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

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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. 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 datasets 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 1676 plot-level time series sourced from 166 studies with samples collected between 1925 and 2018. Sixteen datasets were previously unpublished, and are provided here. Studies were separated into those collected in the terrestrial realm (104 studies with a total of 1061 plots) and those collected in the freshwater realm (63 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 20 years, with 12 sampling years. The number of individuals was reported in 136 studies, the total biomass was reported in 13 studies, and both abundance and biomass were reported in 23 studies. When using (part of) this database, please respect the access licenses of the original datasets and cite the sources appropriately.

Introduction

Insects and ecologically similar arthropod groups (such as arachnids), are the most ubiquitous and diverse group of eukaryotic organisms on Earth. Insects deliver indispensable ecosystem services, including crop pollination (Gallai et al. 2009), pest control (Huang et al. 2018), and as human food (Ramos-Elorduy 2009, Van Huis et al. 2013). Insects also remain one of the most important current and future threats to food security in the form of agricultural pests (Oerke 2006, Deutsch et al. 2018) and silvicultural pests (van Lierop et al. 2015), and 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 been, to date, localized since the data were scattered. Hence, it has long remained unclear whether studies showing dramatic declines are emblematic of global trends, or rather unique special cases (Thomas et al. 2019, Didham et al. 2020, Saunders et al. 2020).

In a meta-analysis of 1676 openly accessible long-term (≥10 years) time series of terrestrial and freshwater insect and arachnid assemblages (Van Klink et al. 2020), 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 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 dataset 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 (NERC Centre for Population Biology Imperial College 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. (2020). In all, we compiled data from 166 studies, 16 of which were previously unpublished (methods provided in Appendix 1). Within those studies, there were 1676 locations leading to a total of 61,971 site × sampling event combinations (Table 1). The standardizations necessary for any datasets of which we obtained raw data are detailed in Appendix 2. We excluded three data sources used in Van Klink et al. (2020) 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 2. 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 1061 plots from the terrestrial realm, and 63 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, 136 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 them appropriately.

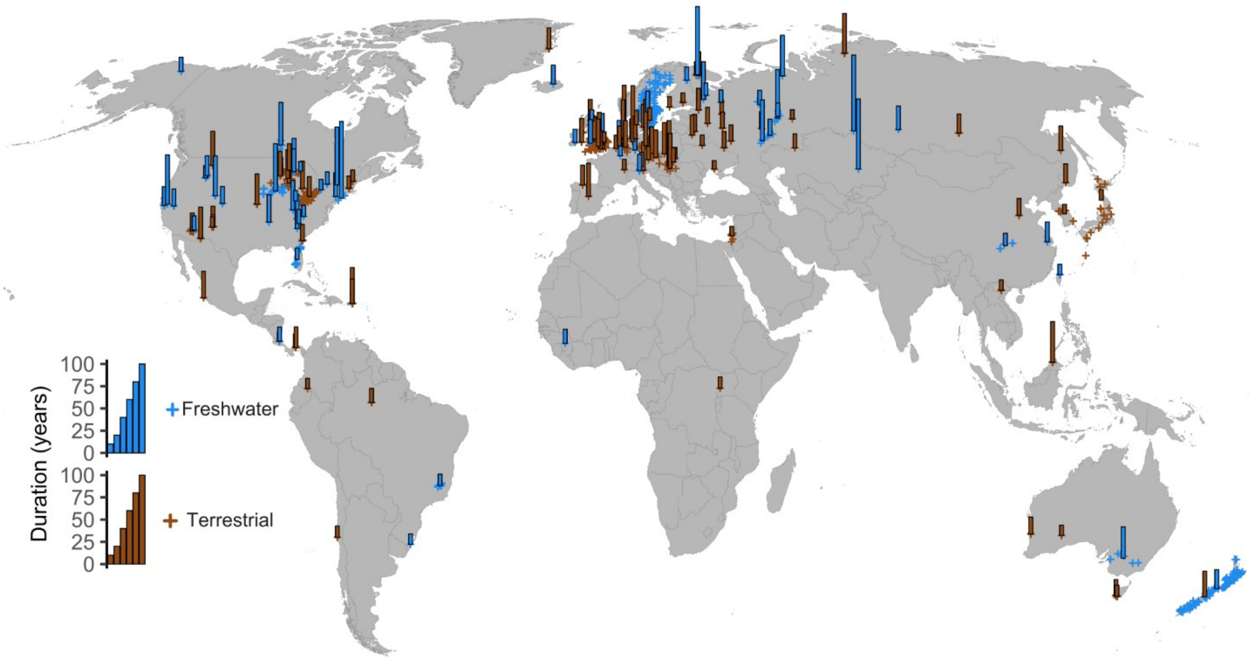

Fig 1. Duration of all datasets (height of the bars corresponds to study duration, centered on the central coordinates of each dataset), and locations of all plots (+).

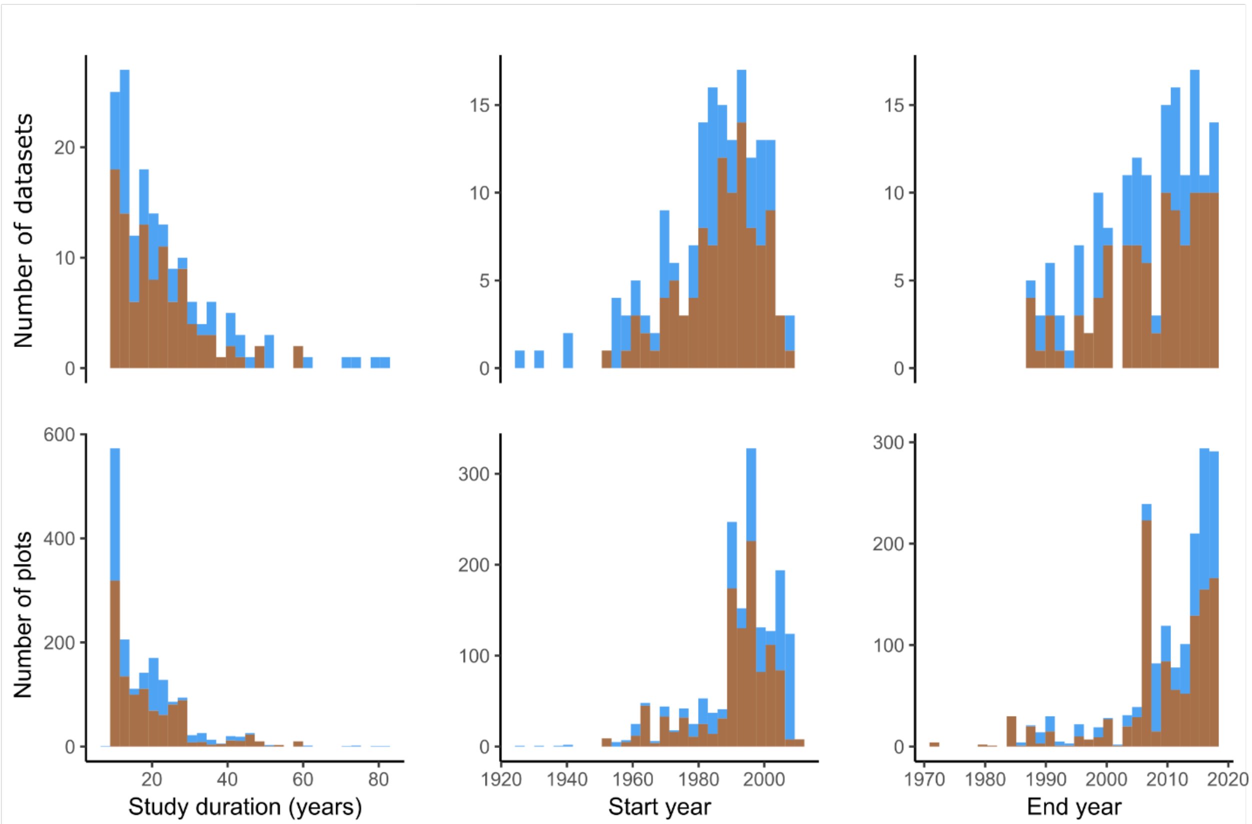

Fig 2. Stacked histograms of study duration, start year and end year of the datasets and plots in both realms. Brown are terrestrial datasets and blue are freshwater datasets.

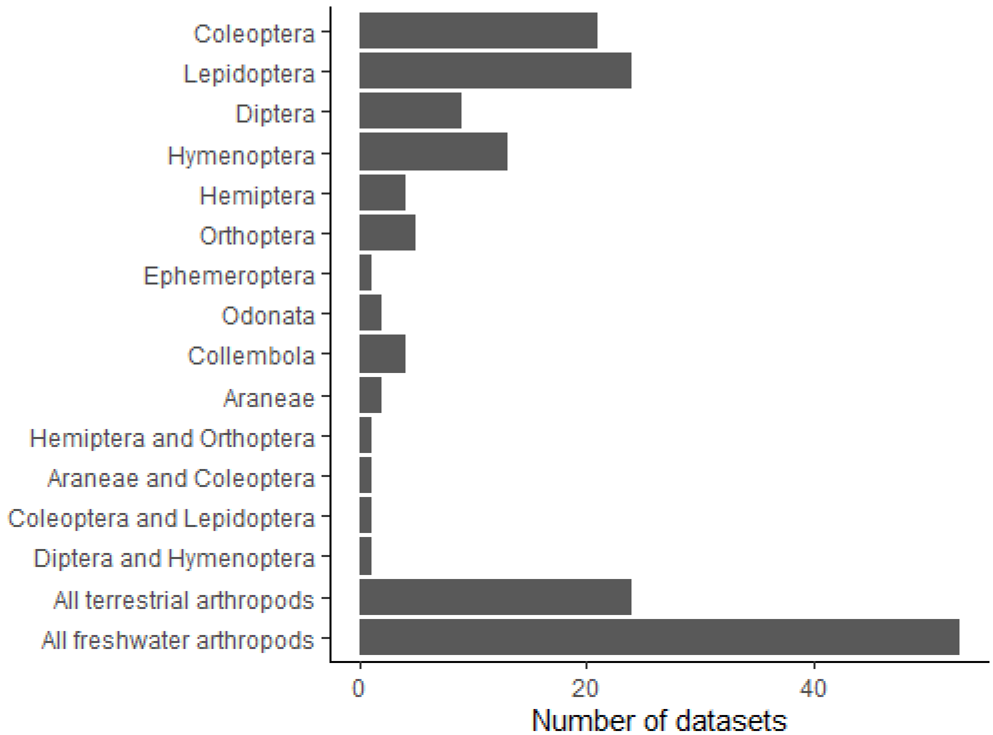

Fig 3. Distribution of studies (A) and plots (B) among continents. (C) Focal taxa of the 166 datasets. Datasets focusing on more than two orders were classified under 'all arthropods' in their respective realms.

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,

The data underlying studies marked bold are published here for the first time

Datasource ID	Place	Taxon	Abundance/ Biomass	Start	End	Time span (yrs)	Nr yrs data	Nr of plots	link	Conditions for use	Reference
63	England	Dragonflies	A	1959	1988	30	29	1		CC-BY	(Moore 1991, Dornelas et al. 2018)
70	Belgium	Migratory Lepidoptera	A	1983	1996	14	14	1		CC-BY	(Dornelas et al. 2018)
79	United Kingdom	Butterflies	A	1976	1989	14	14	30		CC-BY	(Pollard et al. 1986, NERC Centre for Population Biology Imperial College 2010)
249	Denmark	Coleoptera and Lepidoptera	A	1992	2015	24	24	1	Dryad	CC0	(Thomsen et al. 2016, Dornelas et al. 2018)
294	Vietnam	Butterflies	A	2003	2013	11	8	6		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		CC-BY	(Monitoring Site 1000 Project, Biodiversity Center 2015, Dornelas et al. 2018)
380	England	Butterflies	A	1978	1987	10	10	1		PD	(Pollard 1991, NERC Centre for Population Biology Imperial College 2010)
465	Czech Republic	Moths	A	1967	1992	26	26	1		PD	(Novak 1983, NERC Centre for Population Biology Imperial College 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		PD	(Taylor et al. 1990, NERC Centre for Population Biology Imperial College 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		CC_BY	(Bowler et al. 2017, Van Klink et al. 2019)
1261	USA: Massachusetts	Ants	A	2003	2015	13	8	13	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		PD	(Wolda 1992)
1312	Czech Republic	Moths	A	1963	1991	29	29	3		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		PD	(Meijer and Barendregt 2018)
1328	**England**	**Hoverflies**	A	1972	2001	30	30	1		CC-BY	(Hassall et al. 2017)
1335	Czech Republic	Ladybeetles	A	1983	2010	28	2	3		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	Dryad	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	8	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		PD	(Pizzolotto et al. 2014)
1376	Taiwan	Freshwater invertebrates	A	1985	1995	11	2	4		PD	(Shieh and Yang 2000)
1377	Panama	Orchid bees	A	1979	2000	22	20	1		PD	(Roubik 2001)
1378	Costa Rica	Butterflies	A	2003	2012	10	10	1		PD	(Grøtan et al. 2014)
1379	Ecuador	Butterflies	A	1994	2004	11	11	1		PD	(Grøtan et al. 2012)
1381	Brazil: Rio Grande del Sul	Freshwater invertebrates	A	2000	2010	11	10	1		PD	(Souza da Silva et al. 2015)

1382	Chile	All arthropods	AB	2003	2014	12	12	1		PD	(Meserve et al. 2016)
1384	New Zealand	Moths	A	1962	1988	27	2	1		PD	(White 1991)
1385	Brazil: Amazonas	Dung- and Carrion beetles	A	1986	2000	15	2	4		PD	(Quintero and Roslin 2005)
1387	Australia: Western Australia	Spiders	A	1990	2000	11	7	1		PD	(Langlands et al. 2006)
1388	USA: California	Freshwater invertebrates	A	1984	2003	20	20	4	URL	PD	(Bêche and Resh 2007b, Resh 2018)
1391	Russia: Murmansk	Soil fauna	A	1986	2010	25	3	6		PD	(Rybalov and Kamayev 2012)
1392	Slovakia	Butterflies	A	2001	2012	12	6	1		PD	(Kočíková et al. 2014)
1393	Russia: Tatarstan	Insects	A	1978	1995	18	18	3		PD	(Shafigullina 2009)
1394	Uganda	Butterflies	A	2000	2011	12	12	1		PD	(Valtonen et al. 2013)
1395	Guinea	Freshwater invertebrates	A	1984	1998	15	15	1		PD	(Crosa et al. 2001)
1396	Germany	Springtails	A	1980	2000	21	17	2		PD	(Daghighi et al. 2017)
1397	Hungary	Ants (nests)	A	1981	2017	37	28	1		PD	(Gallé 2017)
1398	Czech Republic	Beetles	A	1975	2007	33	7	3		PD	(Hodecek et al. 2015)
1400	Russia: Buryatia	Ground beetles	A	1988	2007	20	20	4		PD	(Ananin and Ananina 2011)
1401	Russia: Lipetsk Oblast	Beetles	A	1995	2004	10	10	1		PD	(Tsurikov 2016)
1402	Russia: Krasnoyarsk Krai	Springtails	A	1969	2010	42	2	8		PD	(Babenko 2013)
1403	Russia: Sverdlovsk Oblast	Parasitoid wasps	A	1994	2003	10	4	1		PD	(Fedyunin 2008)
1404	Greenland	Arthropods	A	1996	2017	22	21	6	URL	No share	(Aarhus University 2018)
1405	Finland	Saproxylic beetles	A	1990	1999	10	10	2		PD	(Martikainen and Kaila 2004)
1406	Russia: Orenburg Oblast	Ground dwelling arthropods	A	1990	2004	15	9	1		PD	(Nemkov and Sapiga 2010)
1407	Russia: Tver Oblast	Ground beetles	A	1996	2012	17	17	2		PD	(Korobov 2015)
1408	Finland	Freshwater invertebrates	A	2000	2013	14	14	23	Dryad	CC0	(Huttunen et al. 2017)
1409	Germany	Flying Insects	B	1989	2016	28	18	24		PD	(Hallmann et al. 2017)
1410	Germany	Arthropods	A	1992	2005	14	8	1		PD	(Karg et al. 2015)
1411	Austria	Soil fauna	AB	1998	2012	15	2	4		PD	(Steinwandter et al. 2017)
1412	Netherlands	Freshwater invertebrates	A	1987	2007	21	5	1		PD	(van dam 2009)
1413	South Korea	Soil fauna	A	1998	2007	10	10	8		PD	(Kwon et al. 2016)
1414	Iceland	Mosquitos	A	1977	1996	20	20	2		PD	(Gardarsson et al. 2004)
1415	USA: Wisconsin	Mayflies	AB	2002	2012	11	2	1		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		PD	(Stout and Rondinelli 1995)
1418	USA: Tennessee	Dragonflies	A	1978	1989	12	12	1		PD	(Crowley and Johnson 1992)
1419	Western Australia	Ants	A	1980	1997	18	2	3		PD	(Bisevac and Majer 1999)
1421	USA: Arkansas	Freshwater invertebrates	A	1971	1999	29	2	2		PD	(Johnson and Harp 2005)
1422	USA: Tennessee	Freshwater invertebrates	A	1986	2003	18	18	4		PD	(Smith et al. 2011)
1423	USA: Colorado	Freshwater invertebrates	A	1989	2006	18	18	4		PD	(Clements et al. 2010)
1424	USA: Wisconsin	Freshwater invertebrates	A	1981	2004	24	21	1		PD	(McCarthy et al. 2006)
1425	USA: Georgia	Freshwater invertebrates	AB	1956	1991	36	2	1		PD	(Grubaugh and Wallace 1995)
1426	USA: Pennsylvania	Freshwater invertebrates	A	1980	1990	11	11	3		PD	(McCreadie et al. 1994)
1427	USA: Idaho	Freshwater invertebrates	AB	1993	2005	13	13	6		PD	(Rugenski and Minshall 2014)
1428	USA: Pennsylvania	Freshwater invertebrates	AB	1972	1996	25	7	1		PD	(Bradt et al. 1999)
1429	USA: New York	Freshwater invertebrates	A	1956	2016	61	61	2		ODC	(Rudstam 2018)
1430	USA: Utah	freshwater invertebrates	A	1958	1999	42	28	3		PD	(Vinson 2001)
1431	USA: Alaska	Freshwater invertebrates	A	1984	1998	15	15	2		PD	(Slavik et al. 2004)
1432	USA: North Carolina	Freshwater invertebrates	B	1992	2006	15	15	1		PD	(Wallace et al. 2015)
1433	Belgium	Freshwater invertebrates	A	1998	2011	14	13	1		PD	(Latli et al. 2017)
1434	Switzerland	Spiders	A	1994	2004	11	11	1		PD	(Blandenier et al. 2014)
1435	USA: Kentucky	Freshwater invertebrates	A	1960	1990	31	2	12		PD	(Johnson et al. 1994)
1437	USA: Idaho	Freshwater invertebrates	B	1979	1989	11	11	10		PD	(Minshall et al. 2001)
1439	China: Jiangsu	Mosquitos (larvae)	A	1987	2007	21	2	4		PD	(Cai et al. 2015)
1440	CA: Winnipeg	Freshwater invertebrates	A	1969	2013	45	12	3		PD	(Hann et al. 2017)
1441	CA: Ontario	Freshwater invertebrates	A	1983	1995	13	3	2		PD	(Haynes et al. 1999)
1444	New Zealand	Freshwater invertebrates	A	1989	2008	20	20	66	GBIF	CC_BY_NC	(Groker 2018)
1445	USA: Arizona	Ants (nests)	A	1977	2009	33	28	2		CC0	(Ernest 2018)
1446	Russia: Kursk Oblast	Ground beetles	A	1983	1999	17	16	3		PD	(Grechanichenko 2014)
1448	Russia: Nenets Okurg	Freshwater invertebrates	AB	1990	2000	11	2	1		PD	(Baranovskaya 1976, Fefilova et al. 2014)
1449	Russia: Komi Republic	Freshwater invertebrates	A	2000	2014	15	5	2		PD	(Baturina et al. 2017)
1451	Russia: Perm Krai	Freshwater invertebrates	B	1964	2014	51	12	1		PD	(Aleksevnina and Presnova. 2017)
1452	Russia: Perm Krai	Freshwater invertebrates	B	2002	2015	14	6	6		PD	(Istomina 2017)

1453	Russia: Karelia	Freshwater invertebrates	AB	1954	1993	40	16	1	PD	(Pavlovsky 2014)
1454	Russia: Karelia	Freshwater invertebrates	B	2003	2015	13	13	1	PD	(Petukhov et al. 2017)
1455	Russia: Nenets Okurg	Freshwater invertebrates	AB	1968	2010	43	6	1	PD	(Baranovskaya 1976, Baturina et al. 2012)
1456	Russia: Saratov Oblast	Freshwater invertebrates	AB	1969	2011	43	6	3	PD	(Nechvalenko 1973, Kurina et al. 2016)
1457	Russia: Samara Oblast	Freshwater invertebrates	AB	1991	2007	17	6	3	PD	(Golovatyuk and Abrosimova 2015)
1458	Russia: Novgorod Oblast	Springtails	A	1981	1995	15	5	3	PD	(Kuznetsova 2005)
1459	Russia: Moscow Oblast	Ground beetles	A	1974	1990	17	6	2	PD	(Gryuntal 2008)
1460	Russia: Leningrad Oblast	Rove beetles	A	1983	2005	23	4	1	PD	(Guseva 2017)
1461	Russia: Khabarovsk Krai	Hoverflies	A	1988	2013	26	5	1	PD	(Mutin 2015)
1462	Russia: Primorsky Krai	Butterflies	A	1986	2005	20	20	1	PD	(Sasova 2008)
1464	Belarus	Hymenoptera	A	1990	2000	11	11	1	PD	(Shlyakhtenok 2007a)
1465	Malaysia	Moths	A	1965	2007	43	2	10	PD	(Chen et al. 2011)
1466	Kazachstan	Freshwater invertebrates	B	1939	2012	74	48	1	PD	(Krupa et al. 2013)
1467	Belarus	Hymenoptera	A	1986	2003	18	16	1	PD	(Shlyakhtenok 2007b)
1468	Spain	Bumblebees	A	1988	2008	21	2	1	PD	(Ploquin et al. 2013)
1470	Belarus	Hymenoptera	A	1985	2005	21	21	1	PD	(Shlyakhtenok 2007c)
1471	Ukraine	Beetles	A	2003	2011	9	9	1	PD	(Nitochko 2012)
1472	Hungary	Moths	A	1990	2004	15	8	1	PD	(Szabó et al. 2007)
1473	USA: Idaho	Freshwater invertebrates	AB	1993	2013	21	19	11	PD	(Mebane et al. 2015b, 2015a)
1474	**Germany**	**Bugs and Grasshoppers**	A	1951	2009	59	2	9	CC-BY	(Schuch 2011, Schuch et al. 2012a)
1475	**Germany**	**Plant- and leafhoppers**	A	1962	2010	49	9	27	CC-BY	(Schuch 2011, Schuch et al. 2012b)
1476	**USA: Wisconsin**	**Butterflies**	A	1987	2017	31	31	56	CC-BY	(Swengel and Swengel 2015a)
1477	**USA: Wisconsin**	**Butterflies**	A	1988	2017	30	30	47	CC-BY	(Swengel and Swengel 2015b, 2015a)
1478	**USA: Wisconsin**	**Butterflies**	A	1990	2017	28	28	35	CC-BY	(Swengel and Swengel 2015b)
1479	**AUS: Tasmania**	**Ground and foliage dwelling arthropods**	A	1999	2015	17	9	6	CC-BY	(Driessen 2016)
1480	**AUS: Tasmania**	**Ground dwelling arthropods**	A	2001	2012	12	4	14	CC-BY	(Doran et al. 2003)
1481	**Israel**	**Butterflies**	A	2009	2018	10	10	10	CC-BY	(Pe'er and Comay 2019)
1484	Mexico	Herb layer arthropods	B	1987	2014	28	3	1	PD	(Lister and Garcia 2018)

1485	Puerto Rico	Herb layer arthropods	B	1976	2013	38	5	3		PD	(Lister and Garcia 2018)
1487	Puerto Rico	Canopy arthropods	A	1991	2016	26	15	65		PD	(Schowalter 2017)
1488	Sweden	Freshwater invertebrates	AB	1969	2017	49	48	361	URL	CC0	(SLU 2018)
1491	Brazil: Minas Gerais	Freshwater invertebrates	A	1999	2010	12	12	13	GBIF	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		PD	(Hu et al. 2016)
1494	England	Sawflies	A	1970	1988	19	19	5		PD	(Aebischer 1990)
1495	United Kingdom	Flying Insects	B	1973	2001	29	29	4		PD	(Shortall et al. 2009)
1496	Scotland	Flying Insects	A	1972	1997	26	26	1		PD	(Benton et al. 2002)
1497	England	Ladybeetles	A	2006	2016	11	11	4		PD	(Brown and Roy 2018)
1498	Ireland	Freshwater invertebrates	A	1985	1998	14	12	1		PD	(Woodward et al. 2015)
1499	Scotland	Freshwater invertebrates	A	1983	1994	12	12	1		PD	(Soulsby et al. 1995)
1500	Wales	Freshwater invertebrates	A	1981	2005	25	21	1		PD	(Durance and Ormerod 2007)
1501	Ireland	Butterflies	A	1992	2016	25	17	2	GBIF	CC-BY	(Irish National Biodiversity Data Centre 2018)
1502	China: Hebei	Ground beetles	A	1997	2014	18	2	3		PD	(Zhang et al. 2018)
1503	Australia: New South Wales	Freshwater invertebrates	A	1980	2012	33	32	6		PD	(Paul et al. 2018)
1504	USA: California	Freshwater invertebrates	A	1998	2015	18	18	6		PD	(Herbst et al. 2018)
1505	Finland	Mining and galling insects	AB	2003	2013	11	11	1	Dryad	CC0	(Blanchet et al. 2018b, 2018a)
1506	Costa Rica	Freshwater invertebrates	AB	1997	2011	15	15	2		PD	(Gutiérrez-Fonseca et al. 2018)
1507	Russia: Orenburg Oblast	Freshwater invertebrates	AB	1981	2005	25	6	1		PD	(Shulepina 2010)
1508	Russia: Murmansk Oblast	Freshwater invertebrates	AB	1992	2005	14	2	4		PD	(Chernenkova et al. 1995, Tanasevitch et al. 2009)
1509	Russia: Murmansk Oblast	Freshwater invertebrates	AB	1939	2010	72	8	2		PD	(Kashulin et al. 2012)
1510	Russia: Archangelsk Oblast	Freshwater invertebrates	AB	2003	2015	13	13	1		PD	(Novoselov et al. 2017)
1511	Russia: Novosibirsk Oblast	Freshwater invertebrates	B	1925	2004	80	19	1		PD	(Bezmaternykh et al. 2008)
1512	Germany	Ground beetles	B	1994	2017	24	24	1		PD	(Homburg et al. 2019)
1513	Italy	Freshwater Insects	A	1997	2013	17	6	6		PD	(Lencioni 2018)
1515	Spain	Dung beetles	A	1983	2017	35	2	1		PD	(Cuesta and Lobo 2019)
1516	Sweden	Saproxylic beetles	A	2001	2013	13	3*	1*		PD	(Gran and Götmark 2019)

1517	China: Chongqing & Hubei	Mosquitos	A	1997	2009	13	13	6		PD	(Guo et al. 2018)
1518	**USA: Ohio**	**Butterflies**	A	1996	2016	21	21	60		CC-BY	(Wepprich et al. 2019)
1519	**USA: New York & New Jersey**	**Mosquitos**	A	1932	2012	81	81	2		CC-BY	(Rochlin et al. 2016)
1520	USA: Iowa	Mosquitos	A	1969	2018	51	47	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		PD	(Petersen et al. 2004)
1524	Netherlands	Light-attracted insects	A	1997	2017	21	21	1		PD	(Hallmann et al. 2020)
1525	USA: Indiana	Mosquitos	A	2008	2018	11	11	13		CC-BY	(Giraldo-Calderón et al. 2015)
1526	USA: Florida	Mosquitos	A	2007	2018	12	12	32		CC-BY	(Giraldo-Calderón et al. 2015)
1527	**USA: California**	**Mosquitos**	A	1954	2005	52	52	1		CC-BY	(Rochlin et al. 2016)

* From DataSource_ID 1516 to 1527, the columns 'Nr yrs data' and 'Nr of plots' were accidentally switched in the supplementary material of Van Klink et al (2020). The data presented here are correct.

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. Dataset 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, Sebastian Schuch, Ann E. Swengel, Scott R. Swengel, Thomas L. Valone, Ilia Rochlin, Rikjan Vermeulen, Tyson Wepprich, Jerome L. Wiedmann, Jonathan M. Chase

Contact: Roel.vanklink@gmail.com

For questions regarding specific datasets, please refer to the author(s) of each section in Appendix 1.

2. Abstract

The data consists of total abundances or biomass data of whole insect or arachnid assemblages in the freshwater and terrestrial realms, sourced from 166 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 166 studies comprised 1676 sites in 41 countries, with 63 studies on freshwater insects and 103 studies on terrestrial insects. The median time-span was 15 years, ranging between 9 and 81 years, and between 1 and 264 plots per dataset. Three datasets 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 dataset are at a temporal resolution between weekly and yearly values. Hence, when the sampling events in the original data source were reported at a higher resolution than a week (e.g., daily), these were summed or averaged, and 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.

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.

The data are stored in 4 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 166 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 and elibrary.ru, 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.

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 al 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 we 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 (NERC Centre for Population Biology Imperial College 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 166 studies with 1676 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 1676 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 urban and croplands 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 land 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 2.

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, 693 plots - for datasets 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 2.

Data harmonization

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

1) Harmonization across datasets:

Many datasets 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 datasets is only guaranteed for the temporal slopes, but not for the intercepts, as sampling effort differed strongly.

2) Harmonization within plots:

Within the plots, sampling was not always temporally or spatially homogeneous in terms of number of samples taken per year or the number of sampling units (e.g., traps) per sampling period. This was particularly true for raw data downloaded from repositories. In many of these raw datasets, samples were occasionally missing for a given plot or sampling event typically 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 datasets, see Appendix 2.

Some datasets 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 datasets 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 datasets, and Inês Martins and Petr Keil for help with the maps. We thank all collectors of the original data for their work, in particular Aaron Elisson, Lars Rudstam, Nick Haddad, Peter Brown, Brad Lister, and Paul Giller for their help understanding their datasets, and Brenda Hann, Petri Martikainen, Elaheh Daghighi, Warren Paul for providing metadata. The Swengel surveys were funded in part by the Lois Almon Small Grants Research Program, Wisconsin Department of Natural Resources, U.S. Fish and Wildlife Service, Jed Bromfield and Henya Rachmiel, Sandra McKibben, and especially Drs. William and Elsa Boyce. 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 datasets included in this database were previously only available upon request. Details on their environmental conditions, collection methods and post processing are detailed in Appendix 1. All other datasets were described in their original source.

Datasource_ID	**Taxon**	**Scientific name**	**Country or state**	
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	Mosquitos	(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 dataset 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 dataset, may not be not comparable.

Finally, 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), a large portion of the Rothamsted Insect Survey data (https://insectsurvey.com/), many mosquito monitoring programs (but see Giraldo-Calderón et al. 2015, Iowa Mosquito Surveillance 2019), and many freshwater monitoring schemes (but see Groker 2018, SLU 2018).

Potential enhancements:

Although the table *SampleData.csv* is not essential for the current dataproduct, 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 available.

This dataset has a relatively simple structure and the addition of new data is encouraged. Please contact roel.vanklink@gmail.com.

Parts of the raw data underlying this dataset may also be suitable for other datasets exploring temporal variation in assemblages, such as the BioTIME database (Dornelas et al. 2018) .

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CLASS III. DATA SET STATUS AND ACCESSIBILITY

A. Status

1. Latest update

18 March 2020

2. Latest archive date

18 March 2020

3. Metadata status

Last checked 16 March 2020

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/F11V5C9V

2. Contact person:

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

3. Copyright restrictions

This dataset 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:

Three data sources that are currently openly accessible, but not provided here due to copyright restrictions include: 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 datasets, 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 4a).

The table *SampleData.csv* has a many-to-many relationship with the *InsectAbundanceBiomass.csv* table (Fig 4b). Thus, although technically possible, these tables should not be linked as it would create duplicate entries for each Datasource_ID with multiple Sample_ID's. The column *'Stratum'* in the table *InsectAbundanceBiomass.csv* was derived from the table *SampleData.csv*.

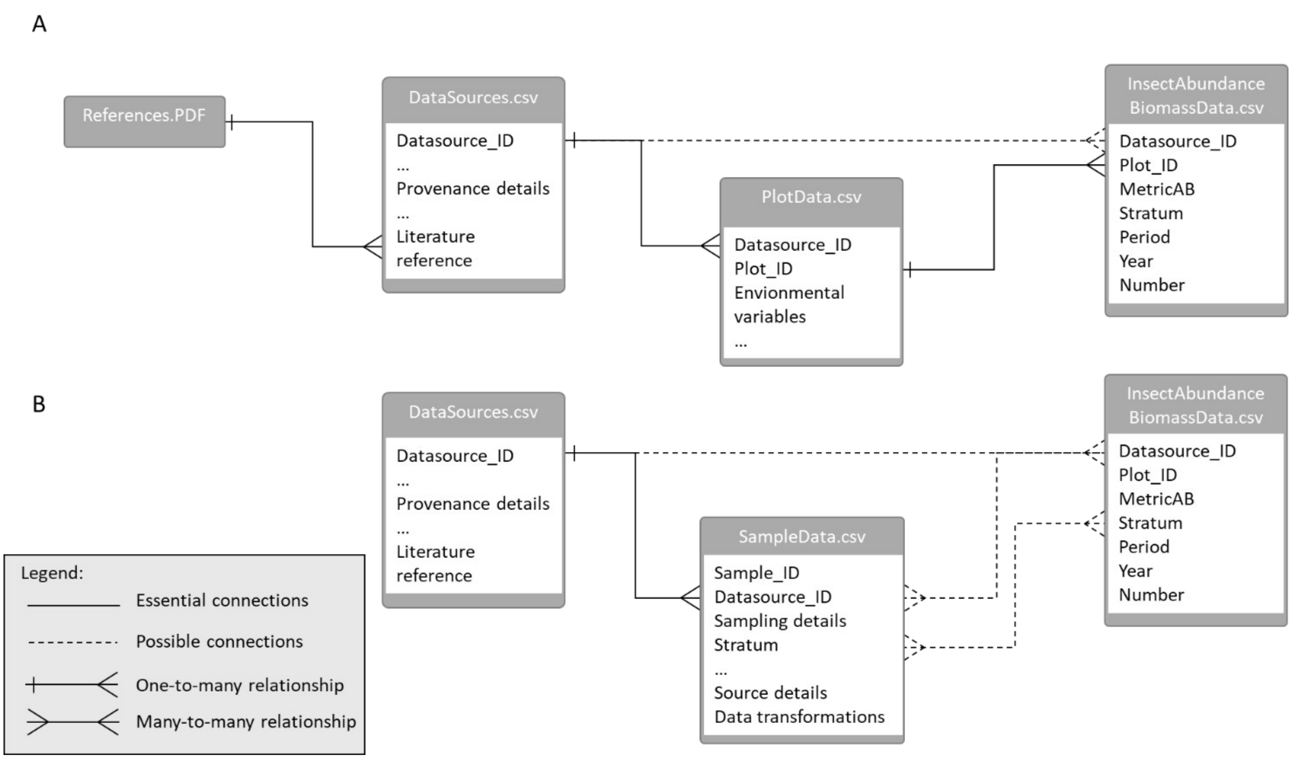

Fig 4. Database schema of the relations between the tables in the dataset. A) Essential relations among studies, plots and the insect abundance/biomass data. B) Possible relations between samples and the

insect abundance data. The table *PlotData.csv* contains information on the location of sampling, whereas the table *SampleData.csv* contains information on the sampling method and the source of the data.

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 group sampled; whether the data terrestrial or freshwater insects, and whether the dataset 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 experimentally manipulated; 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 2).

One row = one plot

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, sampling area, sample size, and 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 may later have been 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 as analyzed in the paper. 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 (this was used as a random effect), 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 we performed, 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	3031 kb 166 rows
PlotData	.csv	800830 kb, 1667 rows
SampleData	.csv	3637 kb, 240 rows
InsectAbundanceBiomassData	.csv	32593353 kb, 70955 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, 166 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 6 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. - **Latin America**: Central and South America, including Mexico and the Caribbean. - **North America**: USA and Canada. - **Oceania**: Australia and New Zealand. (categorical)

Region	Arbitrary grouping of countries and states into geographical regions (factor with 26 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 102 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 (NERC Centre for Population Biology Imperial College 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= 693 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= 693 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= 693 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= 693 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= 693 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; 240 entries)
DataSource_ID	Unique identifier linking to table *DataSources.csv* (integer; 166 entries)
DataCarrier	Source of this part of the data (table, figure number, etc.) (string)
ExtractionMethod	Software used to extract data from graphs or tables (factor with 4 levels: 'ImageJ', 'Metadigitise', 'pdftoexcel.com', 'values from owner') (string)
SamplingMethod	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 ant nest counts), - **Underground** (soil cores) - **Water** (e.g. kicksamplers, Surber samplers, 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 are 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.

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 our INLA analysis. 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 at 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 February 2020.

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

- *DataSources.csv*: "8106974fee871582f7333b27e2e2d6a3"
- *SampleData.csv*: "85bd098a7c8dc388d6e856f325c33ad1"
- *PlotData.csv*: "2513a3b0fce879eef2f2a228dde88ea1"
- *InsectAbundanceBiomassData.csv*: "b55a4cfe14e0dd5b2508b24e59c57bf2"

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 complied data was published by Van Klink et al. (2020).

Code for analysis and data processing of the three datasets 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 datasets see Appendix 2). 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 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. (2020)

G. History of dataset usage

NA

4. Questions and comments from secondary users

NA

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