giraldo-Calderón et al. 2015, Iowa Mosquito Surveillance 2019), many freshwater monitoring schemes (but see Groker 2018, SLU 2018), and at the time the literature searches were conducted, the Rothamsted Insect Survey data (https://insectsurvey.com/). Since then, the abundance values of moths and aphids of the Rothamsted Insect Survey have been published (Bell et al. 2020a, 2020b) and could be integrated into the InsectChange database.

Finally, the global GIS layers we used as explanatory variables are derived data products that depend on models combining different data layers. Therefore, they may not necessarily accurately represent the *in situ* local temperature, precipitation, crop cover or urban cover. We chose to use these data layers because they are the only globally homogenized available products. Despite the uncertainties, we have assumed a homogeneous distribution of errors, making the products useful for broad-scale analyses such as ours. In any case, the numbers given should not be taken at face value for looking at single data sets. At local or regional scales better data products may be available.

Potential enhancements:

Although the table *SampleData.csv* is not essential for the current data product, or for the analyses done on it, we still provide this table as information on the provenance of the data. Tables with data at the level of taxonomic groups, with taxonomic diversity, and with the raw data underlying all derived community metrics, will be added as they become harmonized and available.

This data set has a relatively simple structure and the addition of new data is encouraged. Please contact roel.vanklink@gmail.com if you have appropriate data that you would like to be archived for future analyses and syntheses.

Parts of the raw data underlying this data set may also be suitable for other data sets exploring temporal variation in assemblages, such as the BioTIME database (Dornelas et al. 2018); we will be working with the leaders of that effort to accomplish this in the coming years.

CLASS III. DATA SET STATUS AND ACCESSIBILITY

A. Status

1. Latest update

15 October 2020

2. Latest archive date

15 October 2020

3. Metadata status

Last checked 26 March 2021

4. Data verification

After upload, all tables were downloaded and the MD5-sums verified (see section V.B.)

B. Accessibility

1. Storage location and medium

The data are stored as four linked files (.csv format), accompanied by a list of references and a ReadMe file with descriptions of all column headers. The data can be found at the Knowledge Network for Biocomplexity: https://knb.ecoinformatics.org/view/doi:10.5063/F1ZC817H (Van Klink et al. 2020a)

2. Contact person:

Roel van Klink (Roel.vanklink@gmail.com)

3. Copyright restrictions

This data set is published under a CC-BY license, requiring attribution of the data source. Please cite this paper if the data are used in publications, and respect the licenses of the original data sources when using (part of) their data as detailed in Table 1.

4. Proprietary restrictions:

The three data sources that are currently openly accessible, but not provided here due to copyright restrictions are: DataSource_ID 1339: the National Bison Range grasshopper monitoring data (Belovsky 2018), DataSource_ID 1404: Greenland Ecosystem monitoring program (Aarhus University 2018), DataSource_ID 1416: Hubbard brook LTER caterpillar monitoring (Holmes 2018). These data are accessible at their respective websites, and the code used to process these data is available at Github (https://github.com/roelvanklink/Final-insect-abundance-changes), and archived at Zenodo (Van Klink and Bowler 2020).

5. Costs:

None

CLASS IV. DATA STRUCTURAL DESCRIPTORS

A. Data set files

1. Identity and table attributes

The data set consists of seven files: a ReadMe file to explain the metadata, a list of references to original publications, a google earth file (.KML) with the locations of all data sets, and four tables representing data at different levels of organization: *DataSources.csv*, *PlotData.csv*, *SampleData.csv* and *InsectAbundaneBiomassData.csv*. These tables are linked by the columns *'DataSource_ID'* and *'Plot_ID'* (see Fig. 4). Linking of *InsectAbundanceBiomassData.csv* with *PlotData.csv* by column *'Plot_ID'*, and with *DataSources.csv* by column *'DataSource_ID'* will provide the full dataframe used for all analyses (Fig. 4).

Some of the numbers in *InsectAbundanceBiomass.csv* were derived from multiple entries in the table *SampleData.csv*, and in other cases, multiple plots have the same Sample_ID. In other words, the table *SampleData.csv* has a many-to-many relationship to *InsectAbundanceBiomass.csv*. Thus, although technically possible, the linking of these tables would create duplicate entries for each Datasource_ID with multiple Sample_ID's.

Table *DataSources.csv*

In the table *DataSources.csv*, we provide descriptive data at the level of the study, including: provenance of the data at various geographic scales (continent to state); the taxonomic group sampled; whether the data come from terrestrial or freshwater samples; and whether the data set is on biomass, abundance or both. This table also contains the reference to the original publication and links to repositories. The full reference to the original data is found in the file *References.pdf*.
One row = one DataSource_ID

Table *PlotData.csv*

In the table *PlotData.csv*, we provide details at the plot level: the location of each plot (as exact as possible given the data source); whether the plots were part of a long term experiment; and if there was any spatial grouping (column *'Location'*). Additionally, this table contains a number of environmental variables: climate change variables, land-use variables, protection status (for more information on how these numbers were calculated see Appendix S2).
One row = one plot

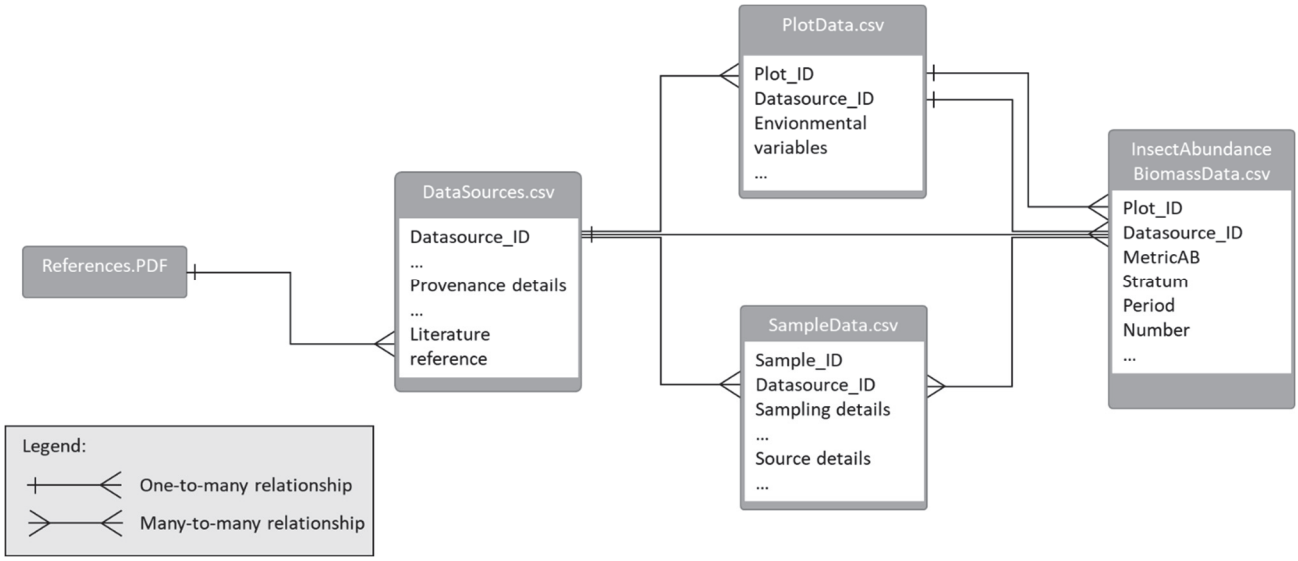

Fig. 4. Database schema of the relations between the tables in the data set. The table *PlotData.csv* contains information on the location of sampling, and the table *SampleData.csv* contains information on the sampling method and the source of the data. The tables *SampleData.csv* and *InsectAbundanceBiomass.csv* have a many-to-many relationship, meaning that linking these tables by DataSource_ID will give duplicate entries of the insect numbers for data sources where the data were derived from multiple tables or figures.

Table *SampleData.csv*

The table *SampleData.csv* describes the source of the data (e.g. table, figure or appendix number), the method for data extraction, and the sampling details (derived from the original publications). This includes the sampling method, area, and size, as well as how the samples were standardized, if reported. In addition, any calculations we did on the original data (e.g. inverse log transformations) are detailed here. Note that each DataSource_ID may contain multiple entries in the *SampleData* table if the data were taken from multiple figures or tables, or if there was any other necessity to split information on sampling details. These multiple Sample_ID entries were later summed to obtain one number for abundance or biomass per plot. The best way to trace the Sample_ID('s) underlying an observation is to link *InsectAbundanceBiomassData.csv* with *SampleData.csv* by the columns *'DataSource_ID*' and *'Stratum'*. One row = one Sample_ID

Table: *InsectAbundanceBiomassData.csv*

The table *InsectAbundanceBiomassData.csv* provides the insect abundance or biomass numbers. It contains columns matching with the tables *DataSources.csv* and *PlotData.csv*, as well as year of sampling, a descriptor of the period within the year of sampling, the metric of assemblage size (abundance or biomass), and the estimated abundance or biomass. In the column for Number, missing data are included as (NA). This is required for certain analyses, and we retained these missing values here because they are easier to remove than to add.
One row = one sampling event in each time series (summed across taxa)

ReadMe.doc

Description of all variables, matching the descriptions above.

References.PDF

References to all studies as referred to in *DataSources.csv*, following *Ecology* citation style.

2/3. size and format

Table 3. Files in the repository

File Name	Format	Size
DataSources	.csv	32 kb 165 rows
PlotData	.csv	812 kb, 1668 rows
SampleData	.csv	39 kb, 237 rows
InsectAbundanceBiomassData	.csv	3.01 mb, 68219 rows
ReadMe	.doc	22 kb
References	.PDF	137 kb

4. Header information

Headers of *DataSources.csv*

The table *DataSources.csv* provides information on each data source. Each source has a number of plots, years, a geospatial location, an access license, and one or more references to the source of the data.

Table 4. Headers of *DataSources.csv*

Header	Explanation
DataSource_ID	Unique identifier for each data source (numerical, 165 entries, not continuous). The DataSource_ID's below 1000 correspond to the unique data source identifiers in the BioTIME database (column *'STUDY_ID'*), and the GPDD (column '*DataSourceID*'). Note that the original sources of the data are the same, but that the actual data used here may have been sourced from the original raw data rather than the repository. See Table 5. (integer)
DataSource_name	Unique descriptive name for each data source. Used for easy reference of the authors. (string)
Realm	Realm in which samples were collected. (factor with 2 levels: 'Terrestrial' and 'Freshwater'). (categorical)
InvertebrateGroup	Coarse description of taxon/ taxa studied in data source (factor with 45 levels). (categorical)
AbundanceOrBiomass	Does the data source provide information on insect biomass (B), abundance (A) or both (AB) (factor with 3 levels). (categorical)
Start	First year of sampling in data source. (integer)
End	Last year of sampling in data source. (integer)
DurationDataSource	Time between first and last sample. (integer)
NrYrsData	Number of years in which data was collected. (integer)
NrSites	Number of plots studied. (integer)
Continent	Continent where samples were collected, based on geography and historical / cultural commonalities. Factor with 7 levels: - **Africa**: African continent - **Asia**: Eurasia east of the Urals, Caucasus and Bosporus, including the Middle East and the Indian subcontinent. The eastern boundary lies west of New Guinea**.** - **Europe**: Eurasia west of the Urals, Caucasus and Bosporus. - **South America**: South America. - **Central America**: Central America including Mexico and the Caribbean. - **North America**: USA, Canada and Greenland.

	- **Oceania**: Australia and New Zealand. (categorical)
Region	Arbitrary grouping of countries and states into geographical regions (factor with 27 levels, categorical)
NationState	Nation state in which the samples were collected (factor with 42 levels, categorical)
CountryOrState	Geographic unit in which samples were collected. 'State' level is only used in large countries such as Russia, Brazil, Canada and the United States. (factor with 100 levels, categorical)
OpenAccessLicense	License for access, use and republishing of the original data source. (categorical): *Open access licenses:* - **PD**: public domain (all data extracted from papers), - **OGL**: Open Government License (UK), - **CC-BY, CC0, CC-BY-NC, CC-BY-ND**, - **ODC**: Open Data Commons - **no share**: data openly accessible, but no redistribution of data or derived products is allowed, access to data via column 'Link', code for processing is available at Github (https://github.com/roelvanklink/Final-insect-abundance-changes)
Link	URL linking to raw data (websites were active until at least 2019). (string)
Reference	Reference to original data source. Reference list is found in Table 'References'. (string)

Table 5. Relations between this database, the BioTIME database (Dornelas et al. 2018), and the Global Population Dynamics Database (Prendergast et al. 2010).

DataSource_ID	Datasource_name	BioTIME *'STUDY_ID'*	GPDD *'DatasourceID'*	Source of data used here
63	Woodwalton fen dragonflies (UK)	63	3	BioTIME
70	Migratory Lepidoptera (BE)	70	594	BioTIME
79	Butterfly monitoring scheme (UK)		79	GPDD
249	Light trap (Copenhagen, DK)	249		BioTIME
294	Tam Dao butterflies (VT)	294		BioTIME
300	Kellogg station LTER ladybirds (USA)	300		Raw data from website
301	Konza prairie grasshoppers (USA)	301		BioTIME
313	Cedar Creek grasshoppers (USA)	313		BioTIME
375	Ground dwelling beetles (JP)	375		BioTIME
380	Chalk grassland butterflies (UK)	380	21	BioTIME
465	Prague light trap (CZ)		465	GPDD
478	Breitenbach Ephemeroptera, Plecoptera, Trichoptera (DE)	478		Raw data from website
502	Aphid monitoring (UK)		502	GPDD

Headers of PlotData.csv

This table provides information about the location of sampling at the highest level, the plot. This includes information about the geospatial location, but also about the sampling and the environmental conditions according to the GIS layers used.

Table 6. Headers of *PlotData.csv*

Header	Explanation
Plot_ID	Unique identifier for each plot. (integer)

DataSource_ID	Unique identifier linking to table *DataSources.csv.* (integer)
PlotName	Descriptive name of the plot within the data source. Used for easy reference by the authors. (string)
Location	Grouping variable in case of groupings of plots within the data source. (string)
DetailsPlots	Descriptive names, locations, or details (e.g. plant species sampled), used in the original data source. (string)
ExperimentalTreatment	In case of experimental setups the experimental treatment of each plot (e.g. polluted, logged, control, number of plant species in plot, etc). (string)
Latitude	Latitude (northing) of the plot in decimal degrees (WGS84), as precise as provided in the original data source. (numerical)
Longitude	Longitude (easting) of the plot in decimal degrees (WGS84), as precise as provided in the original data source (numerical)
Elevation	Elevation of the plot in meters above sea level, if provided (string)
SourceGeogrData	Source of the geographic data ('Google maps' indicates that the locality was manually found on the digital map of Google maps) (string)
StartYear	First year of sampling (integer)
EndYear	Last year of sampling (integer)
Duration	Time between first and last sample (integer)
WWFecoRegion	Original ecoregion according to WWF ecoregions of the world (https://www.worldwildlife.org/biome-categories/terrestrial-ecoregions) (string)
ClimaticZone	Climatic zone by grouping of ecoregions: (factor with 4 levels: Boreal/Alpine, Terrestrial, Drylands, Tropical) (categorical)
ProtectedArea	Protection status of the plot (yes - protected, or no - not protected) (categorical)
frcCrop_start	Fraction of surrounding landscape (~25*25km) covered by crop land in the first year of sampling following the LUH2 database (numerical)
frcCrop_end	Fraction of surrounding landscape (~25*25km) covered by crop land in the last year of sampling following the LUH2 database (numerical)
frcUrban_start	Fraction of surrounding landscape (~25*25km) covered by urban land-use in the first year of sampling following the LUH2 database (numerical)

frcUrban_end	Fraction of surrounding landscape (~25*25km) covered by urban land-use in the last year of sampling following the LUH2 database (numerical)
frcForest_start	Fraction of surrounding landscape (~25*25km) covered by forest in the first year of sampling following the LUH2 database (numerical)
frcForest_end	Fraction of surrounding landscape (~25*25km) covered by forest in the last year of sampling following the LUH2 database (numerical)
Urbanization	Difference in fraction urban land cover between the first and last year of sampling (LUH2 Database) (numerical)
Cropification	Difference in fraction crop land cover between the first and last year of sampling (LUH2 Database) (numerical)
frcCrop900m	Fraction of the local landscape (900*900m) classified as crop land at the end of the sampling period following the ESA-CCI database. Land use codes classified as cropland were: 10, 11, 12, 30 and 40. Because 30 and 40 represent only partial crop cover, the number of cells with code 30 were multiplied by 0.75 and cells with 40 were multiplied by 0.25. Available only for plots where sampling ended in 1992 or later (n = 1572). (numerical)
frcUrban900m	Fraction of the local landscape (900*900m) classified as urban (land use code 190) at the end of the sampling period following the ESA-CCI database. Available only for plots where sampling ended in 1992 or later (n = 1567). (numerical)
CRUmnC	Mean temperature (Celsius) at the landscape scale (0.5° * 0.5°) over the sampled period, calculated from the CRU database for the full period. (numerical)
CRUmnK	Mean temperature (Kelvin) at the landscape scale (0.5° * 0.5°) over the sampled period (= CRUmnC + 273.16), calculated from the CRU database for the full period. (numerical)
CRUdeltaTmean	Modeled change in temperature per decade. We used a generalized additive model with a spline on month to derive the slope of temperature change for each plot. The model estimate is based only on temperature data within the sampling period. (numerical)
CRUrelDeltaTmean	Relative change in temperature for each plot (= CRUdeltaTmean / CRUmnK). (numerical)

CRUmnPrec	Mean monthly precipitation (mm) at the landscape scale (0.5° * 0.5°) over the sampled period, calculated from the CRU database for the full period. (numerical)
CRUdeltaPrec	Modeled change in monthly precipitation per decade. We used a generalized additive model with a spline on month to derive the slope of precipitation change for each plot. The model estimate is based only on precipitation data within the sampling period. (numerical)
CRUrelDeltaPrec	Relative change in precipitation for each plot (= CRUdeltaPrec / CRUmnP). (numerical)
CHELSAmnC	Mean temperature (Celsius) at the local scale (1 km^2) over the sampled period, calculated from the CHELSA database (= CHELSAmnK 273.16). Available only for plots where sampling started after 1978 and ended latest in 2013 (n= 669 plots). (numerical)
CHELSAmnK	Mean temperature (Kelvin) at the local scale (1 km^2) over the sampled period, calculated from the CHELSA database. Available only for plots where sampling started after 1978 and ended latest in 2013 (n= 669 plots). (numerical)
CHELSAdeltaTmean	Modeled change in temperature per decade. We used a generalized additive model with a spline on month to derive the slope of temperature change for each plot. The model estimate is based only on temperature data within the sampling period, and is available only for plots where sampling started after 1978 and ended latest in 2013 (n= 669 plots). (numerical)
CHELSArelDeltaTmean	Relative change in temperature for each plot (= CHELSAdeltaTmean / CHELSAmnK). (numerical)
CHELSAmnPrec	Mean monthly precipitation (mm) at the local scale (1 km2) over the sampled period, calculated from the CHELSA database. Available only for plots where sampling started after 1978 and ended latest in 2013 (n= 669 plots). (numerical)
CHELSAdeltaPrec	Modeled change in monthly precipitation per decade. We used a generalized additive model with a spline on month to derive the slope of precipitation change for each plot. The model estimate is based only on precipitation data within the sampling period, and is available only for

	plots where sampling started after 1978 and ended latest 2013. (numerical)
CHELSArelDeltaPrec	Relative change in precipitation for each plot (= CHELSAdeltaPrec / CHELSAmnP). Available only for plots where sampling started after 1978 and ended latest 2013 (n= 669 plots). (numerical)

Headers of SampleData.csv

This table provides information on the data extraction and sampling methods used in the various data sources

Table 7. Headers of *SampleData.csv*

Header	**Explanation**
Sample_ID	Unique identifier for each sample description. (integer; 237 entries)
DataSource_ID	Unique identifier linking to table *DataSources.csv* (integer; 165 entries)
DataCarrier	Source of this part of the data (table, figure number, etc.) (string)
DataExtractionMethod	Software used to extract data from graphs or tables (factor with 4 levels: 'ImageJ', 'Metadigitise', 'pdftoexcel.com', 'values from owner') (string)
SamplingMethod	Type of sampling method. Categorical with 27 levels: - **Artificial_substrate** (insects collected on artificially placed substrates after a set amount of time) - **Bagged_branches** (insects collected from branches after these were collected in a bag) - **Bait** (insects attracted with group-specific bait) - **Colored_pan_traps** (flower visiting insects attracted by colored bowls or pans) - **Emergence_trap** (insects trapped after emergence from an egg, larval or pupal phase) - **Hand_sorting** (insects collected by hand from soil samples) - **Light_trap** (nocturnal insects attracted by artificial lights) - **Malaise_trap** (flying insects collected in a stationary tent-like net) - **Nest_counts** (visual counts of nests)

	- **Pelagic_net** (Apstein net - aquatic insects collected in the water column) - **Pitfall_traps** (surface dwelling insects collected in containers buried in the soil with the rim flush with the soil surface) - **Sampling ring** (vegetation dwelling insects visually counted within a ring covering a standardized surface area) - **Soil_litter_extraction** (Tullgren/Berlese funnel - soil and litter dwelling arthropods extracted using heat and/or light) - **Sticky_traps** (insects collected on sticky substrate suspended on or above the vegetation) - **Stream_bed_sampling** (Surber/Hess/kick/Tee samplers - aquatic insects collected from the stream bed by disturbing a standardized area of the bed and letting the dislodged individuals drift into a net) - **Substrate_grab** (Petersen/Eckman/Ponar grab – a standardized area of the substrate of a waterbody is collected and sorted) - **Substrate_grab_and_stream_bed_sampling** (both stream bed sampling and substrate grabing methods used) - **Substrate_scraping** (aquatic invertebrates scraped from a standardized surface area of substrate) - **Suction_pipe** (flying insects collected by sucking air into a stationary, upwards directed pipe) - **Suction sampling** (vegetation dwelling insects collected by sucking them into a using motorized suction machine over a standardized surface area) - **Sweep_net** (vegetation-dwelling or aquatic insects collected in a sweep net using a standardized number of sweeps or sampling area - **Timed_counts** (insects are visually counted for a standardized amount of time) - **Transect_counts** (e.g. Pollard walks – insects counted along standardized transects) - **unknown_standardized_methods** (the trapping method is unclear, but is standardized over time) - **Vertical_radar** (upward directed radar to count the number of flying insects)

	- **Visual_counts** (insects visually counted in a standardized area) - **Window_trap** (flying insects collected as they fly against a window-like structure with a collection vessel underneath)
SamplingMethodDetailed	Method the invertebrates were sampled (as described in the original publication) (string)
Stratum	Place in which the insects were sampled: factor with 6 levels (categorical): - **Air** (transect counts, suction pipes, light traps, malaise traps, window traps and pan traps) - **Trees** (arboreal window traps, visual counts, sticky traps), - **Herb layer** (sweep-net transects, suction sampling, sampling rings, visual counts) - **Soil surface** (pitfall traps and nest counts), - **Underground** (soil cores) - **Water** (e.g. kicksamplers, Surber samplers, pelagic nets, aquatic emergence traps).
SampleArea	Surface area of sample, where applicable. Unit is provided in text. 'NA' indicates that the size of the sampling area is unknown, as is the case for activity dependent methods (such as pitfall traps, light traps and malaise traps). (string)
NumberOfReplicates	Number of replicates which constitute one sample. Often not clearly described in the original publication. (string)
AggregationOfReplicates	How these replicates were merged to produce the reported value. Often not clearly described in the original publication. (string)
GroupInData	Invertebrate group represented in the data carrier (factor with 87 levels)
OriginalMetric	Metric of assemblage size as reported in the original data carrier (string)
Calculations	Where applicable, any calculations done by us to standardize the data. For example, standardization of sampling effort or inverse log-transformations. (string)
Metric	Standardized metric of assemblage size (factor with 3 levels: 'biomass', 'abundance', 'density' = abundance per unit area) (categorical)

Headers of InsectAbundanceBiomassData.csv

This table contains the measured insect abundance / biomass at each plot at each timepoint.

Table 8. Headers of InsectAbundanceBiomassData.csv

Header	Explanation
DataSource_ID	Unique identifier linking to table *DataSources.csv*, and to table *PlotData.csv* (integer)
Plot_ID	Unique identifier for plot, linking to table *PlotData*.csv (integer)
MetricAB	Metric of assemblage size: 'abundance' or 'biomass' (categorical)
Stratum	Place in which the insects were sampled: factor with 6 levels, see table *SampleData.csv* for details. (categorical)
Period	Period in the year of sampling. This can be month, season, etc. The finest grain used here is 'month' (i.e. if more than one sample was taken per month, these would get the same value for 'Period'. This variable was used as random effect in the analysis to account for seasonality. (string)
Year	Year in which measurement was taken. This was an explanatory variable in all analyses. (integer)
Number	Value for insect abundance or biomass as measured at a given time and place. The exact meaning of this number depends on the sampling effort (area and duration), and any post-sampling operations performed on the data. Within each plot, this is standardized. NA's are retained, as this was required for many analyses. These are easily removed. (numerical)

5. Alphanumeric attributes

mixed

6. Special characters

The tables *DataSources.csv*, *SampleData.csv* and *PlotData.csv* contain special characters derived from author names and location names. These tables are therefore encoded in ANSI character set. However, the columns with special characters are not crucial for linking tables. Hence, if the files are loaded with a

different encoding, this should not affect the operations or analyses in any way. The tables are only linked by the numeric columns '*Datasource_ID'* and '*Plot_ID'*.

The table *InsectAbundanceBiomassData.csv* is encoded in UTF8, and contains no special characters.

7.Authentication procedures

MD5 sums were checked and are correct. See section V.B for to check the MD5 sums.

B. Variable information

1. Variable identity

The variables in each column are either described under the headers of the columns (Section IV.A.4), or are self-explanatory (stores as long string, see Section IV.A.4).

2. Variable definition

See Section IV.A.4

3. Units of measurement

See Section IV.A.4

4. Data type

See Section IV.A.4

5. Data format

See Section IV.A.4

C. Data anomalies

"NA" ("not available") was added in the main data column of insect abundance or biomass (column *'Number'* in file *InsectAbundanceBiomassData.csv*) for each year within the time series of each plot where no data was available. This is often necessary for analyses, and since it is much easier to remove NA values than to insert them in specific places, we left them in place.

CLASS V. SUPPLEMENTAL DESCRIPTORS

A. Data acquisition

1. Data forms or acquisition methods

Digitization of graphs from PDF files was done using ImageJ (Abramoff et al. 2004) and the R package MetaDigitise (Pick et al. 2019). To extract data from tables in PDF format, we used https://www.pdftoexcel.com/.

2. Data entry verification procedures

We performed several data checks at all stages of data entry and processing:

- **Duplicates**: We confirmed that all duplicate values in the final data frame were correct. Duplicate values are possible when multiple samples within a month have the same total abundance. In the raw data underlying the summed abundances, no duplicate values were present.
- **Unique DataSource_ID, Plot_ID and Sample_ID:** We confirmed that all DataSource_ID's, Plot_ID's and Sample_ID's were unique.
- **No negative values:** We confirmed that no negative values were present in the column *'Number'*.
- **Numeric values:** We confirmed that the entries in column *'Number'* were numeric.
- **Consistency of data frame size:** We confirmed that when tables were merged, the number of rows always stayed the same.

B. Quality assurance

All data and processing code were checked in October 2020.

To verify the file identity, or to check if any of the files is corrupted, you can check the MD5 sums:

- *DataSources.csv*: " 04853f94c864d5ed74eb00d2933b9ff1 "
- *SampleData.csv*: " b686e53b0ee0c4e87c424c47f72758f1 "
- *PlotData.csv*: " 86ca89f0be104285c999548abc8e091e "
- *InsectAbundanceBiomassData.csv*: " 9ab09d29116c3b9ee27cf726bdd886e1 "

This can be checked online (e.g. using http://onlinemd5.com/), or with the R command: tools::md5sum("file_name.csv").

C. Related materials

A first analysis of these compiled data was published by Van Klink et al. (2020b).

Code for analysis and data processing of the three data sets not included here is available at Github (https://github.com/roelvanklink/Final-insect-abundance-changes) and archived at Zenodo (Van Klink and Bowler 2020).

D. Computer programs and data-processing algorithms

All data processing after data extraction was done in R3.6.1 (R Core Team 2019) (for details on all data sets see Appendix S2). The data were first entered into the tables using Microsoft Excel, and processed in R 3.6.1. The data are here available as comma-separated files (.csv) files.

E. Archiving

1. Archival procedures

The data are archived and available at the Knowledge Network for Biocomplexity: https://knb.ecoinformatics.org/view/doi:10.5063/F11V5C9V

2. Redundant archive sites

None

F. Publications and results

Van Klink et al. (2020b)

G. History of data set usage

NA

4. Questions and comments from secondary users

NA

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