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Alien True Bugs of Europe (Insecta: Hemiptera: Heteroptera)

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Abstract

This paper reviews the alien (non-native, non-indigenous, exotic) true bug (Heteroptera) species in Europe. Forty-two established alien Heteroptera are recognized, of which 12 species are alien to Europe (originating outside Europe: eight from North America, three from the Eastern Palaearctic, one from New Zealand), 24 species are alien within Europe (translocated within Europe), and six cryptogenic species are of unknown origin. Since 1990 an approximate arrival rate of 7 species per decade has been observed. A recent trend of increased introductions from North America to Europe is suggested. The most important pathway of alien Heteroptera is translocation as contaminants (49 %), usually with ornamental plants, followed by unintentional introduction through natural dispersal (unaided) across political borders within Europe (28 %), and translocation as stowaways within a transport vector (21 %). The taxonomic composition of the alien Heteroptera of Europe is dominated by Miridae (17 species, 40 %), Tingidae (8 species, 19 %), and Anthocoridae (5 species, 12 %), all of which are overrepresented compared to the native European Heteroptera fauna. More than half of the species are phytophagous (24 species, 57 %) and the advantage of trophic specialization in invasion success is discussed. Most species are currently known to occur in the Czech Republic (19 species) and Germany (17 species), followed by Western European countries (Belgium 15 sp., France and United Kingdom 14 sp. each, and Netherlands 13 sp.), resulting in an apparent (north)west–(south)east gradient probably reflecting horticultural tradition in Europe. No unambiguous

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evidence exists so far for negative ecological or economical impacts, but more research is needed to investigate possible effects. Introductions of alien Heteroptera to and within Europe will increase, and deserve further consideration.

Key words: non-native, non-indigenous, exotic, Hemiptera, pathway, impact

Introduction

"It is unlikely to become established." (Southwood & Leston 1959: 53 on *Nezara viridula* in Great Britain)

Heteroptera, or true bugs, is the most diverse group of paurometabolous insects with incomplete metamorphosis. There are about 40,000 described species worldwide and many more await description (Schuh & Slater 1995). The recent Catalogue of the Heteroptera of the Palaearctic Region lists approximately 3000 species for Europe (Aukema & Rieger 1995–2006). Heteroptera have sucking mouthparts and feed–depending on the species–as parasites, predators, or herbivores on different food sources, from blood or haemolymph to plant sap or the cytoplasma of fungi. Heteroptera –unique among insects– colonize almost the entire planet, including the surface of the ocean and Antarctica (Schuh & Slater 1995).

Investigations on the translocation of species beyond natural boundaries has gained increasing attention as the number of such alien species has increased during the past decades, particularly in insects (e.g., Nentwig 2007; Roques *et al.* 2008). Within the European Union-funded Framework Programme 6 Specific Targeted Research Project DAISIE (Delivering Alien Invasive Species Inventories for Europe (2005–2007), an inventory of the alien (non-native, non-indigenous, exotic) species of Europe was completed and made available via the Internet (www.europe-aliens.org). However, the presence or absence of particular species in this list is not self-explanatory. The aim of the present paper, therefore, is to discuss the database entries, including short accounts of invasion histories and original references for the alien Heteroptera species of Europe. Every database is or should be a living document, and it is hoped that it will be possible to keep track of changes at regular intervals.

Material and methods

Species are considered alien *to* Europe if they originate from outside Europe and alien *in* Europe if they originate from within Europe, but were translocated elsewhere within Europe. Unambiguous evidence or at least reasonable assumptions must exist that the species was transported beyond the boundaries of its natural range by human activities. Consequently, European species considered to have spread as a consequence of favourable climatic conditions or migratory species are excluded. For the Heteroptera of Austria, it was recently shown that this set makes up a considerable part of the newly arrived species (Rabitsch 2008). However, for some species, it is not easy to separate the driving forces behind range expansions, and combinations of several factors probably count for most of the range expansions.

The following list of species is structured into four Categories:

Category 1: Species, that are alien to Europe (1a); of unknown origin, but probably not native (cryptogenic) (1b); and alien in Europe, i.e., translocated within Europe (1c).

Category 2: European continental species that are introduced to European islands.

Category 3: Alien species that are present only in greenhouses.

Category 4: Excluded species (Archaeozoa, Not established species).

Archaeozoa: these are animal species introduced by human activity to Europe before 1492; Not established species: these are species not (yet) able to maintain self-sustaining populations.

The political and biogeographic delimitations of Europe are inherently inconsistently used in the literature (e.g., Fauna Europaea, Catalogue of the Palaearctic Heteroptera). In this paper, Asia Minor and the European part of Russia are excluded, whereas Eastern Thrace (European Turkey) and Macaronesia are included.

Lists of Heteroptera alien to European countries have been published before. Southwood & Leston (1959) listed several species "foreign" to the United Kingdom, but included rare and migratory species. With the growing interest in invasion ecology in recent years, more lists were produced, e.g., Austria (Essl & Rabitsch 2002), Czech Republic (Šefrová & Laštùvka 2005; Kment 2006b), Germany (Geiter & Kinzelbach 2002, but see Hoffmann 2003b for a critical discussion; Hoffmann & Melber 2003), Switzerland (Kenis 2005), United Kingdom (Hill *et al.* 2005).

The following list was developed from a thorough literature survey up to December 2007 with a few later additions, and was verified by experts (see acknowledgements); it also includes a few unpublished data from private or institutional collections. Biological attribute data (origin, food plants, hibernation, voltinism, body size) were taken from the literature. Terminology of pathways and impact follows Hulme *et al.* (2008) and Parker *et al.* (1999), respectively. Habitat classification is based on EUNIS-level 2 typology (http://eunis.eea.eu.int/habitats.jsp). Reports of alien Heteroptera records to the author are much appreciated and will contribute to provide detailed distribution maps of the alien Heteroptera of Europe in the future.

Results and discussion

1) Comments on the alien Heteroptera species of Europe

The following comments are listed alphabetically by family within the four Categories. Table 1 lists the established species of Category 1 with the chronological year of first record for each country (if known). Biological and invasion ecology attribute data for these species are given in Table 2.

Category 1a—Species alien to Europe

COREIDAE

Leptoglossus occidentalis HEIDEMANN, 1910

The native range of this species presumably is west of the Rocky Mountains in North America, from British Columbia to Mexico. Since the 1950s the species spread eastward and reached the eastcoast in the 1990s (e.g., McPherson *et al.* 1990). The first European records date from 1999 near Vicenza (northern Italy, Bernardinelli & Zandigiacomo 2001b; Taylor *et al.* 2001; Tescari 2001; Villa *et al.* 2001). The species spread in Italy (e.g., Tescari 2003; Olivieri 2004) and was subsequently recorded 2002 in Switzerland (Tessin, Colombi & Brunetti 2002; north of the Alps since 2007, Wyniger 2007), 2003 in Slovenia and Spain (Gogala 2003; Jurc & Jurc 2004; Ribes *et al.* 2004; Ribes & Escolá 2005), 2004 in Croatia (Tescari 2004) and Hungary (Harmat *et al.* 2006), 2005 in Austria (Rabitsch & Heiss 2005), 2006 in France (Moulet 2006; Chapin & Chauvel 2007; Dusoulier *et al.* 2007), Germany (Werner 2006; Pérez Vera & Hoffmann 2007) and the Czech Republic (Beránek 2007; Kment *et al.* 2008) and 2007 in the United Kingdom (Nau in litt.; Malumphy & Reid 2007), in Belgium (Aukema & Libeer 2007), the Slovak Republic (Majzlan & Roháčová 2007), and Poland (Lis *et al.* 2008). In most countries rapid spread within the country and increasing abundances were observed.

The species is capable of flying long distances, but also can be translocated as egg, nymph, or adult with its host plant (conifers). From the first record in northern Italy there seems to be natural spread to Switzerland, Slovenia, and Croatia and nearby countries, but the isolated records in Germany (Berlin) and the United Kingdom (Weymouth, Dorset) point to repeated introduction or secondary translocation within Europe from the south to the north.

Leptoglossus occidentalis overwinters as adult in crevices or similar places under bark or other structures. It may enter buildings in large numbers in autumn and so become a nuisance to people (Wheeler 1992). It feeds on the young seeds or flowers of conifer species, with a preference for Pinaceae (*Pinus* sp., *Pseudotsuga menziesii*); but it has also been observed on *Picea*, *Cedrus*, *Abies* and *Juniperus* (Villa *et al.* 2001). Feeding causes reduction of seed fertility, but no economic impact is known so far in Europe, whereas the species is regarded as pest in its native range (Mitchell 2000). The species has conquered a large part of Europe within just a decade and because of the high reproductive and dispersal capabilities the further spread and establishment of the species in Europe is highly likely.

CORIXIDAE

Trichocorixa verticalis verticalis (FIEBER, 1851)

A Nearctic water boatman, first recorded for Europe in January 2004 in southern Spain (Günther 2004) and subsequently recorded in Doñana National Park (Millán *et al.* 2005). However, based on material collected between 1997 and 2003, it apparently was introduced before to the Algarve in Portugal (Sala & Boix 2005). The native range of this subspecies streches along the east coast of North America from Canada to Mexico and the West Indies (Polhemus *et al.* 1988). The species prefers stagnant and slow lentic waters. It was introduced with the mosquito fish *Gambusia affinis* to New Caledonia and South Africa and this pathway is suggested for the European populations as well. Millán *et al.* (2005) hypothesized that it may lead to a simplification of the macroinvertebrtae community in the saline habitats in Doñana National Park. For references and a detailed discussion of its life history see Kelts (1979) and Kment (2006a).

LYGAEIDAE

Nysius huttoni F.B. WHITE, 1878

A New Zealand endemic species unintentionally introduced to Europe probably with shipments via Antwerp (Aukema *et al.* 2005a). First recorded 2002 in the Netherlands and 2003 in Belgium (Aukema *et al.* 2005b) and subsequently found at the French/Belgian border (Aukema *et al.* 2007). It is a polyphytophagous species feeding on different weeds and crops and attaining pest status in its native area. In Europe it was found at dry and warm sites, waste grounds, roadsides, and abandoned fields; and it is expected that this species will spread further across Europe. Smit *et al.* (2007) surveyed the distribution and population characteristics in the Netherlands. *Nysius* species are well known for their high abundances and effective dispersal strategies (e.g., Carillo 1967). *Nysius huttoni* currently is included in the EPPO Alert List. A summary of its biology, damage, and control was given by Sweet (2000).

MIRIDAE

Tupiocoris (Neodicyphus) rhododendri (DOLLING, 1972)

Described from specimens collected 1971 in Kew Gardens, London, and surroundings in the United Kingdom (Dolling 1972); but the origin of the species is North America, where it is distributed along the east coast (Wheeler & Henry 1992). From the United Kingdom it conquered the continent and was found in 2002 in the Netherlands (Aukema *et al.* 2005a), 2004 in Germany (Schrameyer 2004), and 2007 in Belgium (Aukema *et al.* 2007); and its further spread is to be expected. It preys on aphids and lives on ornamental *Rhododendron*.

TABLE 1: List of established alien Heteroptera of Europe. Categories: 1a: alien to Europe, 1b: cryptogenic, 1c: alien in Europe; Asterisks indicate doubts on establishment in this country. ? = occurrence doubtful. ?N = alien status doubtful (species could be native).

Taxon	Category	Origin	Country (Year of first record, Reference)
Anthocoridae			
Amphiareus obscuriceps (Poppius, 1909)	1c?	Eastern Palaearctic	Bulgaria (1987, Péricart & Stehlík 1998); Hungary (1989, Aukema 1990a); Belarus (1992, Rosenzweig 1995); Czech Republic (1994, Jindra & Kabiček 2001); Italy (1995, Bacchi & Rizzotti-Vlach 2000); Austria (1998, Frieß 2000); Slovakia (2000, Kment et al. 2003); Germany (2001, Simon 2002); Finland (2003, Albrecht et al. 2003); Netherlands (2003, Aukema et al. 2005a); Estonia (2004, Selin 2004); Belgium (2007, Aukema et al. 2007).
Anthocoris butleri Le Quesne, 1954	1c	South-Western Europe	Germany **?N** (<1957, Wagner 1957); Czech Republic (1962, Stehlík 1962); Sweden – Gotland (<1967, Ossiannilsson 1967); Netherlands (1969, Cobben & Arnoud 1969); Austria (1974, Heiss 1977); Belgium (1984, Viskens & Bruers in litt.); Ireland (1986, Judd 1986); Luxembourg (<1994, Reichling & Gerend 1994); Switzerland **?N** (2000, Wyniger & Burckhardt 2003); Slovakia (2003; Kment et al. 2005).
Anthocoris sarothamni Douglas & Scott, 1865	1c	South-Western Europe	*Austria (1921, Rabitsch 2004a); Czech Republic (1953, Roubal 1953).
Buchananiella continua (White, 1880)	1b	Pan-tropical – Cryptogenic	Madeira – orig. descript. (1880, White 1880); Italy, France, Portugal (incl. Azores), Spain (incl. Canary Islands), United Kingdom (Péricart & Golub 1996).
Lyctocoris campestris (Fabricius, 1794)	1b	West Palaearctic – Cryptogenic	Albania, Austria, Belgium, Belarus, Bosnia, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Macedonia, Germany, Greece, Hungary, Ireland, Italy (incl. Sardinia, Sicily), Latvia, Lithuania, Luxemburg, Malta, Moldova, Montenegro, Netherlands, Norway, Poland, Portugal (incl. Azores, Madeira), Serbia, Slovakia, Slovenia, Spain (incl. Canary Is.), Sweden, Switzerland, Ukraine, United Kingdom (Péricart & Golub 1996).
Coreidae			
Leptoglossus occidentalis Heidemann, 1910	1a	North America	Italy (1999, Bernardinelli & Zandigiacomo 2001a); Switzerland (2002, Colombi & Brunetti 2002); Slovenia (2003, Gogala 2003); Spain (2003, Ribes et al. 2004); Croatia (2004, Tescari 2004); Hungary (2004, Harmat et al. 2006); Austria (2005, Rabitsch & Heiss 2005); Czech Republic (2006, Beránek 2007, Kment et al. 2008); France (2006, Moulet 2006); Germany (2006, Werner 2006); Serbia (2006, Protić, in litt.); *Belgium (2007, Aukema & Libeer 2007); Poland (2007, Lis et al. 2008); Slovak Republic (2007, Majzlan & Roháčová 2007); *United Kingdom (2007, Malumphy & Reid 2007).
Corixidae			
Trichocorixa verticalis (Fieber, 1851)	1a	North America	Portugal (1997-2003, Sala & Boix 2005); Spain (2004, Günther 2004).
Lygaeidae			
Arocatus longiceps Stål, 1872	1c	Mediterranean	Slovenia **?N** (1983, Gogala & Gogala 1986); Hungary (1990, Kondorosy 1997); Austria (1995, Adlbauer & Frieß 1996); Germany (1995, Rieger 1997); Switzerland (1997, Rietschel 1998); Czech Republic (1998, Stehlík & Hradil 2000); Slovakia (2000, Kment & Bryja 2001); France **?N** (Aukema in litt.); Belgium (2007, Aukema in litt.); Netherlands (2008, Aukema in litt.).
Nysius huttoni F.B.White, 1878	1a	New Zealand	Netherlands and Belgium (2002, Aukema et al. 2005b); France (2005, Aukema et al. 2007.).

...continued

Table 1 continued...

Taxon	Category	Origin	Country (Year of first record, Reference)
Orsillus depressus (Mulsant & Rey, 1852)	1c	Mediterranean	Hungary **?N** (1900, Horváth 1900); Austria **?N** (1948, Rabitsch unpubl., Adlbauer & Rabitsch 2000); Germany (1971, Voigt 1977); *Finland (1978, Lammes 1981); Luxembourg (1983, Reichling 1985); Belgium and Netherlands (1986, Aukema 1988); United Kingdom (1987, Hawkins 1989); Slovakia (1989, Stehlík & Vavrínová 1996); Czech Republic (1993, Hradil et al. 2002).
Oxycarenus lavaterae (Fabricius, 1787)	1c	Western Mediterranean	Montenegro (1985, Velimirovic et al. 1992); Hungary (1994, Kondorosy 1995); Slovakia (1995, Bianchi & Stehlík 1999); Serbia (1996, Protić & Stojanović 2001); Bulgaria (1998, Kalushkov 2000); Northern France (1999, Denosmaison 2001); Austria (2001, Rabitsch & Adlbauer 2001); Northern Switzerland (2002, Wermelinger et al. 2005); *Finland (2003, Rinne in litt.); Czech Republic (2004, Kment et al. 2006); Germany (2004, Billen 2004).
Miridae			
Closterotomus trivialis (A. Costa, 1853)	1c	Mediterranean	Netherlands (1998, Aukema 1999).
Deraeocoris flavilinea (A. Costa, 1862)	1c?	Mediterranean	France – Corsica (1961, Péricart 1965); France – Alsace (1984, Ehanno 1989); Germany (1985, Günther 2002); Netherlands (1985, Aukema 1989); Switzerland (1987, Göllner-Scheiding 1991); Luxembourg (1992, Reichling 1994); Malta (<1993, Schembri 1993); Belgium (1994, Chérot 1998, Aukema et al. 2002); United Kingdom (1996, Miller 2001); Slovenia (1997, Gogala 2006); Albania (<1999, Aukema & Rieger 2001); Austria (2002, Rabitsch 2002b); Czech Republic (2003, Kment et al. 2005); Sweden (<2005, Gillerfors & Coulianos 2005).
Dichrooscytus gustavi Josifov, 1981	1c?	European (Cryptogenic)	Germany – orig. descript. (1934, Josifov 1981); Belgium (1943, Aukema et al. 2002); Luxembourg (1983, Reichling 1985, in litt.); France (<1987, Ehanno 1987); Hungary (<1987, Bakonyi & Vásárhelyi 1987); United Kingdom (<1988, Dolling 1988, Whitehead 1989); Netherlands (1990, Aukema 1990b); Slovakia (1991, Günther 2000); Czech Republic (2000, Bryja & Kment 2002); Austria (2002, Rabitsch 2004b); Finland (2003, Albrecht et al. 2006); ?Italy (Kerzhner & Josifov 1999).
Dicyphus escalerae Lindberg, 1934	1c	Western Mediterranean	Germany (1994, Simon 1995); Switzerland (2004, Hollier & Matocq 2004).
Macrolophus glaucescens Fieber, 1858	1c	Mediterranean	Czech Republic (<1858, Fieber 1858, Šefrová & Laštùvka 2005, Kment 2006b).
Nesidiocoris tenuis (Reuter, 1895)	1b	Pan-tropical – Cryptogenic	Cyprus, France, Greece (incl. Crete), Italy, Malta, Madeira, Spain (incl. Canary Islands) (Kerzhner & Josifov 1999).
Orthotylus adenocarpi (Perris, 1857)	1c	Western Mediterranean	Czech Republic **?N** (Kment 2006b).
Orthotylus caprai Wagner, 1955	1c	Mediterranean	United Kingdom (2006, Nau 2007); Germany (2007, Simon 2007).
Orthotylus concolor (Kirschbaum, 1856)	1c	Western Mediterranean	Czech Republic **?N** (<1892, Spitzner 1892, Kment 2006b).
Orthotylus virescens (Douglas & Scott, 1865)	1c	Western Mediterranean	Czech Republic **?N** (<1957, Roubal 1957, Stehlík 1971); Hungary (2003, Kondorosy 2005).
Taylorilygus apicalis (Fieber, 1861)	1b	Pan-tropical – Cryptogenic	Albania, Bosnia, Bulgaria, Croatia, Cyprus, France (incl. Corsica), Greece, Italy (incl. Sardinia, Sicily), Malta, Portugal (incl. Azores, Madeira), Slovenia, Spain (incl. Canary Islands), Ukraine (Kerzhner & Josifov 1999).

continued...

Table 1 continued...

Taxon	**Category**	**Origin**	**Country (Year of first record, Reference)**
Tupiocoris rhododendri (Dolling, 1972)	1a	North America	United Kingdom – orig. descript. (1971, Dolling 1972); Netherlands (2002, Aukema et al. 2005a); Germany (2004, Schrameyer 2004); Belgium (2007, Aukema et al. 2007).
Tuponia brevirostris Reuter, 1883	1c	Western Mediterranean	United Kingdom (2001, Barclay & Nau 2003); Croatia (2007, Simon 2007); Germany (2007, Simon 2007).
Tuponia elegans (Jakovlev, 1867)	1c	Central Asia	Hungary (1964, Benedek & Jaszai 1968); Czech Republic (1971, Bryja & Kment 2002); Slovakia (<1982, Hradil et al. in prep., Kment 2004a); Austria (2002, Rabitsch 2002a).
Tuponia hippophaes (Fieber, 1861)	1c	Mediterranean	Slovakia (<1982, Hradil et al. in prep., Kment 2004a); Czech Republic (2001, Bryja & Kment 2002); Belgium (2003, Baugnée & Chérot 2004).
Tuponia macedonica Wagner, 1957	1c	Eastern Mediterranean	Slovakia (2003, Hradil et al. in prep.).
Tuponia mixticolor (A. Costa, 1862)	1c	Mediterranean-Central Asia	United Kingdom (1979, Nau 1980); Slovenia **?N** (2000, Gogala 2006); Germany (2007, Simon 2007).
Pentatomidae			
Halyomorpha halys (Stål, 1855)	1a	East Asia	Switzerland (2007, Wermelinger et al. 2008).
Nezara viridula (Linnaeus, 1758)	1c	Ethiopian	*Belgium (1950, Schmitz 1988, Chérot in litt.); *Finland (1956, Kontkanen 1956); Bulgaria **?N** (1959, Simov in litt.); *Austria (1962, Dethier 1989); Germany (1979, Hoffmann 1992); Hungary (2003, Redei & Torma 2003); United Kingdom (2003, Barclay 2004); northern Switzerland (2005, Werner 2005); *Ukraine (Kerzhner, in litt.).
Perillus bioculatus (Fabricius, 1775)	1a	North America	European Turkey (1992, Kivan 2004); Greece (Brustel, in litt.).
Reduviidae			
Empicoris rubromaculatus (Blackburn, 1889)	1b	Pan-tropical – Cryptogenic	Croatia, France (incl. Corsica), Italy, Portugal (incl. Azores, Madeira), Spain (incl. Balearic Is., Canary Is.) (Putshkov & Putshkov 1996).
Ploiaria chilensis (Philippi, 1862)	1b	Pan-tropical – Cryptogenic	Azores, ?Cyprus, ?Italy, Madeira, Spain (incl. Canary Is.) (Putshkov & Putshkov 1996).
Saldidae			
Pentacora sphacelata (Uhler, 1877)	1a	North America	Spain (1953, Wagner 1953); Portugal (1959, Lindberg 1962), Italy (1977, Carapezza 1980).
Tingidae			
Corythucha arcuata (Say, 1832)	1a	North America	Italy (2000, Bernardinelli & Zandigiacomo 2000); Switzerland (2002, Meier et al. 2004).
Corythucha ciliata (Say, 1832)	1a	North America	Italy (1964, Servadei 1966); Croatia (1970, Maceljski & Balarin 1972a); Slovenia (1972, Maceljski & Balarin 1972b); Serbia (1973, Tomić & Mihajlović 1974); France (1974, Aguilar et al. 1977); Switzerland (1975, Dioli 1975); Hungary (1976, Jasinka & Bozsits 1977); Spain (1978, Ribes 1980, Sotres & Vazquez 1981); Austria (1982, Mildner 1983); Germany (1983, Hopp 1984); Bulgaria (1987, Josifov 1990); Greece (1988, Tzanakakis 1988); Portugal (1994, Hoffmann 1996); Czech Republic (1995, Stehlík 1997); Slovakia (<1997, Stehlík 1997); Montenegro (<1998, Protić 1998); United Kingdom (2005, Malumphy & Reid 2006); Belgium (2006, Aukema et al. 2007).
Dictyonota fuliginosa A. Costa, 1853	1c	Western Mediterranean	Czech Republic (1954, Roubal 1956).

continued...

Table 1 continued...

Taxon	**Category**	**Origin**	**Country (Year of first record, Reference)**
Elasmotropis testacea (Herrich-Schäffer, 1830)	1c	Palaearctic	Czech Republic (<1844, Šefrová & Laštùvka 2005); ?Poland (<1956, Lis 1996); Germany **?N** (<1963, Péricart 1983).
Stephanitis oberti (Kolenati, 1857)	1c	Northern Palaearctic	Germany **?N** (1906, Horváth 1906); Netherlands **?N** (1917, Reclaire 1932, Aukema & Hermes 2006); *Austria (<1938, Gulde 1938); Czech Republic **?N** (1948, Péricart 1983, Kment in litt.); Belgium **?N** (1993, Bruers & Viskens 1999).
Stephanitis pyrioides (Scott, 1874)	1a	Japan	Netherlands (1904, Fokker 1905); Greece (1995, Kment 2007); Italy (2004, Del Bene & Pluot-Sigwalt 2005); *France (2005, Streito in litt.); Switzerland (2007, Gusberti in litt.).
Stephanitis rhododendri Horváth, 1905	1a	North America	Netherlands – orig. descript. (<1900, Horváth 1905); United Kingdom (1901, Southwood & Leston 1959); *Belgium (1910, Van der Bruel 1947); Denmark (1912, Andersen & Gaun 1974); *France (1913, Fron 1918); Germany (1915, Steyer 1915); *Poland (<1927, Lis 1996); Switzerland (<1936, Balachowsky & Mesnil 1936); Czech Republic (1941, Štusák 1981); Sweden (<1948, Péricart 1983); *Finland (Péricart 1983, in greenhouses, Rinne in litt.); Bulgaria (2005, Simov & Pencheva 2007).
Stephanitis takeyai Drake & Maa, 1955	1a	Japan	Netherlands (1994, Aukema 1996a); United Kingdom (1995, Malumphy et al. 1998); Poland (1999, Soika & Labanowski 1999); Italy (2000, Colombo & Limonta 2001); Germany (2002, Baufeld 2002, Hommes et al. 2003); Belgium (2003, Aukema et al. 2005c); France (2004, Streito 2006).

PENTATOMIDAE

Halyomorpha halys (STÅL, 1855)

The Brown Marmorated Stink Bug *Halyomorpha halys* is native to Asia (Japan, Korea, China, Taiwan) and was first recorded outside its natural range in 2001 in the United States (Pennsylvania, Hoebeke & Carter 2003), but earlier (unrecognized) findings date back as early as 1996 (Hamilton 2003). The species subsequently spread along the east coast south to South Carolina and a single individual was also recorded on the west coast in Oregon in 2004. In 2007 five records including nymphs were made from the area around Zürich in Switzerland (Wermelinger *et al.* 2008), indicating reproducing populations in Europe. In one case detrimental impacts on ornamentals were observed. The species hibernates as an adult, produces one generation per year, and is regarded as a polyphagous horticultural pest on fruit trees and vegetables. It is also known to be a vector of witches' broom, a phytoplasma disease of *Paulownia tomentosa*, an East Asian ornamental tree introduced to Central Europe in 1834, which has only recently established and spread in urban-industrial areas (Essl 2007). In Asia and America *H. halys* also is regarded as nuisance in households when seeking hibernation sites in large numbers in autumn (Hoebeke & Carter 2003).

Perillus bioculatus (FABRICIUS, 1775)

Native to North America, where it is distributed from Mexico to Canada (Froeschner 1988a). It is believed that the origin of the species is in the southern Rocky Mountains, but its range expanded with the expansion of the range of its primary prey, the Colorado potato beetle, *Leptinotarsa decemlineata*. *P. bioculatus* has repeatedly been introduced into several European countries since 1966 (e.g., Belgium, France, Germany, Italy, Russia, Slovakia, Ukraine, former Yugoslavia; De Clercq 2000), to control *L. decemlineata*. Documentation of establishment in the field is rather vague and often anectodal, but it probably was hindered by the different phenologies of predator and prey (Lipa 1985). However, observations of successful establishment in the field are available for Greece (Brustel in litt.) and confirmed for European Turkey (Eastern Thrace), where the species has been found since 1992 (Kivan 2004; Fent & Aktaç 2007). In the laboratory the species is a polyphagous predator and the recent records come from nonpotato fields and orchards. Further spread in the Balkans seems possible.

SALDIDAE

Pentacora sphacelata (UHLER, 1877)

A species distributed along the east coast of North America from Newfoundland to the West Indies and along the west coast from California to Panama, it is also found on the Galápagos Islands (Polhemus 1968, 1985). It was recorded in the Palaearctic region 1950 from Morocco (Wagner 1953) and subsequently found in nearby coastal regions of Europe: 1953 in Spain, where it was described as new species by Wagner (1953); 1959 in Portugal (Lindberg 1962); 1977 on Sardinia (Carapezza 1980). According to Lindberg (1962) and Péricart (1990), it was probably introduced from the Americas. This halophilous species lives in the tidal zone close to saline waters, but may at times inhabit areas near fresh water as well (Polhemus 1968).

TINGIDAE

Corythucha arcuata (SAY, 1832)

A widely distributed species in North America (Froeschner 1988b). It was first recorded for Europe in northern Italy (Lombardy, Piemont) in spring 2000 (Bernardinelli & Zandigiacomo 2000), but presumably was introduced some years before. It further expanded its distribution in Italy (e.g., Bernardinelli 2000; Bernardinelli & Zandigiacomo 2001a), and was first recorded in Switzerland (Tessin) in spring 2002 with subsequent spread (Meier *et al.* 2004; Forster *et al.* 2005). The oak lace bug lives on native *Quercus* species and was also found in a mixed deciduous forest with old sweet chestnut (*Castanea sativa*). Feeding may cause chlorotic discolouration, desiccation and premature leaf-fall, and may increase susceptibility to other insects, diseases, or pollutants. It is also mentioned from Asia Minor (Bolu, northwestern Turkey) by Mutun (2003).

Corythucha ciliata (SAY, 1832)

A North American species occuring east of the Rocky Mountains (Froeschner 1988b). The first record for Europe dates back to 1964, when the species was found in northern Italy (Padua) (Servadei 1966). It spread further, reaching Slovenia and Croatia within a few years, and Serbia, Hungary, Switzerland, France (including Corsica), and Spain in the 1970s; it reached southern Italy (Sicily), Sardinia, southern Austria (Carinthia), and (along the Rhine) Germany in the early 1980s. It has also been found in the Balkans. It is now distributed over much of Europe with some isolated records in the west (Portugal, Hoffmann 1996; Kment 2007; Grosso-Silva & Aguiar 2007) and east (Krasnodar, Russia, Voigt 2001). Recently it was found in the United Kingdom (Bedfordshire) on *Platanus acerifolia* and *P. orientalis* imported from France and Italy (Malumphy & Reid 2006), and in Belgium (Antwerp, Brussels) (Aukema *et al.* 2007). This species probably has the widest distribution of all alien Heteroptera in Europe. It has also been introduced to China (Streito 2006), Korea (Chung *et al.* 1996), Japan (Tokihiro *et al.* 2003), and Chile (Prado 1990). In its native range the species feeds on different *Platanus* species (Platanaceae), in the introduced range it can be found on *P. occidentalis* and *P. orientalis* and their hybrid *P. acerifolia*. In most parts of Europe *Platanus* is alien as well, used as an ornamental tree in cities. In its native range this species causes serious damage to the host trees. Similar reports are not yet known from within the introduced range, although at high abundances (up to 200 bugs per leaf) discolouration and reduced photosynthetic activity are obvious. The feeding of the bugs may weaken the plant's vitality and support secondary infections by fungi (e.g., *Apiognomonia platani*, *Ceratocystis fimbriata* f. *platani*.) and pathogens (Neal & Schaefer 2000). Passive dispersal by wind-drift, but also human-mediated translocations via clothes, cars, etc., are reported. Arzone (1986) notes that the species can spread at least 100 km per year. Males show mass mortality during winter, which may change in the future because of increasingly mild winter temperatures.

Stephanitis pyrioides (SCOTT, 1874)

The native area of this species is the Far East and it has been introduced to other continents as well (North and South America, Australia). The first European records date back to introduced plant material (*Rhododendron*) from Japan in the beginning of the 20th century (1904 in the Netherlands, Fokker 1905), but it appears that the species failed to establish and disappeared after 1910. Recorded in the Netherlands again in 1995 and 1998 on *Azalea* bonsais from Japan (Aukema 1996b, 1999) and on *Rhododendron* in Greece in the 1990s (Kment 2007), it has recently been found in the Botanical Garden of Lucca in the Toscana (Italy) on *Azalea* and *Rhododendron* (Del Bene & Pluot-Sigwalt 2005), in Nantes (France) on *Rhododendron* imported from Korea (but it is unclear if this establishment was successful [2005, Streito in litt.)], and in Ticino (Switzerland) on *Azalea* (2007, Gusberti in litt.). Biology, damage, and control were summarized by Neal & Schaefer (2000) and Kment (2007).

Stephanitis rhododendri HORVÁTH, 1905

Originally described from the Netherlands (Horváth 1905), this species was introduced around 1890 from North America, where it occurs on the west and east coasts (Froeschner 1988b). In the following decades it was found in northern and western Europe, until records declined. Nowadays, records are scarce, but the species is still present in Europe (recorded in June 2005 in Sofia, the first time for Bulgaria, on *Rhododendron catawbiense* in a private garden and in a nursery of a company trading in ornamental plants [Simov & Pencheva 2007]); and mass occurrences are observed under favourable conditions (e.g., Jones 1993; Jindra & Kment 2006). Repeated introductions with the host plants are highly probable. In Finland it was introduced into greenhouses and it also was introduced to South Africa and New Zealand (Péricart & Golub 1996). It lives on ornamental *Rhododendron*, rarely on other Ericaceae (*Kalmia*, *Pieris*). Taxonomy and biology were discussed by Neal & Schaefer (2000).

Stephanitis takeyai DRAKE & MAA, 1955

This species was first recorded from Europe in the Netherlands in 1994 (Aukema 1996a) and subsequently found in southeastern England in a public garden (1995, Malumphy *et al.* 1998) and in Poland (1999, Soika & Labanowski 1999). The latter findings are supposed to have been introduced with plant material originating from Germany (Soika & Labanowski 1999). Later it was found in Italy (2000, Colombo & Limonta 2001), Germany (2002, Hommes *et al.* 2003; Hoffmann 2003a), Belgium (2003, Aukema *et al.* 2005c), and France (2004, Streito 2006). It also was introduced to the USA (Connecticut in 1946 [Bailey 1950]), whence it spread to other eastern states (Wheeler 1977), Canada (British Columbia, supposed to have been a separate introduction via nursery stock [Scudder 2004]), and India (Péricart & Golub 1996). *S. takeyai* is a Japanese species and lives on ornamental Ericaceae (*Pieris*, *Rhododendron*, *Lyonia*), but prefers *Pieris japonica*, a widely used ornamental plant for private gardens and cemeteries. The species is regarded as pest: because of its feeding on parenchym sap of the leaves of the host plant, heavily attacked leaves dry out, shrink, and fall.

Category 1b—Cryptogenic species

Cryptogenic is used in this paper for widely distributed species with unknown origin (e.g., stored product pest species). Because the alien status in Europe is difficult to classify, only the country distribution in Europe is given in Table 1.

ANTHOCORIDAE

Buchananiella continua (WHITE, 1880)

This pan-tropical species is known in West Europe from the Azores and Madeira, Portugal, Spain, France, Italy, and, in the eastern Mediterranean, from Turkey and Israel (Péricart 1996). After the first casual introduction to the United Kingdom (Liverpool, Péricart 1972), it was found established in the Buckingham Palace gardens in London in the 1990s, probably introduced with plant materials (Kirby 1999). Subsequent spread was reported from several localities from southwestern (Devon) to northern England (Yorkshire) (Whitehead 2005; Aukema 2007). Aukema (2007) found the species under fallen or cut off branches of trees, especially sycamore, with the dry foliage still present, and notes similarities of this typical habitat with findings for *Amphiareus obscuriceps*.

Lyctocoris campestris (FABRICIUS, 1794)

According to Péricart (1972) this species is of Mediterranean origin and according to Kerzhner (in litt.) it is native to the West Palaearctic. Today it has a cosmopolitan distribution and is known from nearly all continents whence it was accidentally introduced with stored food products. In natural habitats it lives in the nests of mice (*Mus musculus*, *Microtus arvalis*) and under the bark of trees; under synanthropic conditions it has been found in stored products, haystacks, in buildings, and in litter samples around domestic animals (Sklyar 1971; Péricart 1972; Kerzhner 1979; Lattin 2007).

MIRIDAE

Nesidiocoris tenuis (REUTER, 1895)

According to Wheeler & Henry (1992), this species is of palaeotropical origin, but has been transported widely with goods; nowadays it is almost cosmopolitan in its distribution. It is a zoophytophagous species feeding on its host plants (Solanaceae), but also preying on small arthropods. In Europe, in the Mediterranean region, it enters greenhouses (especially tomato cultures) and damages crops; but it is also considered beneficial as a predator of small arthropods (Malausa 1989).

Taylorilygus apicalis (FIEBER, 1861)

The origin of this species is unclear. According to Linnavuori (1974) it is of African origin and has been artificially transported throughout the world. Today it is widely distributed in tropical, subtropical, and temperate regions of the world. Wheeler & Henry (1992) suggest that because of its wide distribution (it is one of the most widely distributed nondomestic insect species) this species moves easily with commerce and probably has been introduced several times independently.

REDUVIIDAE

Empicoris rubromaculatus (BLACKBURN, 1889)

Described from Hawai'i, probably of pantropical origin, this species has penetrated into subtropical and temperate regions. It is known from western parts of Europe including Macaronesia, but has also been recorded in Catalonia, Liguria, and was recently found in Croatia (Rus 2004). It was introduced with plant material on ships (e.g., one record in Vladivostok in 1979 on a ship from the Ivory Coast), but wind dispersal also seems possible (Putshkov *et al.* 1999).

Ploiaria chilensis (PHILIPPI, 1862)

Described from Chile, probably of pantropical origin, *P. chilensis* was subsequently recorded from different regions (Nearctic, Neotropical, Australian). In the palaearctic region it is known from Macaronesia and Spain. Records from Italy and Cyprus are doubtful (Putshkov & Putshkov 1996).

Category 1c—Species alien in Europe

The following species are known or suspected to have been introduced intentionally or unintentionally within Europe and are therefore considered alien in (parts of) Europe.

ANTHOCORIDAE

Anthocoris butleri LE QUESNE, 1954

The species status is questioned by some authors, but it is treated as a valid species by most recent workers. The predatory *A. butleri* probably is trophically bound to the psyllid *Psylla buxi* (L.) living on the shrub *Buxus sempervirens* (Buxaceae). This shrub is native to southwestern Europe and parts of Central Europe and is commonly used as an ornamental plant in house gardens and cemeteries across Europe, whence it escaped and established locally. Records of *A. butleri* outside the natural range of *B. sempervirens*, especially in urban settings, should be regarded as alien. If the alien status is doubtful for the host plant or if alien status differs within a country, this applies to *A. butleri* as well. Records of *A. butleri* from Andorra, France, Spain, and the United Kingdom (Péricart 1972) are here considered native.

Anthocoris sarothamni DOUGLAS & SCOTT, 1865

An atlanto-mediterranean species living on *Cytisus scoparius* and preying on aphids and psyllids, and in the Mediterranean region living on other Genistinae. *Cytisus scoparius* is native to western Europe and is commonly used as an ornamental plant across Europe. Records of *A. sarothamni* outside the natural range of the host plant should be considered alien. This probably pertains to Austria (historical records, not established [Rabitsch 2004a]) and the Czech Republic (Kment 2006b). The records from the Balkans (Bulgaria and Greece), although isolated, might well be native (Péricart 1972, 1996).

LYGAEIDAE

Arocatus longiceps STåL, 1872

A ponto-mediterranean species living on *Platanus* trees. The records of Hungary, Austria, Germany, Switzerland, and Czech and Slovak Republics, Belgium, and the Netherlands are regarded as alien (Kondorosy 1997; Adlbauer & Frieß 1996; Rieger 1997; Rietschel 1998; Stehlík & Hradil 2000; Kment & Bryja 2001; Aukema in litt.); the status in Slovenia (present since 1983, Gogala & Gogala 1986) and France (Hérault, Aukema in litt.) is unclear, but probably alien as well. In southern Bulgaria it is considered native on *Platanus orientalis*, and only recently it spread to the north of the country, where it lives on planted *P. acerifolia* (Simov in litt.). The identity of recent records of *Arocatus* sp. on *Platanus* in the United Kingdom (London) is still under discussion (Barclay 2007, Aukema in litt.). The species flies well, but also is unintentionally introduced with cars and the transportation of plant material. According to Rietschel (2003) a western (via the Rhine valley) and eastern (from the Balkan to eastern Austria, the Czech Republic and Saxony) route of expansion can be observed from the Mediterranean into Europe, where the expansion still continues. The expansion of this species is comparatively well known, because it hibernates under the bark of *Platanus* trees and can easily found during the winter moths.

Orsillus depressus (MULSANT & REY, 1852)

A circum-mediterranean species, the northern limit of the natural range is not exactly known. It lives on native (*Juniperus*) and non-native (e.g., *Thuja*, *Chamaecyparis*) Cupressaceae. First recorded in Central Europe in 1971 in Germany (Karlsruhe, Voigt 1977), it was most probably unintentionally introduced with seeds or plant material from the Mediterranean region. Further records are known from the 1980s in Luxembourg (Reichling 1985), the Netherlands and Belgium (Aukema 1988), United Kingdom (Hawkins 1989), Slovak Republic (Stehlík & Vavrínová 1996), and, in the early 1990s, in the Czech Republic (Hradil *et al.* 2002). The species may be native to the pannonian region of eastern Austria and Hungary, where it had already been collected in 1948 and at the end of the 20th century, respectively (Rabitsch unpubl.; Horváth 1898). Hradil *et al.* (2002), Aukema (2003) and Werner (2004) mentioned that this species, after being introduced with non-native host plants, started to invade natural sites of nature conservation value with native *Juniperus communis* stands. This is one of the rare documented cases where ornamental plants and urban sites served as stepping-stones for the further expansion of this species in Central Europe.

Oxycarenus lavaterae (Fabricius, 1787)

A western-mediterranean species, but also occurring on the Arabian peninsula in the east and from tropical Africa to South Africa in the south (Péricart 2001). It probably was introduced to Central Europe repeatedly in the past (e.g., 1966 to Austria [Rabitsch 1999]), but failed to establish. Although the preferred host plant (*Tilia*) has been planted as an ornamental tree along roads and in parks in Central European cities for decades, it was only recently (since the mid-1990s) that established populations were documented for Central and Eastern Europe. The increasing number of introductions (exchange of host plant material, traffic) and the mild winter temperatures, which are suspected to regulate overwintering populations, set the stage for the recent spread of this species. The introduction with plant material from Italy is documented for northern Germany (Deckert 2004) and in 2003 it was found indoors in Finland (Rinne in litt.). The species is extraordinary for large aggregations consisting of thousands of individuals on the bark of their host trees or–in case of very large population densities–any other vertical structures, even buildings or fences (e.g., Reynaud 2000). In fact, the first record for Austria was made by noticing a strange “red-coloured” tree stem from the corner of my eye out of a moving car. As for other Mediterranean species, the northern border is difficult to delimit. It has been known from southern Switzerland (Tessin) since 1863 and mentioned for Slovenia by Montandon (1886), indicating that records south of the Alps may be within its native range. The transition of the bug from the Alps into northern Switzerland and southern Germany happened just recently and is suspected to have been either human-mediated via plant trade or the result of climate change (Billen 2004; Wermelinger *et al.* 2005). The same is true for France: known from southern France since the end of the 19th century, but only recently found (probably introduced) in Paris in 1999 (Denosmaison 2001). There are several host plants known, most of them belonging to Malvales (e.g., *Lavatera*, *Corylus*, *Tilia*). In the introduced range most records are from planted *Tilia cordata* trees in suburban and urban habitats.

MIRIDAE

Closterotomus trivialis (A. Costa, 1853)

A Mediterranean species, suspected to have been accidentally introduced with plant material to the Netherlands (The Hague) in the late 1990s (Aukema 1999). It has become established in public green and private gardens on ornamental shrubs and trees, but has not expanded its range since then.

Dicyphus escalerae Lindberg, 1934

A western Mediterranean species, described from Spain and subsequently recorded from Italy, Corsica, and mainland southern France (summarized by Hollier & Matocq 2004). It was most probably introduced with its food plant (*Antirrhinum majus*, Scrophulariaceae) to southwestern Germany (Rheinland-Pfalz, Simon 1995) and to Paris (Hollier & Matocq 2004). It further spread in Germany (Baden-Württemberg, Heckmann & Rieger 2001) and was also found in Switzerland (Geneva, Hollier & Matocq 2004). Hollier & Matocq (2004) discuss the paradox that this species has spread only recently, although *Antirrhinum majus* is a popular and widespread garden plant for many years; they attribute this phenomenon likely to climate change and the increasing quantity of transportation of goods in Europe.

Orthotylus adenocarpi (PERRIS, 1857), *Orthotylus concolor* (KIRSCHBAUM, 1856), *Orthotylus virescens* (DOUGLAS & SCOTT, 1865)

All three species are zoophytophages on common broom *Cytisus scoparius* (Fabaceae), which is native to western Europe, but widely cultivated as an ornamental shrub and established outside its native range in other parts of Europe as well as North America, Australia, and New Zealand. Like *Dictyonota fuliginosa* and *Anthocoris sarothamni*, records outside the native range of the host plant should be considered alien (e.g., all three species in the Czech Republic – Kment 2006b, *O. virescens* in Hungary – Kondorosy 2005, *O. concolor* and *O. virescens* in North America – Waloff 1966, Wheeler & Henry 1992). Waloff (1966) points to the introduction of eggs or young larvae of these *Orthotylus* species with young host plants.

Orthotylus caprai WAGNER, 1955

Described from Sardinia and recently reported from Switzerland (Valais), Slovenia (Istria), Germany, and the United Kingdom (Wagner 1955; Carapezza 1984; Nau 2007; Simon 2007), where it was found on Cupressaceae (*Chamaecyparis*, *Cupressus*, *Juniperus*), Taxodiaceae (*Sequoiadendron giganteum*), and Pinaceae (*Pinus sylvestris*). Because of the host tree preference, this species is here considered as alien to areas north of the Alps.

Macrolophus glaucescens FIEBER, 1858

Originally described from specimens collected in the botanical garden and the surroundings of Prague (Czech Republic) on *Echinops sphaerocephalus* (Asteraceae) (Fieber 1858), which is considered cryptogenic in the Czech Republic and northern Europe, but archaeophytic in Austria, Hungary, and southern Europe (see also *Elasmotropis testacea*). This plant bug is a Mediterranean species living (mostly) predatory on *Echinops sphaerocephalus*, and it is considered alien outside the natural range of the host plant (Šefrová & Laštùvka 2005; Kment 2006b).

Tuponia sp.

The genus *Tuponia* includes over 70 species, distributed from the Canary Islands to tropical Africa and Central Asia (Kerzhner & Josifov 1999). There is a clear preference for Tamaricaceae as host plants, especially *Tamarix*, on dry, sun-exposed sites with salty soil. The northern limit of the natural range therefore often (not for all species) coincides with the natural range of their host plants. *Tamarix* is frequently used as an ornamental shrub in private gardens and as a shelterbelt in agriculture-dominated land; and *Tuponia* species are easily introduced with plant material. The southeastern European *Tamarix parviflora* is the most widespread alien tamarisk species in Europe, regarded as an established alien in Belgium, France, Italy, Portugal, and Spain and not established in Austria, Slovakia, or Slovenia. Several additional *Tamarix* species are currently regarded as not established aliens in different European countries (e.g., *T. ramosissima* in France and Austria, *T. tetrandra* in Hungary). Because of their host specifity, *Tuponia* species probably do not pose a threat to native plants and usually they occur in urban and suburban settings only. So far, five species have been found outside the natural range of *Tamarix* in Europe. *Tuponia mixticolor* and *T. brevirostris* were recorded first in the British Islands (1979 and 2001, respectively; Barclay & Nau 2003) and were found recently in Germany (Rheinland-Pfalz; Simon 2007), *T. hippophaes* and *T. elegans* are more widespread, the former also feeds on *Myricaria germanica* and is native where its host plant is native (but it prefers ornamental *Tamarix* shrubs); *T. macedonica* was only recently found in the Czech Republic and establishment is not yet evident (Hradil *et al.*, in prep.). Because there are no regulations for the use of *Tamarix* shrubs in Europe so far (although a very high potential for detrimental effects in nutrient-poor, salty soils is known from North America [Zavaleta 2001]), more *Tuponia* species from the Mediterranean region are predicted to make their way to Central Europe in the future.

PENTATOMIDAE

Nezara viridula (LINNAEUS, 1758)

The southern green stink bug originally is a Mediterranean or Ethiopian species, and has since been introduced to tropical and subtropical regions on all continents by transport of goods (Todd 1989). Recent records of reproducing populations in Hungary (Rédei & Torma 2003), the United Kingdom (Barclay 2004; Shardlow & Taylor 2004), southwest Germany, and northern Switzerland (Werner 2005) indicate that the species has the potential to establish in Central Europe. In Central Europe, however, it is alien and single individuals have repeatedly been captured in several localities (e.g., Austria, Belgium, Finland), where the species currently is regarded as not established. *Nezara viridula* is also regularly intercepted by plant quarantine service in the United Kingdom on a wide range of imported plants and products (Reid 2005; Malumphy & Reid 2007). It is a polyphytophagous species feeding on many different host plants, and it may become a pest on several cultivated plants (e.g., soybean, nuts).

TINGIDAE

Dictyonota fuliginosa A. COSTA, 1853

An atlanto-mediterranean species living phytophagously on *Cytisus scoparius* (Fabaceae). The shrub is native to western Europe and is commonly used as an ornamental plant across Europe. Records of *D. fuliginosa* outside the natural range of the host plant should be considered alien. This pertains to Canada (Scudder 1960) and to the Czech Republic, where it was first found in 1954 (Roubal 1956) and subsequently at more localities (Rus 2004; Kment 2006b).

Elasmotropis testacea (HERRICH-SCHä FFER, 1830)

A widely distributed Palaearctic species, occurring from Central Europe to North Africa and Kazakhstan Péricart & Golub 1996). It lives on different species of *Echinops* (*E. sphaerocephalus*, *E. ruthenicus*, *E. commutatus*, *E. exaltatus*, *E. ritro*, etc.) (Asteraceae) and should be considered alien in countries where the host plants are considered alien. According to Kment (2006b), it was introduced to Germany, Poland, Czech Republic, Slovakia, Austria, and Hungary; but because *Echinops sphaerocephalus* is regarded an archaeophyte in Austria and Hungaria and probably Slovakia, *E. testacea* is here not considered alien in these countries. However, this lace bug was also translocated within its range with ornamental *Echinops* species, e.g., to a botanical garden in the pre-alpine part of Lower Austria in the 1950s (Ressl & Wagner 1960), where it has since declined with the hostplant (Ressl 1995).

Stephanitis oberti (KOLENATI, 1857)

A northern Palaearctic species, distributed from Scandinavia and Russia to Japan (Hokkaido) and Korea (Péricart & Golub 1996). The southern border of the range is unknown. It is considered introduced with ornamental plants to Belgium (Bruers & Viskens 1999). The species lives phytophagously on ornamental *Rhododendron*, *Pieris*, and *Andromeda* and probably is translocated with the plants; however, in the Netherlands it is also found on *Vaccinium vitis-idaea* (Aukema & Hermes 2006) and it may well be native in the Czech Republic (Kment in litt.).

The main criterium for categorization as alien species in the present paper is that the species is translocated beyond natural boundaries with direct or indirect help of human beings. However, in some cases, this information is not easily accessible, rather vague, anecdotal, or even contradictory. The following three species are "doubtful European aliens" but for the time being they are included in Table 1 and in the analyses within this category (1c?).

ANTHOCORIDAE

Amphiareus obscuriceps (POPPIUS, 1909)

This eastern Palaearctic species was found in Europe for the first time 1987 in Bulgaria and 1989 in Hungary (Péricart & Stehlík 1998; Aukema 1990a). Further records across Europe were subsequently made and indicate a recent westward spread of this species. Although some records indicate human introduction (e.g., records in a botanical garden in detritus of *Chamaecyparis* by Péricart & Stehlík [1998]; attracted to light within cities [Kment *et al.* 2003]), there is no unequivocal evidence for this and natural spread cannot be ruled out.

MIRIDAE

Deraeocoris flavilinea (A. COSTA, 1862)

Originally described from Sicily and thought to be an endemic species for nearly a century. It has begun to spread over Central Europe since the 1980s. The strongest argument in favour of alien status for this species comes from the fact that most records in Central Europe are from isolated findings in cultivated landscapes and cities. Melber (1998) described that after translocation the species subsequently expanded centrifugally from cities to suburban areas (confirmed by data for Austria and Saxony [Rabitsch 2002b, Dietze *et al.* 2006]). There are still only few records in natural or near-natural sites in Europe, and it is suspected that the species has been introduced unintentionally along transportation routes.

Dichrooscytus gustavi JOSIFOV, 1981

The taxonomy of this species has only recently been solved. So far, it is known from a few localities in western and Central Europe (Kerzhner & Josifov 1999). It lives on *Juniperus communis* and on introduced Cupressaceae (*Chamaecyparis*, *Thuja*, *Juniperus*). Interestingly, it was not (yet) found by Stehlík (1998) in his survey on the Heteroptera species on introduced Cupressaceae in southern Moravia in the 1990s, but was recorded from this region in the year 2000 (Bryja & Kment 2002). It seems this species is currently extending its range, but it is unclear what the native range is. There are clear indications that this species is translocated by man: it was even reported from inside a train by Bryja & Kment (2002), but probably more regularly with its host plants within Europe, e.g., on planted *Juniperus* in a botanical garden in Austria (Rabitsch 2004b), in a park in Finland (Albrecht *et al.* 2006), and on a cultivated juniper (*Juniperus chinensis*) in the West Midlands of Central England (Whitehead 1989). In the Netherlands the only records are on cultivated *Juniperus* and *Chamaecyparis* species in parks and gardens, but not on natural *Juniperus* stands (Aukema 2003).

Category 2—European continental species introduced to European islands

Because of a scarcity of data this is a problematic category for many species and is not included in Table 1 and the analyses. According to Borges *et al.* (2005), *Tingis cardui* (Tingidae, living on *Cirsium* and rarely *Carduus* species) and *Gastrodes grossipes* (Lygaeidae, living on *Pinus* species) are considered alien to the Azores, obviously because of the fact that their host plants are alien as well. For *Cimex lectularius*, *Brachysteles parvicornis*, *Liorhyssus hyalinus*, and *Nabis capsiformis* on the Azores see further below (Category 4). *Microvelia gracillima* Reuter is here considered a native macaronesian-ethiopian species (Andersen 1995). The difficulties in applying the alien status for some species in the United Kingdom were discussed by Southwood (1957), Kirby (1992), Judd & Hodkinson (1998), and Kirby *et al.* (2001).

Category 3—Alien species in greenhouses

Native and non-native predatory or zoophytophagous Heteroptera are used as biological control agents around the world (Schaefer & Panizzi 2000). Some species are exclusively used in greenhouses, others are released into the wild against pest arthropods in agriculture. For Europe, EPPO (2002) lists the following commercially used Heteroptera: *Anthocoris nemoralis, A. nemorum, Orius albidipennis, O. laevigatus, O. majusculus* (Anthocoridae), *Macrolophus melanotoma* (Miridae), *Picromerus bidens* and *Podisus maculiventris* (Pentatomidae); but additional species were either used in the past (e.g., *Perillus bioculatus*) or more recently (e.g., *Macrolophus pygmaeus*). In the Mediterranean region some species in the tribe Dicyphini (*Dicyphus*, *Macrolophus*, *Nesidiocoris*, *Cyrtopeltis*) spontaneously colonize tomato fields and greenhouses (e.g., Calvo & Urbaneja 2003, Castañé *et al.* 2004, Gabarra *et al.* 2004). However, the same species are commercially available for use as biocontrol agents in northern countries, where they may be released or escape into the wild. On the risks of releasing exotic biocontrol agents see e.g., van Lenteren *et al.* (2006), Babendreier (2007), or Thomas & Reid (2007). With one exception (*Perillus bioculatus*, see Category 1) no establishment of these species in the field outside their native range is known in Europe so far, and these species are neither included in Table 1 nor used for the analyses.

ANTHOCORIDAE

Orius insidiosus (SAY, 1832)

A western hemisphere species released for biological control of western flower thrips (*Frankliniella occidentalis*) in greenhouses in many countries in Europe. Occasional occurrence in the wild has been reported (e.g., Czech Republic, Šefrová & Laštùvka 2005), but the species is regarded as not established in Europe. Similarly, Gillespie & Quiring (2006) reported that *O. insidiosus* escaped from greenhouses in British Columbia, Canada, but probably has not become established in the surroundings over 8 years of investigation.

Orius laevigatus (FIEBER, 1860)

This western and southern European species is commercially available for biological control against small arthropods, particularly *Frankliniella occidentalis* (Pergrande), Thysanoptera, in greenhouses. Aukema & Loomans (2005) show recent records in the Netherlands "in greenhouse areas" and discuss the possibilities of a northern shift of its range caused by climate change or the escape of specimens from greenhouses.

MIRIDAE

Dicyphus tamaninii WAGNER, 1951

In its natural Mediterranean range this zoophytophagous species spontaneously colonizes greenhouses and unprotected, unsprayed tomato fields (Alomar *et al.* 2002). Lucas & Alomar (2002) found no significant interspecific competition with released *Macrolophus melanotoma* in the laboratory. Outside its range it is a potential agent for biological control against thrips and whiteflies, but it is not commercialized yet. Establishment in the field outside its natural range is not known so far.

Macrolophus melanotoma (A. COSTA, 1853) [=*caliginosus* WAGNER, 1951]

A Mediterranean species, commercially available for use against whiteflies in greenhouses. In southern Europe this species also colonizes tomato and vegetable fields by natural means and effectively preys on pests (Alomar *et al.* 2002). So far, it is not established in the wild in northern Europe, but this species has the potential to overwinter in the wild even in the United Kingdom (Hart *et al.* 2002; Hatherly *et al.* 2005). It was reported to occur occasionally synanthropically in the Czech Republic (Šefrová & Laštùvka 2005) and is included in the list of the alien species of Norway (Artdatabanken 2007). Within the EU-project REBECA it is suggested that this species is not used in countries where it does not naturally occur, because of possible non-target effects (http://www.rebeca-net.de/).

Tenthecoris bicolor Scott, 1886, *Tenthecoris orchidearum* (Reuter, 1902), and *Tenthecoris colombiensis* Hsiao & Sailer, 1947

These orchid plant bug species are of Neotropical origin and live on Orchidaceae and Amaryllidaceae in glasshouses. They were introduced to the United Kingdom at the end of the 19th century and were found until 1928 (Reuter 1907; Carvalho 1951; Carvalho & Leston 1952; Southwood & Leston 1959). Mentioned for Sweden by Ossiannilsson (1946) and in a compilation for Germany by Geiter & Kinzelbach (2002) without reference. No recent data on the fate of these species are available and they are here considered as not established in Europe.

PENTATOMIDAE

Podisus maculiventris (Say, 1832)

The most common asopine species in North America, distributed from Mexico and the West Indies to Canada (Froeschner 1988a). It is a polyphagous predator living in a wide variety of habitats. For a detailed account of its biology and control potential see De Clercq (2000). In Europe it was released against *Leptinotarsa decemlineata* in the European part of Russia, but did not become established. According to De Clercq (2000), some 40.000 to 100.000 second and third instars were released per hectare and year in potato fields around the Black Sea coast in Russia, Ukraine, and Moldavia. In some countries it is commercially available (e.g., in the Netherlands since 1997) for biological control in greenhouses; it was also introduced to Korea and Japan (De Clercq 2000). At present it has not become established in Europe in the field.

Category 4—Excluded species

Introduction and establishment of alien insects often go unnoticed. The following annotated list of species, not aimed to be exhaustive, includes selected species excluded from the present analyses for the reasons stated. Some of the not-established species clearly have the potential to become established in Europe in the future.

ANTHOCORIDAE

Amphiareus constrictus (Stål, 1860)

Known from all zoogeographic regions, particularly abundant in the subtropics and tropics. Recorded from the Czech Republic by Jindra & Kabíček (2001), but Kment et al. (2003) questioned the correct identification. Recently recorded in Belgium (Viskens & Bruers, in prep.). It was also introduced with orchids from Colombia to California (Lattin & Lewis 2001) and is known to be translocated with food supplies and plant materials by air cargo. It is less likely that this species will become established in Europe.

Brachysteles parvicornis (A. Costa, 1847)

Borges *et al.* (2005) consider this species native to the Azores, but treat it later as introduced (Borges *et al.* 2006). It is a west-mediterranean species, occurring from the Canary Islands, northwest and northern Africa, to southern Great Britain and Denmark in the north and to the Balkans and the Ukraine in the east (Péricart 1972, 1996). Without evidence for human-mediated introductions, the occurrence of this species on remote islands is regarded as natural dispersal.

Orius pallidicornis (REUTER, 1884)

This circum-mediterranean species is one of the very few phytophagous anthocorid species. It feeds on the pollen of *Ecballium elaterium* (Cucurbitaceae) and according to Péricart (1972) it is restricted to the occurrence of its host plant around the Mediterranean coast. Recently, the species was captured in Austria (Vienna, Rabitsch 2001) and Hungary (Balatongyörök, Kondorosy 2005). *Ecballium elaterium* is commercially available for cultivation and as an ornamental plant for house gardens, so the introduction of *O. pallidicornis* with its host plant is possible. Whereas the Austrian record was made in a near-natural site far from possible introduction sources, the Hungarian specimen was captured in a light trap in the city. However, only single specimens are currently available and establishment is not yet clear. Lattin (1999) mentioned that animal prey is used by this species as well, which means that a recent natural spread northwards is equally possible.

Xylocoris flavipes (REUTER, 1875)

Predator of stored grain pests, particularly larvae of flour beetles (*Tribolium*, Tenebrionidae), widely distributed and of an unknown, probably palaeotropical origin (Péricart 1972). It was discovered in ships and ports in France (e.g., Rouen, Dunkerque, but also in Paris), in the United Kingdom, the Netherlands (Rotterdam in 1913), Italy, Germany, and Sweden (e.g., Southwood & Leston 1959; Péricart 1972; Péricart & Golub 1996). In the Czech Republic the occurrence in flour in a bakery was mentioned by Vysloužil (1986) and in Sicily small colonies were recorded in *Triticum*-silos (Russo *et al.* 2004). Its alien status on the Canary Islands and the Azores is doubtful as is establishment. In continental Europe the species has not yet become established in the wild and therefore is included in this category.

Xylocoris afer (REUTER, 1884)

An African species, occasionally introduced with stored products to the United Kingdom (Southwood & Leston 1959). Recently collected in Antwerpen Harbour on a Gabonese tree (Viskens & Bruers, in litt).

CIMICIDAE

Cimex lectularius LINNAEUS, 1758

The common bed bug, a nocturnal, bloodsucking ectoparasite on humans (and rarely birds and bats), is supposed to have its origin in the Middle East (Usinger 1966). For Europe it was mentioned as early as the ancient Greek and Latin literature (e.g., Aristophanes, Aristotle, Dioscorides). Although human-mediated introductions to parts of Europe may have occurred later than 1492, e.g., the first documented record for Great Britain dates back to 1503 or 1583 (Usinger 1966), the species is here excluded from the list as it is considered as archaeozoan for most parts of Europe, e.g., recorded for Germany in the 11th century and for France in the 13th century (Kemper 1936).

The closely related (and difficult to separate) tropical and subtropical *Cimex hemipterus* (F.), supposed to have its origin in southern Asia or in tropical Africa, is another species associated with man. It was mentioned for Germany (Lederer 1950), but establishment failed. It has a high potential of being introduced with increasing travel activities, but establishment in Europe seems rather unlikely.

COREIDAE

Strobilotoma typhaecornis (FABRICIUS, 1803)

A Mediterranean species with an isolated record from Kolín in the Czech Republic in 1992. According to Kment (2004b), here considered as mislabelling or accidentally introduced specimen without subsequent establishment in Central Europe.

CYDNIDAE

Adrisa sepulchralis (ERICHSON, 1842)

A "very obscure species," previously known from only a single female from Tasmania (Lis & Webb 2007). The first male was found in 2004 in association with the tree fern *Dicksonia antarctica* in a plant nursery in the United Kingdom (Lis & Webb 2007). The species very probably is of Australian origin.

LYGAEIDAE

Apterola lownii (SAUNDERS, 1876)

A Mediterranean species with an isolated record from Őrség in Hungary in 1983. According to Kondorosy (2005) here considered as a mislabelling or an accidentally introduced specimen without subsequent establishment in Central Europe.

Elasmolomus squalidus (GMELIN, 1790)[=*E. sordidus* (FABRICIUS, 1787)]

Widely distributed, palaeotropical species, introduced also to South America (Brazil). Southwood & Leston (1959) reported this species introduced to the United Kingdom with shipments of groundnuts from Africa, but since then no further records are available. For notes on damage and control see Sweet (2000), and for the unstable taxonomy see Péricart (2001).

Orsillus maculatus (FIEBER, 1861)

This Mediterranean species is trophically bound to Cupressaceae. It was mentioned 1968 for the Czech Republic by Dobšik (1972), but it did not establish. Similar to the other *Orsillus* species it may profit from the increased use of ornamental Cupressaceae across Europe.

Orsillus reyi PUTON, 1874

Recorded 1972 in Brno (Czech Republic, Dobšik 1972) and 1998 in Graz (Austria, Adlbauer 1999) for the first time outside its native, Mediterranean range, but considered as not established so far. This species is trophically bound to Cupressaceae and may make use of the increasingly planted ornamental shrubs of this plant family.

Oxycarenus hyalinipennis (A. COSTA, 1843)

Distributed in the southern Palaearctic, Oriental, and Afrotropical regions, but also introduced to South America and the West Indies (Péricart 1999, 2001). Translocations are facilitated via host plants as this species is a well known pest on cultivated and ornamental Malvaceae (e.g., *Althaea*, *Gossypium*, *Hibiscus*, *Lavatera*) (Sweet 2000). It has been irregularly recorded in Central Europe (e.g., Austria and Slovakia, Péricart 1999) but has failed to become established so far.

Spilostethus pandurus (SCOPOLI, 1763)

Widespread species in the Mediterranean, Palaeotropical, and Australian regions, the natural northern border of its distribution in Central Europe probably are the Alps. Single introduced specimens were recorded, e.g., 1946 from southern Germany (Rabitsch, unpubl.), 1949 from northern Austria (Ressl 1983), southern Moravia (Štys 1976), and Scotland (McKinlay 1976), usually intercepted with imported vegetables of Mediterranean origin. No established populations in Central Europe are known so far. In some parts of its distribution it is regarded as a pest on crops (e.g., Sweet 2000). It prefers feeding on Asclepiadaceae, but has a wide spectrum of food plants. With impending climatic change this species is a possible future invader into temperate Europe.

MIRIDAE

Fulvius anthocoroides (REUTER, 1875)

This species was described from a specimen captured in the harbour of Rouen (France) on a ship from Senegal (Reuter 1875). The origin probably is tropical West Africa, but nowadays the species has a pantropical distribution. It was also recorded in Europe from Great Britain (Woodroffe & Halstead 1959) and the Netherlands (1979 in Vlissingen, Gorczyca 2006), but no established populations are known so far.

Heterocordylus tibialis (HAHN, 1833),

A zoophytophagous species living predominantly on the western European *Cytisus* and mentioned as alien to the Czech Republic by Kment *et al.* (2006b), because common broom is regarded alien in this country. However, *H. tibialis* also lives on other plants (e.g., *Genista*) and is widely distributed to the east (Kerzhner & Josifov 1999). Therefore, it is excluded from the analyses, although its alien status deserves critical re-evaluation within Central Europe.

NABIDAE

Nabis capsiformis GERMAR, 1838

Distributed and abundant in most tropical and subtropical regions of the world, including remote oceanic islands (Kerzhner 1983). The northern limit of the distribution in Europe streches from southern France and Central Italy to the Balkan region and there are no indications of established populations north of this line. Records in Central and Northern Europe (and temperate Asia as well) are scarce and scattered (e.g., Austria, Czech Republic, Hungary) and originate from migrating or wind-drifted individuals, as shown by Kerzhner (1983) and the high frequency of this species in aerial trap catches. In conclusion, there is no evidence for human-mediated translocations of *N. capsiformis*.

PENTATOMIDAE

Acrosternum millierei (MULSANT & REY, 1866)

A single specimen of this Mediterranean species, extending to tropical Africa, was captured in a light trap in 2004 in Zala County, Hungary (Kondorosy 2005). Its status deserves further attention as it may become established under current climatic conditions in temperate Europe as observed for *Nezara viridula*.

REDUVIIDAE

Oncocephalus sp.

Members of this species-rich (some 200 species are known worldwide) assassin bug genus are repeatedly introduced to Central Europe, but no established populations north of the Alps are known so far. A single male of *O. squalidus* (Rossi, 1790), found 1987 at light in Styria (Austria), was considered a stowaway with entomological equipment from Croatia (Adlbauer 1992). A single female of *O. pilicornis* Reuter, 1882 was found 1990 on a floodplain in Worcestershire (UK) (Whitehead 2006). Contrary to Whitehead (2006), who gives detailed instructions where to look for this species, and even considers it to be of high conservation value at its whole-range edge, it is here treated as a single, accidentally introduced specimen not established in the UK. This is corroborated by the clear distributional gap of occurrence of this record to the Mediterranean region, the biogeography of the genus and, not the least, no further specimens having been discovered in the United Kingdom for 17 years.

RHOPALIDAE

Liorhyssus hyalinus (FABRICIUS, 1794)

This bug is a migratory species with strong dispersal capabilities. It is known to occur in all regions. There may be doubts about the alien status on some islands (e.g., considered as alien for the Azores by Borges *et al.* 2005), but because of its migratory capability, these records are here considered as vagrants or temporarily established colonies without human-mediated translocations. Records in temperate Europe have increased recently (e.g., Germany – Heckmann & Rieger 2001, United Kingdom – Kirby *et al.* 2001), probably because of climatic change. A very detailed account of its distribution and biology is provided by Hradil *et al.* (2007).

STENOCEPHALIDAE

Dicranocephalus setulosus (FERRARI, 1874)

A Mediterranean species, mentioned for Austria by Moulet (1995), based on a single specimen collected 1982 in Salzburg. Not considered native to Austria by Rabitsch (2005) and also here considered as accidentally introduced without subsequent establishment.

2) Numbers of alien species

In this paper 42 established alien Heteroptera species are given for Europe (Table 1). The alien Heteroptera of Europe make up only a small fraction of established alien insects of Europe (approximately 3 %, Roques *et al.* 2008), of the Palaearctic Heteroptera (approximately 0.5 %, Aukema & Rieger 1995–2006) and of the European Heteroptera (approximately 1.4 %, Aukema & Rieger 1995–2006). Compared to the 83 alien Heteroptera of Canada (6.8% of the land-bug fauna) (Scudder & Foottit 2006; Wheeler *et al.* 2006) (most of them of European origin), this are a fairly low number and percentage. In the following analyses only species of category 1 are included, unless mentioned otherwise: that means alien species on European islands, not established species used for biological control, and species with doubtful or unclear alien status are excluded.

3) Origin of alien species and temporal trends

Within the 42 alien Heteroptera 12 species (29 %) are alien to Europe, *id est* they have their origin outside Europe (eight are from North America, three from the Eastern Palaearctic, and one from New Zealand). Six species (14 %) are considered cryptogenic with unclear origins and pan-tropical or cosmopolitan distribution. The majority of species (24 species, 57 %) is of European origin, but translocated to other parts of Europe, and therefore alien in Europe. There are slightly different ratios in the complete inventory of alien terrestrial invertebrates for Europe: 39 % of the species are of European origin, 9 % are cryptogenic, and 52 % are alien to Europe (Roques *et al.* 2008), indicating a strong potential for intra-European exchange of Heteroptera species. A high percentage of intra-European exchange of pest species was also observed in European interception data during 1995-2004 (Roques & Auger-Rozenberg 2006).

Although sampling size is small, there is a trend for the number of North American Heteroptera species coming to Europe to increase in recent decades (Fig. 1). Most interestingly, the opposite pattern is true in reverse direction. Carpinera (2002) also observed a peak of European introduction to America for non-native vegetable pests in the past between 1850 and 1899. Although this trend needs to be verified by applying a larger data set including other insect groups, it may indicate that more insects from North America are to be expected to arrive in Europe in the future. Figure 1 may also demonstrate different policies of regulation between both regions. Whereas the United States restrict entrance at different invasion hubs (successfully, if declining numbers of Heteroptera species are used as an indicator) since around the 1910s, Europe does not. This explanation adds to the possible hypotheses that may explain this asymmetrical North American-European insect exchange (Niemelä & Mattson 1996; Mattson *et al.* 2007). And this extends to secondary introductions: The origin of the Brown Marmorated Stink Bug *Halyomorpha halys* in Switzerland, which is native to Asia, may well be North America, whither it was recently introduced. Because of genetic bottlenecks it may be possible to elucidate the origin of these specimens by genetic fingerprint methods. The fact that North America has contributed relatively few insects (particularly pests) to Europe is known (at least) since Lindroth (1957) and was confirmed with recent data (Roques & Auger-Rozenberg 2006).

The analysis of the year of first record indicates an increasing trend of new arrivals at a rate, on average, of 2.7 species per decade in the 20th century, but 7 species in each of the last two decades (Fig. 2). Moreover, half the alien species currently exhibit moderate or strong expansive spread across Europe (Table 2), so that not only additional species will arrive but species already present will increase in abundance and range in Europe. Heteroptera still play only a minor role in the complete alien insect inventory; Roques *et al.* (2008) calculated an average of 17.5 new insect species in Europe per year between 2000 and 2007. This number is well below the estimations of approximately 5 to 10 new arrivals per year for insect species in the United States by Levine & D'Antonio (2003) and Work *et al.* (2005).

4) Pathways and habitats of alien species

The most important pathway of alien Heteroptera is translocation as contaminant (49 %), ususally with ornamental plants, followed by unintentional introduction through natural dispersal (unaided) across political borders within Europe (28 %), and translocation as stowaways within a transport vector (21 %) (Table 2). This corresponds to results of Kirby *et al.* (2001) for the Hemiptera of the United Kingdom and of Kenis *et al.* (2007) for the alien insects of Austria and Switzerland. Introductions of eggs or young larvae with ornamental plants provide a hostile environment during the movement, but also during the first, most critical, days or weeks in the new environment. A few Heteroptera species are domestic (synanthropic) species. Beside the notorious bedbug, this pertains to both assassin bugs, although records outside buildings are known as well. Wygodzinsky (1966) noted with respect to *Ploiaria chilensis*: "The distribution of this apterous species over several continents and its presence on many islands speak for dispersal by man."

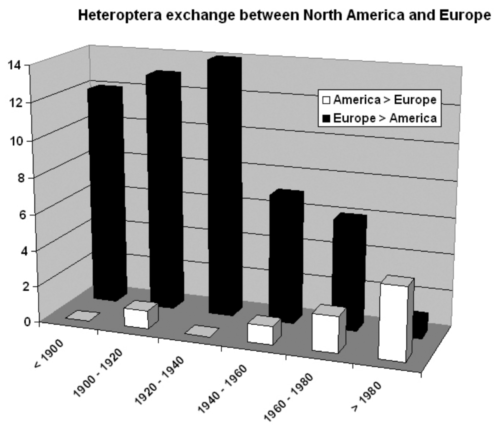

FIGURE 1. Number of alien Heteroptera species translocated from Europe to North America (data from Scudder & Foottit 2006) and from North America to Europe (this study).

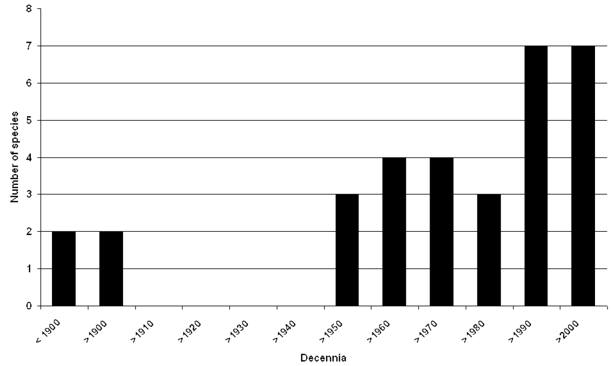

FIGURE 2. Year of first discovery of alien Heteroptera in Europe according to Table 1. Cryptogenic species excluded.

In agreement with the dominant pathway, most Heteroptera species live in cultivated horticultural and domestic habitats (Table 2). Among natural habitats, grasslands and woodlands are most frequently colonized.

Several Heteroptera species (*Orius* sp., *Macrolophus* sp., and others) are successfully employed in biological control against greenhouse pests, especially *Frankliniella occidentalis*, white flies, and aphids. Approximately 30 species within the family Anthocoridae have been introduced into other countries worldwide, deliberately as biocontrol agents or unintentionally with commerce (Lattin 1999). In North America, 16 alien anthocorid species are recognized, seven of these used for biological control of which two have become established (Lattin 1999). In Europe, only one documented case of establishment after escape is known so far (*Perillus bioculatus*), but it is likely for other species (e.g., *Orius laevigatus*). Under a precautionary approach, the use of native predators is to be favoured over the use of alien species. This is particularly true as most predatory Heteroptera are generalists in their diet and therefore suspected to be of higher risk and unpredictability in their ecological effects to native biota if established (Horton *et al.* 2004; Snyder & Evans 2006).

5) Taxonomy and Biology of alien species

The taxonomic composition of the alien Heteroptera of Europe is dominated by Miridae (17 species, 40 %), Tingidae (8 species, 19 %), and Anthocoridae (5 species, 12 %). All of which are overrepresented compared to the native European Heteroptera fauna (Aukema & Rieger 1995–2006). More than half of the species are phytophagous (24 species, 57 %), followed by predatory species (12 species, 29 %), and zoophytophagous species (5 species, 12 %).

Only 5 of the phytophagous species are considered poly-phytophagous, whereas the majority are regarded oligo- or even mono-phytophagous with a restricted dietary spectrum, limited to a single plant family, genus or species. Invasion biology theory assumes that polyphagy is advantageous over stenophagy for establishment success (Kolar & Lodge 2001). While this is doubtless true for colonizing events, when species are translocated to new territories without their food plant, the situation may differ if translocation occurs as egg or nymph together with the food plant. In such a case, oligophagous and monophagous species are at advantage being highly adapted to and translocated with their food, which may be alien in the new territory as well. Similarly, 45 % of the non-native vegetable pests in North America have a narrow host range (a single plant family) (Carpinera 2002), and this pattern is also true for European forest insects introduced to North America (Niemelä & Mattson 1996). As well, a high percentage of non-native insects living exclusively on non-native host plants was found by Kenis *et al.* (2007) for Central Europe, and Roques *et al.* (2006) showed for phytophagous species on exotic conifers that if highly specialized species were introduced along with their host, this species caused more damage than in the original range, most probably because of the absence of natural enemies and indigenous competitors.

The average body size of the alien Heteroptera of Europe (5.0 mm, n = 42) is smaller than the average of the Central European Heteroptera (5.6 mm, n = 996). This corresponds with data for non-native British insects: probability of establishment decreased with increasing body size (Lawton & Brown 1986).

A few European Heteroptera species are trophically bound to *Juniperus* sp., the only native genus of the plant family Cupressaceae in Europe, with endangered species in some parts of Europe. For ornamental reasons additional genera and non-native species of *Juniperus* are used (e.g., *Thuja*, *Chamaecyparis*, *Juniperus chinensis*) and regularly planted in house gardens, public parks, and cemeteries. Native and non-native Heteroptera species adapted to this new resource and made their way into suburban and urban sites and increased their range considerably. These species are the native *Chlorochroa juniperina* (Pentatomidae), *Cyphostethus tristriatus* (Acanthosomatidae), *Gonocerus juniperi* (Coreidae), *Phytocoris parvulus* (Miridae), the (eventually?) non-native *Dichrooscytus gustavi* (Miridae), and the Mediterranean *Orsillus depressus* (Lygaeidae). Native juniper-feeding species may suffer from high population densities of alien species on their hosts via intraguild competition for food, egg deposition and hibernation sites, particularly in invaded natural *Juniperus*-stands (Aukema 2003; Werner 2004). To the contrary, Heteroptera species preferring *Juniperus* at higher altitudes (e.g., *Globiceps juniperi*, *Phytocoris juniperi*) have so far not profited much from the new resource in the lowlands.

6) Distribution of alien species in Europe

Most species are currently known to occur in the Czech Republic (19 species) and Germany (17 species), followed by Western European countries (Belgium 15 sp., France and United Kingdom 14 sp. each, and Netherlands 13 sp.) (Fig. 3), resulting to an apparent (north)west–(south)east gradient. As this only partly reflects distribution of collectors, it is assumed to rather reflect horticultural tradition in Europe, which serves as a major invasion hub for alien Heteroptera species. This is partly corroborated by the invasion foci of Heteroptera alien to Europe (n = 12), three species having been first recorded in the Netherlands and Italy, two in the United Kingdom, and one each in Portugal, Spain, Switzerland, and the European part of Turkey.

In some cases a range expansion in the natural range (e.g., *Leptoglossus occidentalis*) or in the secondary range (e.g., *Halyomorpha halys*) was observed well before the introduction into Europe. Such a pattern may enable prediction of future arrivals in Europe and it is recommended that an eye be kept on ongoing expansions in other regions, especially North America. A large native range is generally acknowledged advantageous for a successful establishment in new territories (Kolar & Lodge 2001), but exceptions from this rule are *Deraeocoris flavilinea* (previously considered endemic to Sicily) and *Orthotylus caprai* (previously considered endemic to Sardinia).

It is well known that only a small proportion of introduced species is able to establish and proliferate (Williamson & Fitter 1996). Most of the unsuccessful introductions go unnoticed, particularly in insects. Heteroptera are rarely intercepted (Southwood & Leston 1959; Caton *et al.* 2006; McCullough *et al.* 2006; Roques & Auger-Rozenberg 2006; Kenis *et al.* 2007) and accidentally introduced single specimens are rarely noticed and more rarely published, e.g., *Arilus cristatus* (Linnaeus) [Reduviidae] imported from the USA to the United Kingdom with cut flowers (Reid 2005), *Macchiademus diplopterus* (Distant) [Lygaeidae] imported repeatedly from South Africa to the United Kingdom with plum, nectarine, orange and, apple fruits (Malumphy & Reid 2007), or *Solenosthedium bilunatum* (Lefebvre) [Scutelleridae] imported with salad from the Mediterranean and found in a supermarket in Ludwigsburg, Germany (Heckmann & Rieger 2001). Hoffmann & Melber (2003), in their checklist of the Heteroptera of Germany, listed more intercepted Heteroptera: *Centrocoris spiniger* (Fabricius) [Coreidae], *Crocistethus waltlianus* (Fieber) [Cydnidae], *Eurygaster hotten-*

totta (Fabricius) [Scutelleridae], *Paraparomius leptopoides* (Baerensprung), and *Remaudiereana annulipes* (Baerensprung) [Lygaeidae]. All these species are of Mediterranean origin and repeated northerly introductions as stowaways with transports are likely, where they may profit from the changed environmental settings and climatic change and establish resident populations in the future. However, because these (and other) factors are interdependently enforced, it is difficult to unambiguously separate the ultimately driving factor (but see e.g., Didham *et al.* 2007).

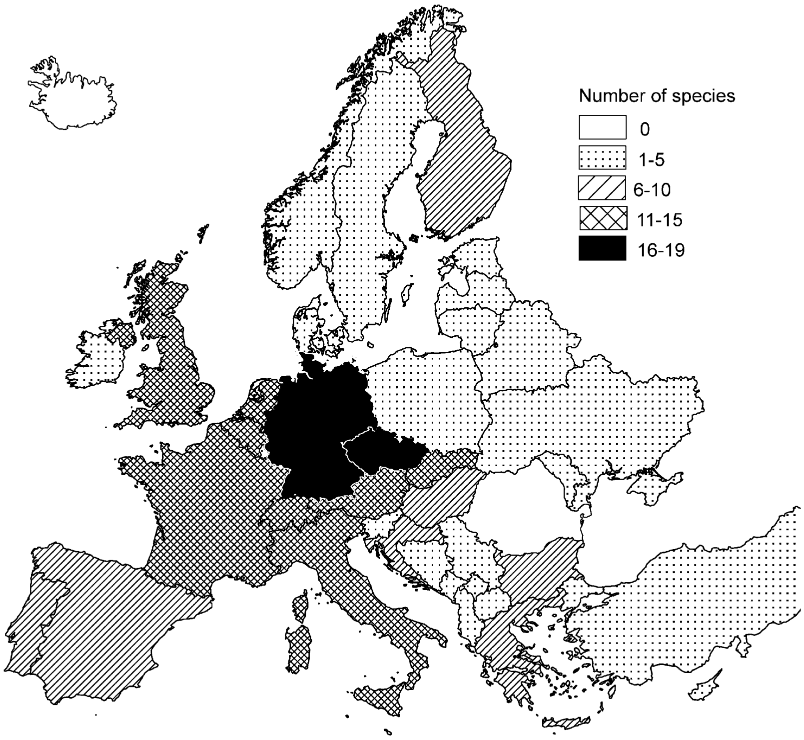

FIGURE 3. Numbers of alien Heteroptera species in European countries according to Table 1. Probably native species excluded.

7) Impacts of alien species

Scudder & Foottit (2006) mentioned that no evidence exists for a negative ecological impact on native Heteroptera species in Canada. While this holds true for Europe, however, it also must be mentioned that no targeted research has yet addressed this question (Kenis *et al.* 2008). Much research is devoted to the invasion process and discussing the scale of the problem, but relatively little emphasis has been laid on the effects to resident biota.

Parker *et al.* (1999) identified five levels of ecological impact of invaders: (i) on individuals, (ii) genetic effects, (iii) on populations, (iv) on communities, and (v) on ecosystem processes. No data are available for negative effects of alien Heteroptera at the populations and ecosystem level. Genetic effects of alien species are generally poorly investigated; among heteropterans, hybridization between native and alien *Macrolophus* or *Arocatus* species may happen, but this is highly speculative without any genetic evidence. Interference at the community level is supposed locally for *Trichocorixa* and within the juniper-feeding guild for *Orsillus*, but also not investigated.

TABLE 2: Invasion and biological attribute data of established alien Heteroptera of Europe. Pathways: Escape, Contaminant, Stowaway, Unaided, according to Hulme et al. (2008). Impacts: Negative to Economy (neg. Econ.), Positive to Economy (pos. Econ.), Negative to native Biodiversity on individuals (e.g., herbivory, predation, competition, disease transmission) (Ecol. indiv.) or on communities (Ecol. comm.), according to Parker et al. (1999). Habitat classification: B-Coastal habitats, C-Inland surface waters, E-Grasslands, G-Woodland, I-Cultivated agricultural, horticultural and domestic habitats, according to EUNIS, level 2 (http://eunis.eea.eu.int/habitats.jsp).

Taxon	**Pathway**	**Impact**	**Habitat**	**Trophic guild / Host plant(s)**	**Hibernation stage**	**Number of Generations**	**Average Body Size (mm)**	**Population and Range Trend**
Anthocoridae								
Amphiareus obscuriceps (Poppius, 1909)	Stowaway Unaided	–	E, I	zoophagous	adult?	1–2?	2,75	moderate expansion
Anthocoris butleri Le Quesne, 1954	Contaminant Unaided	–	I	zoophagous / Buxaceae (*Buxus*)	adult	1–2	4,00	stable
Anthocoris sarothamni Douglas & Scott, 1865	Contaminant Unaided	–	I	zoophagous / Fabaceae (*Cytisus*)	adult	1–2	3,45	stable
Buchananiella continua (White, 1880)	Stowaway	–	I	zoophagous	adult	1–2?	2,45	moderate expansion
Lyctocoris campestris (Fabricius, 1794)	Stowaway	–	I	zoophagous	adult	2	3,70	stable
Coreidae								
Leptoglossus occidentalis Heidemann, 1910	Contaminant	neg. Econ. Ecol. indiv.	G, I	phytophagous / Pinaceae	adult	1	18,00	strong expansion
Corixidae								
Trichocorixa verticalis (Fieber, 1851)	Contaminant	Ecol. comm.	C	omnivorous	larvae, adult	2	4,50	stable
Lygaeidae								
Arocatus longiceps Stål, 1872	Contaminant Unaided	–	I	phytophagous / Platanaceae (*Platanus*)	adult	1–2	5,55	strong expansion
Nysius huttoni F.B.White, 1878	Stowaway	neg. Econ.	I	poly-phytophagous	adult	2	3,50	moderate expansion
Orsillus depressus (Mulsant & Rey, 1852)	Contaminant Unaided	Ecol. indiv. Ecol. comm.	E, I	phytophagous / Cupressaceae	adult (larvae)	1	7,45	moderate expansion
Oxycarenus lavaterae (Fabricius, 1787)	Stowaway Unaided	neg. Econ. Ecol. indiv.	G, I	phytophagous / Malvaceae, Tiliaceae	adult (larvae)	2–4	5,40	moderate expansion
Miridae								
Closterotomus trivialis (A. Costa, 1853)	Contaminant	–	I	poly-phytophagous	egg	1	7,25	stable
Deraeocoris flavilinea (A. Costa, 1862)	Stowaway Unaided?	–	I	zoophagous	egg	1	6,75	moderate expansion
Dichrooscytus gustavi Josifov, 1981	Contaminant Unaided?	–	I	phytophagous / Cupressaceae	egg	1–2	4,05	moderate expansion

...continued

Table 2 continued...

Taxon	**Pathway**	**Impact**	**Habitat**	**Trophic guild / Host plant(s)**	**Hibernation stage**	**Number of Generations**	**Average Body Size (mm)**	**Population and Range Trend**
Dicyphus escalerae Lindberg, 1934	Contaminant Unaided?	–	I	phytophagous / Veronicaceae (*Antirrhinum majus*)	egg, larvae, adult	2	3,40	moderate expansion
Macrolophus glaucescens Fieber, 1858	Contaminant Unaided	–	E	zoophagous / Asteraceae (*Echinops*)	egg, larvae	2	3,35	stable
Nesidiocoris tenuis (Reuter, 1895)	Stowaway	neg. Econ. pos. Econ.	I	zoophytophagous	egg	up to 8	3,50	stable
Orthotylus adenocarpi (Perris, 1857)	Contaminant Unaided	–	E, G, I	zoophytophagous / Fabaceae (*Cytisus*)	egg	1	4,35	stable
Orthotylus caprai Wagner, 1955	Contaminant Unaided	–	I	(zoo?)phytophagous / Cupressaceae	egg	1?	3,25	moderate expansion?
Orthotylus concolor (Kirschbaum, 1856)	Contaminant Unaided	–	E, G, I	zoophytophagous / Fabaceae (*Cytisus*)	egg	1	4,25	stable
Orthotylus virescens (Douglas & Scott, 1865)	Contaminant Unaided	–	E, G, I	zoophytophagous / Fabaceae (*Cytisus*)	egg	1	4,40	stable
Taylorilygus apicalis (Fieber, 1861)	Stowaway	–	I	poly-phytophagous	egg	1	5,20	stable
Tupiocoris rhododendri (Dolling, 1972)	Contaminant	–	I	zoophagous / Ericaceae (*Rhododendron*)	egg	1	4,00	moderate expansion
Tuponia brevirostris Reuter, 1883	Contaminant	–	I	phytophagous / Tamaricaceae (*Tamarix*)	egg	1	2,80	moderate expansion
Tuponia elegans (Jakovlev, 1867)	Contaminant	–	I	phytophagous / Tamaricaceae (*Tamarix*)	egg	1	3,20	moderate expansion
Tuponia hippophaes (Fieber, 1861)	Contaminant	–	I	phytophagous / Tamaricaceae (*Tamarix*)	egg	1–2	2,85	stable?
Tuponia macedonica Wagner, 1957	Contaminant	–	I	phytophagous / Tamaricaceae (*Tamarix*)	egg	1	3,60	moderate expansion
Tuponia mixticolor (A. Costa, 1862)	Contaminant	–	I	phytophagous / Tamaricaceae (*Tamarix*)	egg	1	3,00	moderate expansion
Pentatomidae								
Halyomorpha halys (Stål, 1855)	Contaminant	–	I	poly-phytophagous	adult	1	15,00	unknown
Nezara viridula (Linnaeus, 1758)	Contaminant Unaided?	neg. Econ.	I	poly-phytophagous	adult	up to 5	14,00	moderate expansion
Perillus bioculatus (Fabricius, 1775)	Escape	pos. Econ. Ecol. indiv.	G, I	zoophagous	adult	2–3	10,00	moderate expansion

...continued

Table 2 continued...

Taxon	Pathway	Impact	Habitat	Trophic guild / Host plant(s)	Hibernation stage	Number of Generations	Average Body Size (mm)	Population and Range Trend
Reduviidae								
Empicoris rubromaculatus (Blackburn, 1889)	Stowaway	–	I	zoophagous	egg, larvae, adult	acyclic?	5,25	stable
Ploiaria chilensis (Philippi, 1862)	Stowaway	–	I	zoophagous	egg, larvae, adult	acyclic?	5,00	stable
Saldidae								
Pentacora sphacelata (Uhler, 1877)	Stowaway	–	B	zoophagous	egg	1	4,55	stable
Tingidae								
Corythucha ciliata (Say, 1832)	Contaminant Stowaway	neg. Econ.	I	phytophagous / Platanaceae (*Platanus*)	adult	1–3	3,50	moderate expansion
Corythucha arcuata (Say, 1832)	Contaminant Stowaway	Ecol. indiv.	G	phytophagous / Fagaceae (*Quercus*, *Castanea*)	adult	3	3,50	moderate expansion
Dictyonota fuliginosa A. Costa, 1853	Contaminant Unaided	–	E, G, I	phytophagous / Fabaceae (*Cytisus*)	egg	1	4,45	stable
Elasmotropis testacea (Herrich-Schäffer, 1830)	Contaminant Unaided	–	E	phytophagous / Asteraceae (*Echinops*)	adult	2	3,10	stable
Stephanitis oberti (Kolenati, 1857)	Contaminant	neg. Econ.	I	phytophagous / Ericaceae (*Rhododendron*, *Vaccinium*)	egg, (adult)	1	3,60	moderate expansion?
Stephanitis pyrioides (Scott, 1874)	Contaminant	neg. Econ.	I	phytophagous / Ericaceae (*Rhododendron*)	egg, (adult)	1	3,50	moderate expansion?
Stephanitis rhododendri Horváth, 1905	Contaminant	neg. Econ.	I	phytophagous / Ericaceae (*Rhododendron*)	egg, (adult)	1	3,15	moderate expansion?
Stephanitis takeyai Drake & Maa, 1955	Contaminant	neg. Econ.	I	phytophagous / Ericaceae (*Pieris*)	egg, (adult)	2–4	3,25	moderate expansion

Regarding impact on individuals, field observations indicate competition, pathogen-transfer, predation, and herbivory, but all these cases need more thorough investigations. The case of transmitting spores of the pathogenic fungus *Seiridium cardinale*, responsible for cypress bark canker disease by *Orsillus* species, needs further study (Rouault *et al.* 2005). Escaped polyphagous predatory biocontrol agents (*Perillus*, *Orius*, etc.) may pose a threat to native prey, but this is rather unlikely at currently low abundances. Feeding of *Leptoglossus occidentalis* on conifers is known to reduce seed fertility (Mitchell 2000), and this may be relevant not only to forestry but for native stands as well. The weakening of food plants (chlorosis, reduced sap flow, discoloration of the leaf surface, reduced photosynthetic activity, premature leaf fall, increasing susceptibility to infections) was reported for *Tilia* sp. and *Quercus* sp., caused by *Oxycarenus lavaterae* and *Corythucha arcuata*, respectively (Tomic & Mihajlovic 1974; Velimirovic *et al.* 1992; Forster *et al.* 2005). Similar effects were also observed in ornamental plants (e.g., *Pieris*, *Platanus*, *Rhododendron*) in urban settings by *Corythucha* *ciliata* and *Stephanitis* sp., including negative economic and aesthetic effects (Halstead & Malumphy 2003; Rietschel 2007). Some species are considered to be household pests, nuisances to people, usually when invading houses or aggregating on walls (e.g., *Oxycarenus lavaterae*, *Leptoglossus occidentalis*). In general, the ecological impacts of alien heteropteran species on native species, their host plants, or their role as vectors for pathogens are not well understood and clearly require further studies.

Negative economic effects are known for many heteropteran species (Schaefer & Panizzi 2000), but among the alien Heteroptera of Europe there is so far no major pest species in agriculture or forestry. *Leptoglossus occidentalis*, however, has the potential to become such, as this species is currently increasing rapidly in range and abundance in Europe. Also, *Nezara viridula*, a well known pest on vegetables and fruits (Todd 1989), deserves watchful attention. There is currently one EPPO Alert-listed Heteroptera species (*Nysius huttoni* was added to the Alert List in 2006) and three deleted species (*Corythucha arcuata* was deleted from the Alert List in 2007, *Stephanitis pyrioides* was deleted 2002, *S. takeyai* was deleted 2004). *Nysius huttoni* may pose a risk to a large number of weeds and crops, especially wheat and Brassicaceae (Smit *et al.* 2007). Although no negative impacts are yet confirmed in the introduced range in Europe, current data on the invasion in Central Europe cannot rule out possible effects in the future.

8) Excluded Species

Not a few Heteroptera species are currently expanding their range from the Mediterranean region northwards. This phenomenon may be directly linked with global warming, but unambiguous conclusions are difficult to be made since species also may have been overlooked so far. Most probably a mixture of mutually not exclusive factors (natural expansion, range expansion because of global warming, direct translocation with vehicles and passive translocation with the increasing exchange of ornamentals and goods) is responsible for the observed patterns. Also, altered land use practices and the increasing eutrophication has led to a change in European phytocoenoses, which in turn is changing the possibilities for establishment of newly arrived species. Among these species, just to mention a few, are *Brachynotocoris puncticornis* Reuter, 1880 and *Conostethus venustus* Fieber, 1859 (Miridae), *Metopoplax ditomoides* (A. Costa, 1847) and *Oxycarenus pallens* (H.-S., 1850) (Lygaeidae). These species are excluded in the present work, although their alien status deserves critical re-examination and also depends on the scale of the investigation. Whereas the western invasion route of *Oxycarenus pallens*, for example, is regarded as natural spread, the eastern invasion route may be because of accidental introduction with plant nursery stock material, as suggested by Dietze *et al.* (2006). Also, Deckert (2004) suggested an introduction with plant material for the west European *Metopoplax ditomoides* to eastern Germany (Brandenburg, Saxony-Anhalt). Some of these species were also recently introduced to North America (e.g., *Metopoplax ditomoides*, Lattin & Wetherill 2002), indicating a strong potential for translocation. According to Aukema (2003) 27 species were newly recorded in the Netherlands between 1980 and 2002. He suggested a natural pathway (active dispersal) for 17 species and a transport-related pathway (passive dispersal) for 4 species, the remaining six species being either overlooked or species with unknown pathway(s). In a similar comparison, Rabitsch (2008) found 84 newly recorded species in Austria between 1991 and 2007. Two-thirds of the species were overlooked and 18 species were considered as established new arrivals, of which four species are regarded as having been introduced with ornamental plants or transport, and 14 species favoured by current climatic conditions. Regular monitoring activities are necessary to detect and interpret the ongoing changes of the Heteroptera inventory of Europe.

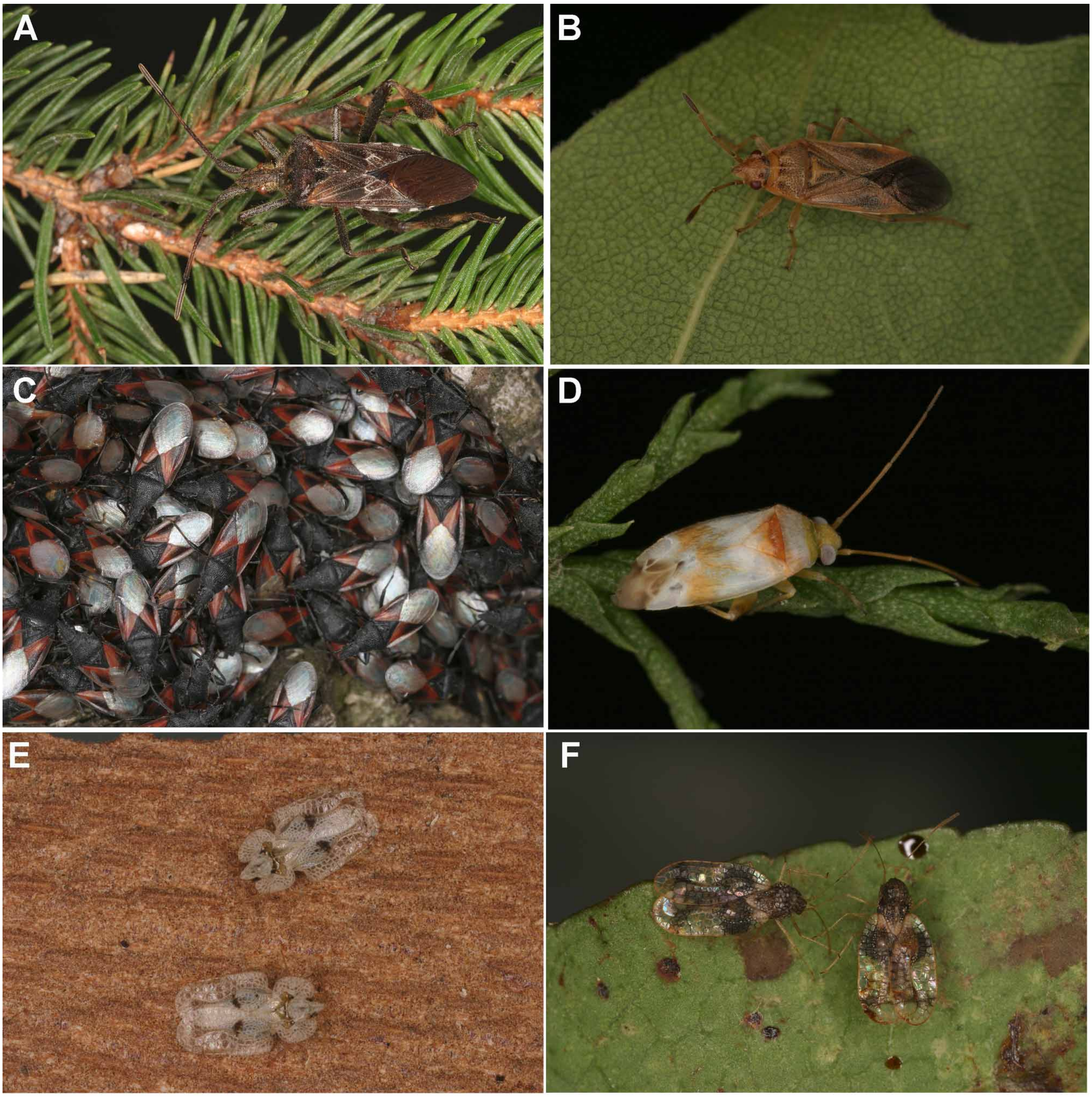

FIGURE 4. Selection of alien Heteroptera of Europe. (a) *Leptoglossus occidentalis* Heidemann, 1910, (b) *Arocatus longiceps* Stål, 1872, (c) Aggregation of *Oxycarenus lavaterae* (Fabricius, 1787), (d) *Tuponia elegans* (Jakovlev, 1867), (e) *Corythucha ciliata* (Say, 1832), (f) *Stephanitis takeyai* Drake & Maa, 1955. Photos: W. Rabitsch.

9) Conclusions and Outlook

This study revealed that introductions of alien Heteroptera to Europe increase and that next to nothing is known about their ecological effects on native species or their economic effects on human interests. Translocations as contaminants with ornamental plants and as stowaways with transport are considered the major pathways for alien Heteroptera into Europe. The former pathway should be more efficiently regulated and restricted by intensified quarantine inspections of imported plant material from outside and within Europe. Preference should be given to regionally grown plants for gardening and restoration.

The statement of Southwood & Leston (1959, see Introduction) on *Nezara viridula* in Great Britain is symptomatic of the unprecedented acceleration of biotic homogenisation around the globe. Within the last decades, the exchange of insect species in Europe has increased (Roques *et al*. 2008), and the successful establishment of more species will without doubt be promoted by climate change and habitat simplification.

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