

ANALYSIS OF THE INSECT FAUNA OF TURKEY AND SUGGESTIONS FOR FUTURE STUDIES

Serdar Tezcan*

* Department of Plant Protection, Faculty of Agriculture, Ege University, 35100 Bornova, Izmir, TURKEY. E-mail: serdar.tezcan@gmail.com; <http://orcid.org/0000-0003-1980-9291>

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ABSTRACT: Turkey constitutes a biogeographical bridge that connects Europe, Asia and Africa. Publications on its insect fauna began almost 180 years ago. To date, no studies have summarized the data in the massive body of publications compiled on its insect diversity. The current research addressed that situation by thoroughly analyzing published notes, catalogues, databases and systematic revisions and other work on the insect fauna of Turkey. This study reports that the insect fauna of Turkey as of end-2019 is composed of 33820 known species and subspecies in 562 families and 25 orders. The number of species and subspecies of the dominant orders and their percentages are given in descending order, as follows: Coleoptera (11910 / 35.22%), Hymenoptera (6641 / 19.64%), Lepidoptera (5580 / 16.50%), Diptera (3742 / 11.06%), Hemiptera (3424 / 10.13%) and Orthoptera (734 / 2.17%). For these six orders, the total number of species and subspecies is 32031, which is 94.71% of the total. The extraordinary biogeographic diversity of Turkey, which includes Mediterranean, Irano-Anatolian and Caucasian biodiversity hotspots, is reflected in the chorotype analyses which showed that Mediterranean, European and Asiatic chorotypes are prominent. Moreover, there is a high proportion of endemic species and subspecies (3785 / 11.20% of total), with the numbers and percentages varying widely across the taxa. Furthermore, the number of reported endemics has increased by 49% since 2008. The data compiled in this study highlights the urgent need for protection of the extraordinarily diverse insect fauna of Turkey and their habitats.

KEY WORDS: Insecta, endemism, fauna, insect diversity, Turkey

In Turkey, 16600 bibliographically recorded studies had been carried out in the fields of entomology and agricultural zoology to the end of 2011 (Onder et al., 1982, Onder et al., 1986, Tezcan et al., 2013). The actual number of studies is more than 200 during the period 2011-2019. Some of these studies were related specifically to insect diversity but many others were conducted in related fields of entomology such as applied entomology, pest management and physiology.

The earliest information on the insects of Turkey was in the publications of Pictet in 1841 (Pictet, 1841), Schneider in 1845 (Schneider, 1845) and Hochhut in 1847 (Hochhuth, 1847). After 1920, M. S. Özek, Ş. N. İyriboz, B. Alkan, A. Acatay, M. A. Tolunay, T. Karabag, R. Erdem and later Z. Düzgüneş, N. Lodos, A. I. Kansu, H. Çanakçıoğlu and H. Giray were among the leading entomologists of the modern Turkish Republic (Tezcan & Tezcan, 2012).

Some of the first insect fauna studies in Turkey, with respect to insect orders, were as follows: for Microcoryphia and Zygantoma, Wygodzinsky in 1952 (Wygodzinsky, 1952); for Ephemeroptera, Demoulin in 1963 (Demoulin, 1963) and Puthz in 1972 (Puthz, 1972); for Odonata, Hagen in 1863 (Hagen, 1863); Spagnolini in 1877 (Spagnolini, 1877); Selys-Longchamps in 1887 (Selys Longchamps, 1887); Mc Lachlan in 1899 (McLachlan, 1899) and Bartenef in 1909

(Bartenev, 1909); for Orthoptera, Retowski in 1889 (Retowski, 1889); Krauss in 1896 (Krauss, 1896); Bolivar in 1899 (Bolivar, 1899); Kuthy in 1907 (Kuthy, 1907); Ebner in 1910 and 1919 (Ebner, 1910, Ebner, 1919); for Dermaptera, Werner in 1901 and Penther in 1905 (Werner, 1901, Penther et al., 1905); for Plecoptera Pictet in 1841 (Pictet, 1841) and Zwick in 1971 (Zwick, 1971); for Isoptera, Weidner in 1972 (Weidner, 1972); for Mantodea, Maran in 1957 (Maran, 1957); for Blattodea, Harz in 1983 (Harz, 1983); for Auchenorrhyncha, Haupt in 1930 (Haupt, 1930) and Dlabola in 1957 (Dlabola, 1957); for Heteroptera, Costa in 1875 (Costa, 1875); Horvath in 1883 (Horvath, 1883); Puton in 1892 (Puton, 1892); Delagrange in 1895 (Delagrange, 1895); Escherich in 1897 (Escherich, 1897a) and Horvath in 1901 (Horvath, 1901); for Sternorrhyncha, Lindinger in 1906 (Lindinger, 1906); Shugorov in 1907 (Shugorov, 1907) and Bodenheimer in 1941 (Bodenheimer, 1941); for Psocoptera, Alkan in 1961 (Alkan, 1961); for Coleoptera, Hochhut in 1847 (Hochhuth, 1847); Peyron in 1858 (Peyron, 1858); Fairmaire in 1866 (Fairmaire, 1866); Schneider and Leder in 1878 (Schneider and Leder, 1878); Frivaldszky in 1880 (Frivaldszky, 1880); Heyden and Faust in 1888 (Heyden and Faust, 1888); Reitter in 1892 (Reitter, 1892); Escherich in 1897 (Escherich, 1897b); Daniel and Daniel in 1903 (Daniel and Daniel, 1903); Ganglbauer in 1905 (Ganglbauer, 1905); Bodemeyer in 1906 (Bodemeyer, 1906); Desbrochers des Loges in 1907 (Desbrochers des Loges, 1907) and Sahlberg and Saalas in 1912-1913 (Sahlberg and Saalas, 1912-1913); for Neuroptera, Schneider in 1845 (Schneider, 1845); Hagen in 1863 (Hagen, 1863) and Esben-Petersen in 1932 (Esben-Petersen, 1932); for Hymenoptera, Rigler in 1852 (Rigler, 1852); Morawitz (Morawitz, 1876) and Stein in 1876 (Stein, 1876); Radoszkowski in 1890 (Radoszkowski, 1890) and Kohl in 1905 (Kohl, 1905); for Trichoptera, Brauer in 1876 (Brauer, 1876) and Malicky in 1972 (Malicky, 1972); for Lepidoptera, Mann in 1861 (Mann, 1861); Oberthür in 1872 (Oberthür, 1872); Staudinger in 1878 (Staudinger, 1878); Holtz in 1897 (Holtz, 1897) and Wagner in 1929 (Wagner, 1929); for Siphonaptera, Jordan in 1946 (Jordan, 1946); for Mecoptera, Esben-Petersen in 1932 (Esben-Petersen, 1932); for Diptera, Theodor in 1952 (Theodor, 1952) and Minar in 1974 (Minar, 1974).

Some of these studies were conducted over large areas (Schneider, 1845, Fairmaire, 1866, Oberthür, 1872, Heyden and Faust, 1888, Werner, 1901, Kuthy, 1907, Dlabola, 1957) and some aimed to determine the insect fauna in specific areas [Mount Erciyes (Erciyes Dagı), Akbez (Akbes), Toros Dagları (Taurus Mountains) and Agri Dagı (Mount Ararat)] (Peyron, 1858, Mann, 1861, Radoszkowski, 1890, Puton, 1892, Delagrange, 1895, Ganglbauer, 1905, Kohl, 1905, Bartenev, 1909, Ebner, 1910, Ebner, 1919).

Different totals have been reported for the number of insect species in Turkey. While the estimated number of species is between 50000 and 100000 (Kocak, 2009, Kiziroglu et al., 2013, Yildirim, 2017), Tezcan in 2008 (Tezcan, 2008) reported 22749 and Koçak in 2014 (Koçak, 2014) specified 23773 species.

Against that background, the aim of this study was to more precisely determine the approximate number of insect species of Turkey which overall has extraordinary biogeographic diversity.

MATERIAL AND METHODS

This research was conducted by analyzing previously published notes, catalogues, databases and systematic revisions related to the insect fauna of Turkey and also by analyzing reports from other countries that provide additional insights into its insect fauna. Unpublished museum material and uncorroborated

records were not taken into account. Fauna lists were accessed either directly or from a secondary source and quoted studies were added to the reference list. Unless a different reference was employed by the authors, nomenclature based on the Fauna Europaea Database (Database, 2019) was followed.

RESULTS

1. Orders and families of the insects of Turkey

This study reports that the insects of Turkey belong to 25 orders; and that there are no records for the Grylloblattodea (rock crawlers) and Zoraptera (zorapterans). Based on the Fauna Europaea Database (Database, 2019) and (Wheeler et al., 2001), the orders extant in Turkey are listed below. After specifying the families in each order, the numbers of species and subspecies are shown in parentheses. At the end of the suborders and orders, the total number of species and subspecies are specified.

Microcoryphia (Jumping bristletails): Machilidae (6) (Wygodzinsky, 1952, Lodos, 1983, Mendes, 1984, Mendes, 1993, de Roca et al., 2013). The six species and subspecies all belong to one family.

Zygentoma (Silverfish): Ateluridae (1) (Mendes, 1984); Lepismatidae (8) (Lodos, 1983, Mendes, 1984, Mendes, 1993, Mendes et al., 2011, Molero et al., 2018); Nicoletiidae (1) (Kunt et al., 2010); Protrinemuridae (1) (Kahrarian and Molero-Baltanas, 2015). The 11 species and subspecies in total belong to four families.

Ephemeroptera (Mayflies): Prosopistomatidae (2); Ameletidae (2); Baetidae (42); Siphonuridae (3); Caenidae (8); Ephemerellidae (7); Ephemeridae (6); Palingeniidae (1); Polymitarcyidae (1); Potamanthidae (1); Heptageniidae (62); Isonychiidae (1); Oligoneuriidae (7); Leptophlebiidae (14) (Kazancı and Türkmen, 2012, Salur et al., 2016). The 157 species and subspecies in total belong to fourteen families.

Odonata-Anisoptera (Dragonflies): Aeshnidae (17); Gomphidae (20); Cordulegastridae (8); Corduliidae (5); Libellulidae (50) (Kalkman et al., 2003, Kalkman, 2006). The 100 species and subspecies in total belong to five families.

Odonata-Zygoptera (Damselflies): Calopterygidae (10); Euphaeidae (1); Coenagrionidae (36); Platynemididae (4); Lestidae (11) (Kalkman et al., 2003, Kalkman, 2006). The 62 species and subspecies in total belong to five families.

Orthoptera-Caelifera (Grasshoppers): Acrididae (177); Pamphagidae (93); Pyrgomorphidae (4); Tetrigidae (9); Tridactylidae (4) (Unal, 2019). The 287 species and subspecies in total belong to five families.

Orthoptera-Ensifera (Crickets, katydids): Gryllidae (36); Gryllotalpidae (1); Mogoplistidae (4); Myrmecophilidae (5); Rhabdophoridae (18); Schizodactylidae (1); Tettigoniidae (382) (Unal, 2019). The 447 species and subspecies in total belong to seven families.

Phasmatodea (Walkingsticks): Bacillidae (4) (Scali and Mantovani, 1989, Ivković and Lagja, 2019); Heteronemiidae (1) (Karabag, 1955). The five species and subspecies in total belong to two families.

Dermaptera (Earwigs): Anisolabididae (3); Labiduridae (2); Spongiphoridae (3) (Anlas and Kočárek, 2012); Forficulidae (12) (Anlas and Kočárek, 2012, Nishikawa and Kacar, 2018). The 20 species and subspecies in total belong to four families.

Plecoptera (Stoneflies): Capniidae (7); Leuctridae (27); Nemouridae (40); Taeniopterygidae (10); Chloroperlidae (10); Perlidae (13); Perlodidae (10) (Darılmaz et al., 2016). The 117 species and subspecies in total belong to seven families.

Embioptera (Web spinners): Oligotomidae (1) (Fontana, 2002). The one species belong to one family.

Dictyoptera-Isoptera (Termites): Kalotermitidae (1); Rhinotermitidae (1); Hodotermitidae (1) (Caesar et al., 2015). The three species in total belong to three families.

Dictyoptera-Mantodea (Mantids): Amorphoscelididae (1); Empusidae (4); Eremiaphilidae (4); Mantidae (16) (Caesar et al., 2015). The 25 species and subspecies in total belong to four families.

Dictyoptera-Blattodea (Cockroaches): Blattellidae (9); Blattidae (3) (Ozar, 1980, Caesar et al., 2015); Polyphagidae (3) (Caesar et al., 2015). The 15 species and subspecies in total belong to three families.

Hemiptera-Auchenorrhyncha (Cicadas, leafhoppers) : Aphrophoridae (16); Cercopidae (7); Cicadidae (16); Tibicinidae (16); Cicadellidae (443); Membracidae (6); Achilidae (5); Caliscelidae (8); Cixiidae (55); Delphacidae (60); Derbidae (4); Dictyopharidae (16); Flatidae (3); Issidae (124); Meenoplidae (2); Ricaniidae (3); Tettigometridae (20) (Onder et al., 2011, Kocak, 2014); Tropiduchidae (1) (Kocak, 2014). The 805 species and subspecies in total belong to eighteen families.

Hemiptera-Heteroptera (Bugs): Anthocoridae (41); Cimicidae (2); Nabidae (24); Miridae (515); Reduviidae (65); Tingidae (89); Dipsocoridae (2); Enicocephalidae (1); Leptopodidae (4); Saldidae (20); Corixidae (37); Gerridae (11); Veliidae (10); Hebridae (4); Hydrometridae (2); Mesovelidae (2); Aphelocheiridae (2); Naucoridae (2); Belostomatidae (1); Nepidae (2); Notonectidae (9); Ochteridae (1); Pleidae (1); Aradidae (18); Alydidae (8); Coreidae (50); Rhopalidae (30); Stenocephalidae (7); Berytidae (24); Lygaeidae (275); Pyrrhocoridae (3); Acanthosomatidae (9); Cydnidae (41); Pentatomidae (168); Plataspidae (7); Scutelleridae (40); Thyreocoridae (2); Piesmatidae (6); Pachynomidae (1) (Onder et al., 2006, Cerci, 2019). The 1536 species and subspecies in total belong to thirty-nine families.

Hemiptera-Sternorrhyncha (Aphids, scales): Aleyrodidae (43) (Onder et al., 2011, Kocak, 2014, Uulu et al., 2017); Aphididae (554) (Görür et al., 2012, Görür et al., 2017); Asterolecaniidae (11); Cerococcidae (1); Coccidae (67); Dactylopiidae (1); Diaspididae (134); Eriococcidae (29); Kermesidae (11); Lecanodiaspididae (1); Marchalinidae (1); Margarodidae (5); Matsucoccidae (2); Micrococcidae (1); Monophlebidae (3); Ortheziidae (1); Phoenicococcidae (1); Pseudococcidae (101); Putoidae (4); Rhizoecidae (4) (Kaydan et al., 2013); Adelgidae (6); Phylloxeridae (3) (Görür et al., 2012); Calophytidae (1); Homotomidae (2); Psyllidae (73); Triozidae (23) (Drohojowska and Burckhardt, 2014, Kocak, 2014). The 1083 species and subspecies in total belong to twenty-six families.

Thysanoptera (Thrips)-Terebrantia: Aeolothripidae (30) (Tunc and Hastenpflug-Vesmanis, 2016, Basar and Yasar, 2018); Fauriellidae (1); Thripidae (109) (Tunc and Hastenpflug-Vesmanis, 2016). The 140 species and subspecies in total belong to three families.

Thysanoptera-Tubulifera: Phlaeothripidae (54) (Tunc and Hastenpflug-Vesmanis, 2016). The 54 species and subspecies all belong to one family.

Psocoptera (Book and bark lice)-Psocomorpha: Caeciliusidae (2); Stenopsocidae (1); Epipsocidae (1); Elipsoecidae (3); Lachesillidae (4); Mesopsocidae (1); Peripsocidae (2); Psocidae (3) (Lienhard, 2016). The 17 species and subspecies in total belong to eight families.

Psocoptera-Troctomorpha: Proctroctopsocidae (1) (Lienhard, 2005); Liposcelididae (5) (Ozsisli, 2010, Lienhard, 2016). The six species and subspecies in total belong to two families.

Psocoptera-Trogiomorpha: Trogiidae (1); Prionoglarididae (1) (Lienhard, 2016). The two species and subspecies in total belong to two families.

Phthiraptera (Lice)-Amblycera: Gyropidae (2); Laemobothriidae (1) (Inci et al., 2010b); Menoponidae (55) (Inci et al., 2010a, Inci et al., 2010b, Dik et al., 2011a, Dik et al., 2011c, Dik et al., 2017, Karatepe et al., 2017, Dik et al., 2011b); Ricinidae (3) (Dik et al., 2017). The 61 species and subspecies in total belong to four families.

Phthiraptera-Anoplura: Linognathidae (6); Polyplacidae (5); Pthiridae (1); Microthoraciidae (1); Haematopinidae (5); Pediculidae (2) (Inci et al., 2010b). The 20 species and subspecies in total belong to six families.

Phthiraptera-Ischnocera: Philopteridae (74) (Inci et al., 2010b, Dik et al., 2011a, Dik et al., 2011b, Dik et al., 2011c, Dik and Dinçer, 2012, Dik et al., 2013, Girisgin et al., 2013, Kilinc et al., 2013, Dik et al., 2015, Dik et al., 2017, Karatepe et al., 2017); Trichodectidae (8) (Inci et al., 2010b). The 82 species and subspecies in total belong to two families.

Coleoptera (Beetles)-Adephaga: Carabidae (1100†) (Kazantsev, 2011, Kocak, 2014); Dytiscidae (149) (Darilmaz and Kiyak, 2009, Erman and Aldemir, 2010, Kocak, 2014, Darilmaz et al., 2018); Hygrobiidae (1) (Kocak, 2014); Spercheidae (2) (Darilmaz et al., 2018); Gyrinidae (12); Haliplidae (16); Noteridae (3) (Darilmaz and Kiyak, 2009, Kocak, 2014). The 1283 species and subspecies in total belong to seven families.

Coleoptera-Myxophaga: Hydroscaphidae (1) (Ertorun, 2018). The one species belong to one family.

Coleoptera-Polyphaga: Bostrichidae (25) (Ozbek and Szaloki, 1998, Kocak, 2014, Liu and Beaver, 2017); Dermestidae (86) (Lodos, 1998, Háva, 2007, Kocak, 2014); Lyctidae (5) (Lodos, 1998); Ptinidae (130) (Lodos, 1998, Toper Kaygın, 2004, Borowski and Zahradnik, 2007); Bruchidae (122) (Lodos, 1998, Ozdikmen, 2012, Kocak, 2014); Cerambycidae (799) (Lodos, 1998, Ozdikmen, 2012, Kocak, 2014, Ozdikmen and Tuzun, 2018); Chrysomelidae (784) (Ozdikmen, 2012, Ekiz et al., 2013, Kocak, 2014); Megalopodidae (3); Orsodacnidae (3); Vesperidae (1) (Ozdikmen, 2012); Cleridae (77) (Lodos, 1998, Löbl et al., 2007, Kocak, 2014); Dasytidae (62) (Majer, 1996, Liberti, 2017); Malachiidae (110) (Švihla and Hajek, 2009, Yildirim and Bulak, 2012); Melyridae (153) (Mayor, 2007, Kocak, 2014); Trogoidea (9) (Lodos, 1998); Alexidae (3) (Tomaszewska et al., 2007); Biphyllidae (1) (Jelínek, 2007); Bothriideridae (2) (Ślipiński, 2007a); Byturidae (3) (Lodos, 1998, Löbl, 2007, Kocak, 2014); Corylonidae (4) (Ślipiński, 2007b); Coccinellidae (113) (Kováč, 2007, Kocak, 2014); Corylophidae (17) (Bowstead, 2007); Cryptophagidae (53) (Lodos, 1998, Johnson et al., 2007); Cucujidae (11) (Lodos, 1998, Wegrzynowicz, 2007a); Cybocephalidae (4) (Jelinek and Audisio, 2007); Endomychidae (12) (Rücker et al., 2007); Erotylidae (5) (Wegrzynowicz, 2007b); Kateretidae (19) (Jelinek and Audisio, 2007, Lasoń, 2007, Avgin et al., 2015); Laemophloeidae (2) (Wegrzynowicz et al., 2007); Latridiidae (45) (Johnson, 2007); Monotomidae (7) (Jelinek et al., 2007); Nitidulidae (163) (Lasoń, 2007, Kocak, 2014, Avgin et al., 2015); Phalacridae (31) (Svec, 2007); Silvanidae (15) (Lodos, 1998, Halstead et al., 2007); Anthribidae (35) (Tryzna and Valentine, 2011, Kocak, 2014); Apionidae (132) (Alonso-Zarazaga, 2011a, Kocak, 2014); Attelabidae (33) (Alonso-Zarazaga, 2011b, Kocak, 2014); Brachyceridae (13) (Colonnelli, 2011, Kocak, 2014); Brentidae (3) (Sforzi, 2011, Kocak, 2014); Curculionidae (1477†) (Avgin and Colonnelli, 2011, Avgin and Colonnelli, 2011, Gültekin and Korotyaev, 2011, Knizek and Prena, 2011, Borovec and Germann, 2013, Löbl and Smetana, 2013, Kocak, 2014, Davidian and Gültekin, 2015a, Davidian and Gültekin, 2015b, Cerci, 2016, Davidian and Gültekin, 2016, Davidian et al., 2017, Hacet and Colonnelli, 2019); Dryophthoridae (5) (Lyal, 2011); Eirrhinidae (13) (Caldara, 2011); Nanophyidae (12) (Alonso-Zarazaga, 2011c); Nemonychidae (3) (Alonso-Zarazaga, 2011d); Raymondionymidae (2) (Osella et al., 2011); Rhynchitidae (38) (Alonso-Zarazaga et al., 2011); Lymexylidae (2) (Lodos, 1998); Aderidae (5) (Nardi, 2008); Alleculidae (139) (Lodos, 1998, Novak and Pettersson, 2008, Novák et al., 2011); Anthicidae (132) (Chandler et al., 2008, Kocak, 2014); Ciidae (10) (Jelínek, 2008); Melandryidae (15) (Nikitsky and Pollock, 2008); Meloidea (187) (Ozbek and Szaloki, 1998, Kocak, 2014); Mordellidae (66) (Lodos, 1998, Horák, 2008, Kocak, 2014); Mycetophagidae (13) (Nikitsky, 2008); Mycteridae (2) (Löbl, 2008); Oedemeridae (58) (Švihla, 2008, Kocak, 2014); Prostomidae (2) (Schawaller, 2008); Pyrochroidae (2) (Pollock and Young, 2008, Kocak, 2014); Ripiphoridae (10) (Batelka, 2007, Kocak, 2014); Scaptiidae (12) (Leblanc et al., 2008); Tenebrionidae (596) (Keskin, 2008, Canpolat and Hasbenli, 2012, Chigray et al., 2018, Korkmaz and Gök, 2018, Nabozhenko et al., 2018, Soldati et al., 2019); Tetratomidae (2) (Nikitsky et al., 2008); Zopheridae (25) (Ślipiński and Schuh, 2008); Buprestidae (443) (Kubán et al., 2006, Kocak, 2014); Dryopidae (12) (Tasar, 2018a, Ozgen et al., 2019); Elmidae (29) (Tasar, 2018a); Heteroceridae (13) (Tasar and Mascagni, 2014); Psephenidae (1) (Jäch et al., 2006); Dascillidae (1) (Löbl, 2006); Rhipiceridae (3) (Wurst, 2006); Cantharidae (249) (Lodos, 1998, Kazantsev and Brancucci, 2007, Kazantsev, 2011, Kocak, 2014); Cebionidae (1) (Lodos, 1998, Kocak, 2014); Drilidae (5) (Bocak, 2007a); Elateridae (498) (Gülperçin and Tezcan, 2010, Kocak, 2014, Tarnawski et al., 2018); Eucnemidae (4) (Lodos, 1998); Lampyridae (16) (Lodos, 1998, Geisthardt and Sató, 2007, Kocak, 2014); Lycidae (2) (Bocáková and Bocák, 2007, Kocak, 2014); Omalidae (1) (Bocak, 2007b); Phengodidae (2) (Bocak, 2007c, Kocak, 2014); Plastoceridae (1) (Bocak, 2007d); Scirtidae (42) (Kocak, 2014); Throscidae (10) (Lodos, 1998); Clambidae (10) (Löbl et al., 2006); Eucinetidae (2) (Vit, 2006); Scirtidae (37) (Klausnitzer, 2006); Cetoniidae (65) (Pehlivan et al., 1995, Carpaneto et al., 2000, Polat et al., 2017); Geotrupidae (24); Scarabaeidae (84) (Pehlivan et al., 1995, Carpaneto et al., 2000, Kocak, 2014); Glaphyridae (89) (Pehlivan et al., 1995, Carpaneto et al., 2000, Kocak, 2014, Polat et al., 2017); Glaresidae (1) (Carpaneto et al., 2000); Lucanidae (10) (Lodos, 1989, Kocak, 2014); Trogididae (8) (Pehlivan et al., 1995, Carpaneto et al., 2000, Zidek, 2013, Kocak, 2014); Aphodiidae (154); Dynastidae (19); Euchiridae (1); Hybosoridae (4); Melolonthidae (165); Ochodaeidae (6); Orphnidae (2);

Rutelidae (59) (Pehlivan et al., 1995, Carpaneto et al., 2000); Histeridae (206) (Rozner, 2010, Kocak, 2014, Polat and Yildirim, 2017); Hydrophilidae (163) (Darılmaz and Kiyak, 2008, Mart et al., 2009, Darılmaz and İncekara, 2011, Kocak, 2014, Polat et al., 2015, Tasar, 2018b); Agrytidae (2) (Růžička, 2004); Hydraenidae (212) (Ertorun et al., 2011, Kocak, 2014, Darılmaz et al., 2017); Leioididae (5) (Kocak, 2014); Ptiliidae (13) (Johnson, 2004); Scydmaenidae (43) (Vit and Besuchet, 2004); Silphidae (24) (Háva et al., 1998, Kocak, 2014, Ciftci et al., 2018); Staphylinidae (1962) (Anlas, 2009, Bordoni, 2010, Kocak, 2014, Schülke and Smetana, 2015, Anlas, 2019). The 10626 species and subspecies in total belong to one hundred ten families.

Neuroptera (Lacewings, owlflies, mantispids, antlions): Berothidae (2); Chrysopidae (53); Coniopterygidae (27); Dilaridae (2); Hemerobiidae (31); Mantispidae (4); Osmylidae (4); Sisyridae (1) (Canbulat, 2007, Ari, 2014); Ascalaphidae (15) (Canbulat, 2007, Dobosz and Ábrahám, 2007, Ari, 2014); Myrmeleontidae (57); Nemopteridae (13) (Canbulat, 2007, Ari, 2014, Satar et al., 2014). The 209 species and subspecies in total belong to eleven families.

Raphidioptera (Snakeflies): Inocelliidae (2); Raphidiidae (38) (Canbulat, 2015). The 40 species and subspecies in total belong to two families.

Megaloptera (Alderflies, dobsonflies and fishflies): Sialidae (2) (Dobosz, 2007). The two species all belong to one family.

Hymenoptera (Bees, ants, wasps)-Apocrita: Ampulicidae (2) (Yildirim, 2016); Apidae (245) (Kocak and Kemal, 2015, Ozbek and Terzo, 2016); Crabronidae (558); Sphecidae (76) (Kocak and Kemal, 2015, Yildirim, 2016, Yildirim et al., 2016); Megachilidae (420) (Ozbek and Zanden, 1992, Kocak and Kemal, 2015); Bethyidae (4); Ceraphronidae (4) (Oncuer, 1991); Eulophidae (256) (Doğanlar and Mendel, 2007, Gencer, 2009, Güler and Kodan, 2010, Gencer, 2012, Kocak and Kemal, 2015); Eurytomidae (88) (Cam, 2011, Cam, 2012, Kocak and Kemal, 2015); Chrysididae (444) (Oncuer, 1991, Strumia and Yildirim, 2010, Kocak and Kemal, 2015, Yildirim, 2016, Ozbek and Franco, 2018); Dryinidae (17) (Kocak and Kemal, 2015, Antropov et al., 2017); Cynipidae (148) (Kocak and Kemal, 2015, Azmaz and Katilmis, 2017); Torymidae (62) (Stojanova et al., 2012, Kocak and Kemal, 2015); Braconidae (813) (Cikman et al., 2006, Beyarslan and Aydogdu, 2012, Kocak and Kemal, 2015); Ichneumonidae (965) (Klausnitzer, 2006, Gürbüz et al., 2009, Kocak and Kemal, 2015, Coruh and Calmasur, 2016, Coruh and Kolarov, 2016, Kolarov et al., 2016, Ozdan and Gurbuz, 2016); Platygasteridae (3) (Oncuer, 1991, Kocak and Kemal, 2015); Evanidae (5); Gasteruptionidae (12); Sapygidae (15); Tiphidae (22) (Kocak and Kemal, 2015, Yildirim and Lelej, 2016); Stephanidae (5) (Hilszczański, 2011, Kocak and Kemal, 2015, Yildirim and Lelej, 2016); Bradynobaenidae (2) (Yildirim, 2016, Antropov et al., 2017); Formicidae (306) (Kiran and Karaman, 2012, Kocak and Kemal, 2015); Mutillidae (78) (Kocak and Kemal, 2015, Yildirim, 2016, Yildirim and Lelej, 2016); Pompilidae (217) (Yildirim and Wahis, 2011, Kocak and Kemal, 2015, Yildirim, 2016, Yildirim and Lelej, 2016); (Yildirim and Gusenleitner, 2012, Kocak and Kemal, 2015, Yildirim, 2016) Scolidae (22) (Ozbek and Anlas, 2011, Kocak and Kemal, 2015); Vespidae (301) (Yildirim and Gusenleitner, 2012, Kocak and Kemal, 2015, Yildirim, 2016); Andrenidae (385); Colletidae (109); Halictidae (311); Melittidae (25); Agaonidae (1); Aphelinidae (54); Chalcididae (41); Encyrtidae (125); Eucharitidae (8); Eupelmidae (8); Leucospidae (6); Mymaridae (18); Ormyridae (13); Perilampidae (6); Pteromalidae (144); Signiphoridae (3); Tetracampidae (8); Trichogrammatidae (24); Figitidae (3); Ibalidae (1); Aulacidae (5); Scelionidae (8) (Kocak and Kemal, 2015). The 6396 species and subspecies in total belong to forty-nine families.

Hymenoptera-Symphya: Cephidae (26) (Calmasur and Ozbek, 2010, Korkmaz et al., 2010, Kocak and Kemal, 2015); Siricidae (8) (Ozkazanc, 1986, Antropov et al., 2017); Argidae (32) (Calmasur and Ozbek, 2006, Kocak and Kemal, 2015); Cimbicidae (23) (Calmasur, 2011, Kocak and Kemal, 2015); Tenthredinidae (117) (Calmasur, 2006, Kocak and Kemal, 2015, Calmasur, 2019); Orussidae (2); Megalodontesidae (18); Pamphiliidae (10); Xyelidae (4) (Kocak and Kemal, 2015); Diprionidae (4); Xiphodriidae (1) (Antropov et al., 2017). The 245 species and subspecies in total belong to eleven families.

Trichoptera (Caddisflies)-Annulipalpia: Ecnomidae (3); Polycentropodidae (24); Psychomyiidae (35); Philopotamidae (18) (Darılmaz and Salur, 2015); Hydropsychidae (75) (Darılmaz and Salur, 2015, Küçükbasmacı and Kiyak, 2017). The 155 species and subspecies in total belong to five families.

Trichoptera-Integripalpia: Calamoceratidae (1); Odontoceridae (2); Goeridae (5); Lepidostomatidae (10); Uenoidae (2); Phryganeidae (6); Beraeidae (16); Helicopsychoidea (1); Sericostomatidae (22) (Darılmaz and Salur, 2015); Leptoceridae (52) (Darılmaz and Salur, 2015, Sipahiler, 2018); Brachycentridae (5) (Darılmaz and Salur, 2015, Küçükbaşmacı and Fındık, 2019); Limnephilidae (101) (Darılmaz and Salur, 2015, Sipahiler, 2015, Sipahiler, 2017). The 223 species and subspecies in total belong to twelve families.

Trichoptera-Spicipalpia: Glossosomatidae (21); Ptilocolepidae (2); Rhyacophilidae (27) (Darılmaz and Salur, 2015); Hydroptilidae (64) (Darılmaz and Salur, 2015, Sipahiler, 2018). The 114 species and subspecies in total belong to four families.

Lepidoptera (Moths, butterflies): Adelidae (32); Incurvariidae (2); Prodoxidae (3); Alucitidae (13); Brahmaeidae (1); Endromidae (1); Lemoniidae (7); Saturniidae (6); Sphingidae (36); Carposinidae (2); Choreutidae (10); Brachodidae (15); Cossidae (49); Sesiidae (110); Cimeliidae (3); Drepanidae (6); Epermeniidae (11); Eriocraniidae (1); Autostichidae (37); Agonoxenidae (7); Blastobasidae (3); Coleophoridae (246); Cosmopterigidae (45); Deoclonidae (1); Elachistidae (60); Ethmiidae (27); Gelechiidae (284); Lecithoceridae (10); Momphidae (6); Pterolonchidae (3); Stathmopodidae (1); Geometridae (687); Bucculatricidae (11); Gracillariidae (81); Roeslerstammidae (1); Hepialidae (5); Lasiocampidae (38); Douglassiidae (8); Micropterigidae (10); Nepticulidae (49); Opostegidae (4); Ctenuchidae (18); Erebiidae (67); Lymantriidae (25); Micronoctuidae (1); Noctuidae (1242); Notodontidae (36); Thaumetopoeidae (9); Hesperidae (43); Libytheidae (1); Satyridae (81); Lycaenidae (179); Argynniidae (55); Papilionidae (13); Pieridae (38); Riodinidae (1); Danaidae (1); Pterophoridae (110); Pyralidae (678); Schreckensteiniidae (1); Thyridae (1); Eriocottidae (6); Psychidae (40); Tineidae (104); Tischeriidae (3); Tortricidae (507); Glyphipterigidae (4); Heliodinidae (1); Lyonetiidae (5); Yponomeutidae (67); Limacodidae (4); Zygaenidae (57) (Kocak and Kemal, 2018); Thyatiridae (10); Oecophoridae (161) (Torun and Caliskan, 2016, Kocak and Kemal, 2018); Scythridae (78) (Nuppenon, 2010, Kocak and Kemal, 2018); Crambidae (1) (Akin et al., 2018). The 5580 species and subspecies in total belong to seventy-six families.

Siphonaptera (Fleas): Ceratophyllidae (27); Leptopsyllidae (11); Hystrichopsyllidae (4); Pulicidae (11) (Keskin et al., 2018); Ischnopsyllidae (14); Vermipsyllidae (6) (Keskin et al., 2018, Keskin et al., 2019); Ctenophthalmidae (48) (Keskin et al., 2018, Keskin and Beaucournu, 2019b, Keskin and Beaucournu, 2019a). The 121 species and subspecies in total belong to seven families.

Mecoptera (Scorpionflies): Panorpidae (13) (Penny and Byers, 1979, Dvorak, 2017). The 13 species and subspecies all belong to one family.

Strepsiptera (Twisted-winged parasites): Mengenillidae (2) (Kathirithamby, 2017); Stylopidae (3) (Straka et al., 2006); Xenidae (3) (Borowiec et al., 2012, Kathirithamby, 2017). The eight species and subspecies in total belong to three families.

Diptera (Flies)-Brachycera: Agromyzidae (208) (Kocak, 2014, Dursun et al., 2015); Anthomyzidae (5) (Roháček, 2011, Kocak, 2014); Canacidae (6) (Munari, 2011); Chamaemyzidae (40) (Kocak, 2014, Ebejer and Barták, 2019); Chloropidae (114) (Kocak, 2014, Kubík and Barták, 2017); Cryptochetidae (2) (Papp et al., 2018); Curtonotidae (1) (Kirk-Spriggs and Freidberg, 2007); Dolichopodidae (192) (Kocak, 2014, Tonguc et al., 2016, Küçükberber et al., 2017); Empididae (103) (Kocak, 2014, Barták and Shamshev, 2018); Hippoboscidae (2) (Maa, 1969, Kocak, 2014); Hybotidae (51) (Kocak, 2014, Bartak and Kubík, 2018, Bartak and Shamshev, 2018); Helcomyzidae (1) (Mathis, 2011); Lonchaeidae (1) (Giliomee et al., 2007); Oestridae (2) (Uslu and Dik, 2006); Platypezidae (1) (Tkoč and Barták, 2013); Sarcophagidae (153) (Kocak, 2014, Verves et al., 2018); Scenopinidae (1) (Carles-Tolrá, 2001); Stenomicrophoridae (1) (Roháček, 2011); Stratiomyidae (71) (Kocak, 2014, Demirözer et al., 2017); Syrphidae (341) (Kocak, 2014, Sarıbiyik, 2014); Tabanidae (191) (Kilic, 2006, Kocak, 2014, Altunsoy, 2018); Tachinidae (156) (Kocak, 2014, Lutovinovas et al., 2018); Tephritidae (164) (Kocak, 2014, Kutuk et al., 2019); Acroceridae (7); Anthomyiidae (8); Asilidae (237); Athericidae (1); Bombyliidae (271); Braulidae (2); Calliphoridae (10); Carnidae (2); Chyromyidae (2); Conopidae (58); Drosophilidae (37); Ephydriidae (28); Fanniidae (6); Heleomyzidae (14); Lauxaniidae (11); Lonchopteridae (2); Micropezidae (3); Milichiidae (2); Muscidae (135); Mydidae (1); Mythicomyiidae (10); Nemestrinidae (10); Nycteribiidae (11); Opomyzidae (1); Phoridae (8); Piophilidae (1); Pipunculidae (6); Platystomatidae (17); Psilidae (4); Pyrgotidae (1); Rhagionidae (8); Rhinophoridae (8); Scathophagidae (4); Sciomyzidae (36); Sepsidae (18); Sphaeroceridae

(21); Strebiidae (1); Tethinidae (5); Therevidae (33); Trixoscelididae (5); Ulidiidae (30); Xylomyiidae (4) (Kocak, 2014). The 2886 species and subspecies in total belong to sixty-five families.

Diptera-Nematocera: Bibionidae (7); Bolitophilidae (1); Keroplatidae (6); Mycetophilidae (38); Sciaridae (9); Blephariceridae (11); Ceratopogonidae (55); Chaoboridae (2); Culicidae (49); Trichoceridae (2) (Kocak, 2014); Hesperinidae (1) (Ozgül, 2015); Cecidomyiidae (118) (Kocak, 2014, Skuhřavá and Skuhřavý, 2016); Chironomidae (131) (Kocak, 2014, Cetinkaya and Bekleyen, 2017); Simuliidae (59) (Caglar and Ipekdal, 2009, Kocak, 2014, Basoren and Kazanci, 2016); Dixidae (4) (Koc et al., 2006); Psychodidae (63) (Wagner et al., 2013, Kocak, 2014); Ptychopteridae (2) (Zwick, 1988); Cylindrotomidae (2) (Kocak, 2014, Ozgöl, 2015); Limoniidae (118) (Kocak, 2014, Ozgul and Koc, 2014); Pediciidae (17) (Kocak, 2014, Ozgul and Koc, 2016); Tipulidae (161) (Kocak, 2014, Koc et al., 2015). The 856 species and subspecies in total belong to twenty-one families.

A summary of the insect fauna of Turkey is presented in Table 1.

Table 1. Taxonomic distribution of the insect fauna of Turkey.

Orders and suborders	Families	Species and subspecies	Percentage of total (%)
Microcoryphia	1	6	0.02
Zygentoma	4	11	0.03
Ephemeroptera	14	157	0.46
Odonata-Anisoptera	5	100	0.48
Odonata-Zygoptera	5	62	
Orthoptera-Caelifera	5	287	2.17
Orthoptera-Ensifera	7	447	
Phasmatodea	2	5	0.01
Dermaptera	4	20	0.06
Plecoptera	7	117	0.35
Embioptera	1	1	0.01
Dictyoptera-Isoptera	3	3	0.13
Dictyoptera-Mantodea	4	25	
Dictyoptera-Blattodea	3	15	
Hemiptera-Auchenorrhyncha	18	805	10.13
Hemiptera-Heteroptera	39	1536	
Hemiptera-Sternorrhyncha	26	1083	
Thysanoptera-Terebrantia	3	140	0.57
Thysanoptera-Tubulifera	1	54	
Psocoptera-Psocomorpha	8	17	0.07
Psocoptera-Troctomorpha	2	6	
Psocoptera-Trogiomorpha	2	2	

Phthiraptera-Amblycera	4	61	0.48
Phthiraptera-Anoplura	6	20	
Phthiraptera-Ischnocera	2	82	
Coleoptera-Adephaga	7	1283	35.22
Coleoptera-Myxophaga	1	1	
Coleoptera-Polyphaga	110	10626	
Neuroptera	11	209	0.62
Raphidioptera	2	40	0.12
Megaloptera	1	2	0.01
Hymenoptera-Apocrita	49	6396	19.64
Hymenoptera-Symphyla	11	245	
Trichoptera-Annulipalpia	5	155	1.46
Trichoptera-Integripalpia	12	223	
Trichoptera-Spicipalpia	4	114	
Lepidoptera	76	5580	16.50
Mecoptera	1	13	0.03
Siphonaptera	7	121	0.36
Strepsiptera	3	8	0.02
Diptera-Brachycera	65	2886	11.06
Diptera-Nematocera	21	856	
Total	562	33820	100.00

Table 1 shows that the total number of species and subspecies of insects recorded in Turkey to the end of 2019 was 33820. Amongst them, five orders were dominant, i.e., they included > 5% of all reported species and subspecies. In decreasing order of species and subspecies richness, they were as follows: Coleoptera (35.22%), Hymenoptera (19.64%), Lepidoptera (16.50%), Diptera (11.06%) and Hemiptera (10.13%). Another order, Orthoptera (2.17%), was subdominant. The abundance of each of the remaining orders was < 2%.

2. Chorotype analysis and endemism of insect fauna of Turkey

In earlier studies of the insect fauna of Turkey, some species records were given as checklists and some of the species' world wide distributions were provided. In a few studies, the zoogeographical distributions of some insect taxa were reported (Carpaneto et al., 2000, Ertorun et al., 2011, Akyildirim et al., 2013, Canbulat, 2015, Darilmaz et al., 2016, Skuhřav and Skuhřavy, 2016, Verves et al., 2018). In addition, in some publications, the status of some groups of insects such as Odonata (Packer et al., 2009), Lepidoptera (Karaçetin and Welch, 2011), saproxylic beetles (Avgin et al., 2014) and saproxylic Cerambycidae (Ozdikmen, 2016) were evaluated by using the IUCN criteria for the assessment of their protection and conservation status. These reports on the zoogeographical distributions of insect taxa were based on a proposal for a chorotype classification (Vigna Taglianti et al., 1999). In some of the publications, species and subspecies were described as "Endemic to Turkey", "Anatolian endemic" or "Turkey endemic", without chorotype analysis (Saribiyik, 2014, Avgin et al., 2015, Darilmaz and Salur, 2015, Koc et al., 2015, Salur et al., 2016, Tonguc et al., 2016, Tasar, 2018a). In the present study, chorotype analyses showed that

Mediterranean, European and Asiatic chorotypes were particularly prominent in different insect groups. Besides the cosmopolitan and subcosmopolitan species, endemic species and subspecies are also very common in Turkey and therefore important in the context of local, regional and global biodiversity. The proportion of endemic species and subspecies varies widely, according to the group of insects. However, there is no information about some insect groups such as Phthiraptera and Siphonaptera (Inci et al., 2010b, Dik et al., 2011a, Dik et al., 2011c, Dik et al., 2013, Dik et al., 2017, Keskin et al., 2018).

The proportions of endemic species and subspecies of the known orders and suborders, and families in the major orders, follow the taxa in parentheses (%):

Ephemeroptera (15.29%) (Salur et al., 2016); **Odonata**, Gomphidae (5.00%); Libellulidae (4.00%); Calopterygidae (30.00%); Coenagrionidae (2.78%) (Kalkman, 2006); **Orthoptera**, Caelifera (37.45%) (Ciplak and Demirsoy, 1996); Ensifera (57.26%) (Mol et al., 2016); Tettigoniidae (83.13%) (Ciplak, 2003); **Dermoptera** (5.00%) (Anlas and Koçarek, 2012); **Plecoptera** (37.61%) (Darilmaz et al., 2016); **Dictyoptera**, Mantidae (13.33%); Eremiaphilidae (25.00%); Blattellidae (11.11%); Empusidae (25.00%) (Caesar et al., 2015); **Hemiptera**, **Heteroptera** (8.30%) (Dursun and Fent, 2017); **Auchenorrhyncha**, Achilidae (25.00%); Cercopidae (50.00%); Cicadidae (31.25%); Calicelidae (33.33%); Cixiidae (15.22%); Delphacidae (2.44%); Derbidae (50.00%); Dictyopharidae (21.43%); Tettigometridae (5.26%) (Onder et al., 2011); Cicadellidae (8.33%) (Onder et al., 2011, Demir, 2016); Issidae (46.30%) (Demir, 2007, Onder et al., 2011, Demir, 2017); **Sternorrhyncha**, Aphididae (2.40%) (Akyildirim et al., 2013); Coccidae (11.11%); Diaspididae (2.75%); Eriococcidae (17.24%); Kermesidae (44.44%); Pseudococcidae (5.06%); Psyllidae (12.50%); Triozidae (11.11%) (Onder et al., 2011); **Psocoptera** (4.00%) (Lienhard, 2016); **Coleoptera**, **Adephaga**, Carabidae (41.00%) (Casale and Vigna Taglianti, 1999); **Polyphaga**, Cerambycidae (40.00%) (Ozdikmen, 2012); Chrysomelidae (10.44%) (Ekiz et al., 2013); Cleridae (10.39%) (Lodos, 1998); Nitidulidae (8.60%) (Avgin et al., 2015); Alleculidae (37.50%) (Lodos, 1998); Mordellidae (8.89%) (Lodos, 1998); Tenebrionidae (38.77%) (Keskin, 2008); Buprestidae (23.58%) (Lodos and Tezcan, 1992); Elmidae (20.69%) (Tasar, 2018a); Cantharidae (53.88%) (Lodos, 1998); Elateridae (42.77%) (Tarnawski et al., 2018); Scarabaeoidea (37.40%) (Carpaneto et al., 2000); Hydrophilidae (3.70%) (Darilmaz and Incekara, 2011); Hydraenidae (49.05%) (Ertorun et al., 2011); Staphylinidae (32.82%) (Anlas, 2009); **Raphidioptera** (47.50%) (Canbulat, 2015); **Hymenoptera** Apidae, Xylocopinae (15.38%); Ichneumonidae (5.70%) (Kocak and Kemal, 2015); Crabronidae (9.31%); Sphecidae (8.00%); Chrysididae (14.08%); Mutillidae (6.85%); Pompilidae (9.00%); Sapygidae (20.00%); Tiphidae (30.00%); Vespidae (22.26%) (Yildirim, 2016); Argidae (3.13%) (Calmasur and Ozbek, 2006); **Trichoptera** (41.38%) (Darilmaz and Salur, 2015); **Lepidoptera** (5.54%) (Kocak and Kemal, 2018); **Mecoptera** (84.62%) (Penny and Byers, 1979); **Diptera**, Canacidae (16.67%) (Munari, 2011); Chamaemyiidae (5.00%) (Ebejer and Barták, 2019); Chloropidae (3.51%) (Kubík and Barták, 2017); Dolichopodidae (6.77%) (Tonguc et al., 2016); Empididae (4.85%) (Barták and Shamshev, 2018); Sarcophagidae (4.58%) (Verves et al., 2018); Stratiomyidae (1.41%) (Demirözer et al., 2017); Syrphidae (8.00%) (Saribiyik, 2014); Psychodidae (12.70%) (Wagner et al., 2013); Limoniidae (3.39%) (Ozgul and Koc, 2014); Tipulidae (18.75%) (Koc et al., 2015).

The number of endemic species in 2008 was reported as 2535, which constituted 11.14% of the total (Tezcan, 2008). The current study reports that 11 years later the number of known endemic species has reached 3785. That meant that the number of endemic species and subspecies had risen by a remarkable 49.3% but the proportion was almost unchanged at 11.20%. Moreover, it is extremely likely that future studies will add many new species and subspecies to the current list.

Overall, the complete data set of the current study shows relatively high endemism levels in the orders Orthoptera, Plecoptera, Raphidioptera, Trichoptera and Mecoptera. Prominent in Odonata is the Calopterygidae; in Orthoptera, the Tettigoniidae; in Hemiptera, the Cercopidae, Derbidae, Issidae and Kermesidae; and in Coleoptera, the Carabidae, Cerambycidae, Cantharidae and Hydraenidae, are prominent.

3. Invasive alien insect species of Turkey

Invasive alien species are any species that are not native to an area but which are able to establish themselves and often spread quickly, causing environmental and/or economic

damage (Invasivesnet, 2019). Some of these species have entered Turkey and naturalised in local areas or over very large areas. Their destructive pressure on ecosystems and insect fauna is a cause for major concern in Turkey, as in other countries. Some examples of these species are listed below with their entry dates into the insect fauna list for Turkey:

Viteus vitifoliae (Fitch, 1855) (Hemiptera: Phylloxeridae), the grape phylloxera, in 1881 (Bodenheimer, 1958); *Leptinotarsa decemlineata* (Say, 1824) (Coleoptera: Chrysomelidae), the Colorado potato beetle, in 1963; *Hyphantria cunea* (Drury, 1773) (Lepidoptera: Erebididae), the fall webworm, in 1975; *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera: Gracillariidae), the citrus leafminer, in 1994; *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae), the oak lace bug, in 2003; *Rhynchophorus ferrugineus* (Oliver, 1790) (Coleoptera: Dryophthoridae), the red palm weevil, in 2005; *Corythucha ciliata* (Say, 1832) (Hemiptera: Tingidae), the sycamore lace bug, in 2007; *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae), the tomato leafminer, in 2009; *Leptoglossus occidentalis* (Heidemann, 1910) (Hemiptera: Coreidae), the western conifer seed bug, in 2009; *Cydalima perspectalis* (Walker, 1859) (Lepidoptera: Crambidae), the box tree moth, in 2011; *Anoplophora chinensis* (Forster, 1771) (Coleoptera: Cerambycidae), the citrus longhorned beetle, in 2014 (Oztemiz and Doğanlar, 2015, Uzun and Tezcan, 2017) and *Drosophila sukukii* (Matsumura, 1931) (Diptera: Drosophilidae), the spotted wing drosophila, in 2014 (Orhan et al., 2016). Recently, 41 alien aphid species were listed as present in Turkey (Akyildirim et al., 2013).

These species naturalise in various local ecosystems, especially in agricultural and forest areas, after invading via various means that include transport, trade, travel and tourism. The invasion of ecosystems in Turkey by alien species will continue into the future and the necessary precautions should be taken to reduce the number of species that invade and become established, and minimize the harm they cause.

Global climate change is likely to increase the number and speed of invasions, e.g., *Aedes aegypti* (Linnaeus, 1762), the yellow fever mosquito, and *A. albopictus* (Skuse, 1894), the Asian tiger mosquito, (Diptera: Culicidae) the vector of dengue fever and other diseases, are rapidly expanding their range both in Europe and in Turkey (Akiner et al., 2018).

Suggestions

In the context of the current global biodiversity crisis, a biodiversity crisis is entrained in Turkey which is located in a particularly diverse biogeographic region of the world (Sekercioglu et al., 2011). It is inevitable that this crisis will continue to affect insects, as well as other organisms. Climate change; deforestation; habitat loss; depletion of pastures through overgrazing, loss of arable land due to salination, nutrient depletion, loss of soil carbon and erosion; urbanisation, population growth and pollution, will continue to destroy the insect biodiversity of Turkey, as well as in other countries. Although the drastic consequences of human activity on organisms such as mammals and birds can be easily observed, it is not as easy to estimate the losses small animals such as insects and the effects that will have on global ecosystems (Potts et al., 2010, Hallmann et al., 2017, Sánchez-Bayo and Wyckhuys, 2019).

Although the history of entomological studies in Turkey goes back 180 years, many studies, especially since the 1970s, have highlighted the diversity of its insect fauna, which has a substantial endemic component. However, there are essential institutional and social changes that need to be implemented and studies that need to be done to address research and public policy deficiencies.

The required actions include:

- Increase the level of biodiversity related entomological research;
- Most of the studies on insects of Turkey have been undertaken in the western and southern regions of Turkey. Future studies should focus on research in less frequently studied regions/areas that include South-eastern Anatolia, Eastern Anatolia and the Black Sea Region;
- Identification of unstudied material from different insect groups that is preserved in collections / museums;
- Faster publication of the results of entomological research projects and theses;
- Some species may be overlooked when collecting insects which is usually done in the spring/summer period, and surveys are not being done systematically. Studies should be

conducted methodically in order to identify rare, vulnerable and endangered species, and the continuity of these studies is essential;

- Resolving the identity of doubtful species;
- Regular updating of existing information, taking into account the changes in nomenclature and synonyms;
- The lack of faunal checklists for many insect groups is an important gap. The establishment of checklists and their frequent updating is important;
- The compilation of a national insect database for Turkey to which new species records can be uploaded should be a high priority;
- Increased funding and training/mentoring in taxonomics/systematics, field ecology and ethology for young persons who may want to engage in biodiversity studies; most currently funded projects are in applied research e.g. crop and forest pests and their management;
- Educate the community on the importance of insects to society;
- Develop partnerships between government, private sector and community groups to help prevent or at least substantially reduce the current rate of loss of biodiversity in all environments, including urban areas, agricultural fields, forests and national parks;
- Comprehensive public education programs to enlist more support for the recognition of the cultural and economic value of many insects and their conservation, including that of their habitat;
- Inclusion of non-governmental organizations (NGOs) and public participation in insect studies to raise the profile of insect biodiversity and conservation in the general community;
- Increase the use of molecular methods (Rokas et al., 2003, Doğanlar et al., 2009, Papadopoulou et al., 2009, Budak et al., 2011, Hernando et al., 2012, Sevgili and Simsek, 2012) to complement the use of morphological methods in taxonomic studies;
- Carry out studies on the protection and monitoring of insects in cooperation with national and international organizations such as the Ministry of Environment and Urbanisation (MoEU), Nature Conservation Centre (DKM), Butterfly Conservation Europe (BCE) and the International Union for Conservation of Nature (IUCN).

The urgent implementation of this list of measures would substantially increase the knowledge of the insects of Turkey, considerably raise their public profile and greatly assist in their protection and that of their habitat. It is also important for scientists and the community to advocate for the preservation of their habitats. Every year dozens of new insect species are described in Turkey and there are first record notifications for many more species, especially from the Mediterranean, Irano-Anatolian and Caucasus biodiversity hotspots. As in most countries across the world, if not all of them, Turkey is highly likely to be losing species before they can be described and protected and that is a tragedy for Turkey and the world that must be confronted and addressed.

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