

Alien and invasive scale insect species in Poland and their threat to native plants

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Abstract

A complete list of scale insect species (Coccoidea) alien to Poland is presented for the first time. A total of 51 species have been introduced to Poland since the 19th century, mainly from the Neotropical and Oriental regions. Of this group, 46 species live only indoors, 4 species develop outdoors and 1 species *Pulvinaria floccifera* (Westwood) develops both indoors and outdoors. Among the scale insects introduced into Poland, 16 species are considered to be invasive, while 13 species pose the greatest threats to native plants. For each species, the date of the first record in Poland, their origin, category and period of introduction, environment and principal hosts in Poland, invasive status and threat to native plants are provided based on bibliographic sources.

Key words: Poland, alien scale insects, geographic origin, invasive species, threat to native plants.

Introduction

Scale insects (Coccoidea) form the largest group of alien insects in Europe (Pellizzari and Germain, 2010). This group includes 129 species and this number represents about 30% of the total European scale insect fauna. Scale insects alien to Europe are native mainly to the tropical regions of Asia (21.7%) and South America (17.8%). The origin of 26 species (20.2%) is not known and they are so-called cryptogenic species (Pellizzari and Germain, 2010).

In Europe, most alien scale insect species occur in France (96 species) and Italy (92 species) (Germain, 2008; Pellizzari and Germain, 2010). In the Maltese Archipelago, Canary Islands and Spain, 64, 51 and 50 species have been recorded respectively, while slightly fewer species have been recorded in the Autonomous Region of Madeira (44 species), Great Britain (43 species), Portugal (41 species) and Bulgaria (34 species) (Pellizzari and Germain, 2010; Trencheva *et al.*, 2010; Mifsud *et al.*, 2014).

So far, no comprehensive analysis has been available of the alien scale insects in Poland. The information given by Pellizzari and Germain (2010) as well as in domestic and international databases is incomplete and partially incorrect and needs revision.

The aim of this paper is to provide a complete list of scale insects introduced to Poland since the 19th century and to present data on their first detection in Poland, along with bibliographical references, their origin, category and period of introduction, environment and principal hosts in Poland, invasive status and threat to native plants based on available literature.

Materials and methods

In this paper, the definition of an alien species is that given in The Nature Conservation Act of 16 April 2004 (article 120, paragraph 1), where it is defined as a spe-

cies appearing outside its natural range, either as individual specimens or their parts, gametes, spores, seeds or eggs, from which they could survive and reproduce. We have treated species as introduced when they have become established both outdoor or indoors, but excluded those that have been discovered only once on imported plant material and where there is no evidence that they have become stabilized either in the field or indoors.

Alien scale insects species have been classified into trophic groups according to Nickel and Remane (2002); these are: 1st degree monophagous species - those restricted to a single plant host species; 2nd degree monophagous species - those restricted to a few host species from a single plant genus; 1st degree oligophagous species - those that can feed on many plant species within a single taxonomic family; 2nd degree oligophagous species - those that can feed on many plant species within two closely-related taxonomic families or on a few plant species from at most four taxonomic families; and polyphagous species - those that have a broad host range, without any apparent host plant specialization.

Further categories were introduced by Głowaciński *et al.* (2012), e.g., spatial: T - transoceanic (intercontinental); C - continental (Eurasian); R - regional introductions; and time-based classification: A - early historic, before 1800; H - historic - between 1800-1982; L - current introductions, those between 1983-2014.

Invasive alien species are commonly regarded as a major threat to ecosystems, human safety, and agriculture, forestry and fisheries (Mito and Uesugi, 2004). The alien scale insect species recorded in Poland have been classified here in respect of their invasive abilities and their threat level to native flora. Three groups of alien scale insects have been distinguished: S₁ - invasive species described in the literature as a pest, frequently present in large numbers and causing severe damage to host plants; S₂ - a non-invasive species, rarely noted and usually only present in low numbers; S₃ - a post-invasive species, one that was introduced a long time

ago and which has become well established in a natural environment, with either a relatively stable or a declining population.

Evaluating the threat level to native plants, the presence of closely-related native host plants, the environmental requirements of each scale insect species, and their invasive status in neighbouring countries with similar climate, have also been taken into consideration. The following threat levels have been distinguished: R₁ - high risk; R₂ - low risk; R₃ - risk unknown.

The families, as well as genera within each family and species within each genus are listed by alphabetical order and defined according to the classification used by Ben-Dov *et al.* (2014), while zoogeographical analysis was based on Łagowska (2001), Pellizzari and Germain (2010), Ben-Dov *et al.* (2014).

Results

Fifty-one scale insect species in 35 genera and 7 families (table 1) are here recorded from Poland. Alien species clearly dominate over the native ones in the Diaspididae, while the family Rhizoecidae is represented only by non-indigenous species. In the remaining families, the number of alien species is less than that of native species (figure 1).

The first alien scale insect species to be recorded from Poland was the brown soft scale (*Coccus hesperidum*) in 1829 (Brischke, 1883). Most alien scale insect species (16) were introduced between 1958-1982, while for Europe as a whole, most introductions (43 species) were noted between 1800-1907. As a result of introductions over the last 30 years, 14 alien species have been discovered in Poland, while 32 alien species have been recorded from Europe (figure 2).

As a result of an intercontinental (transoceanic) introduction, 29 species of Coccoidea have been introduced to Poland (figure 3). Significantly fewer species (14 spe-

cies) have been brought to Poland as a result of continental (Eurasian) introductions, and only 2 species (*Aonidia lauri* and *Dynaspidotus britannicus*) are indigenous to the Far Eastern subregion of the Palearctic (regional introduction) (table 1, figure 3). In the case of 6 alien species, namely *Parthenolecanium* sp., *Parthenolecanium perlatum*, *Hemiberlesia gliwicensis*, *Howardia biclavis*, *Parlatoria pergandii*, *Parlatoria proteus*, the estimation of the range of introduction has not been possible due to lack of information about their origin.

Figure 4 shows the probable origin of alien insects recorded in Poland. Those from the Neotropical region (21.6%) dominate over those from the Oriental (17.6%), Afrotropical (11.8%) and Far East (9.8%), and species from the Australasian and Nearctic regions each constitute only 5.9%. Two species - *A. lauri* and *D. britannicus* - are from the Mediterranean (3.9%). The precise origin remains unknown for about 23.5% of species (cryptogenic species) recorded from Poland.

Quite a lot of alien species (46) can live and develop only indoors in Poland, although five, namely *Aulacaspis rosae*, *Comstockaspis pernicioso*, *Pulvinaria floccifera*, *Parthenolecanium fletcheri* and *Parthenolecanium* sp. can overwinter and develop in the field. Of these, *P. floccifera* can also develop indoors (table 1).

In the trophic groups of alien scale insects, the polyphagous species (39) predominate. The remaining species are oligophagous of the 1st degree (*A. lauri*, *A. rosae*, *Aulacaspis yasumatsui*, *Gymnaspidium aechmeae*, *Kuwanaspis pseudoleucaspis*, *Lepidosaphes tokionis* and *Spilococcus mammillariae*) or the 2nd degree (*Furchadiaspis zamiae*, *P. fletcheri* and *P. perlatum*). Only *H. gliwicensis* and *Parthenolecanium* sp. have been included to the monophagous group (table 1).

Almost all alien species living indoors in Poland are found on exotic plants, e.g., on species of Agavaceae, Araceae, Arecaceae and Orchidaceae within the monocotyledons and on Apocynaceae, Araliaceae, Euphorbiaceae and Moraceae in the dicotyledons (table 1).

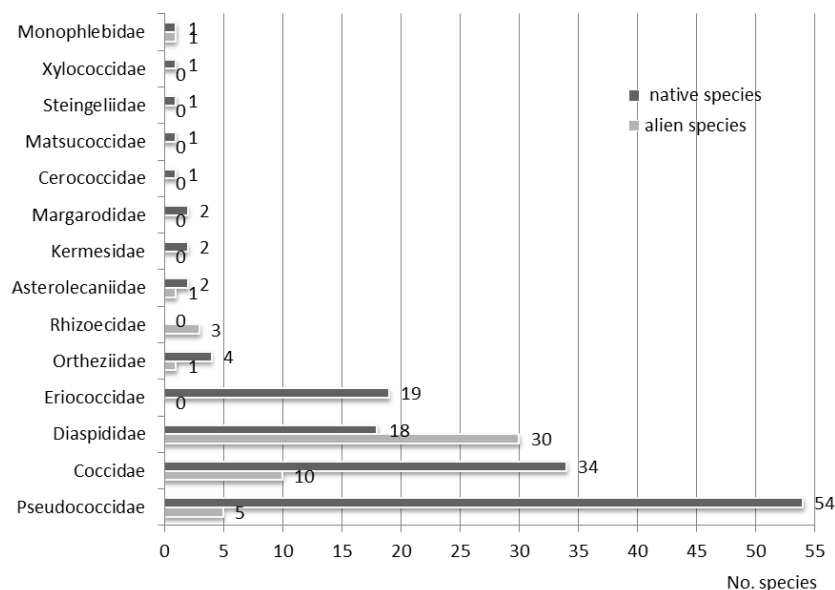


Figure 1. The number of scale insect species alien to Poland compared to the native fauna.

Table 1. List and characteristics of the scale insect species alien to Poland. Abbreviations: T - transoceanic (intercontinental) introduction; C - continental introduction (Euroasian); R - regional introduction; H - historic introduction, between 1800-1982; L - current introduction, 1983-2014; I - indoors; O - outdoors; S₁ - invasive alien species; S₂ - non-invasive alien species; S₃ - post-invasive alien species; R₁ - high risk; R₂ - low risk; R₃ - risk unknown.

Family species	Origin	Category of introduction	First record in Poland and valid references	Period of introduction	Environment	Trophic group/ principal hosts in Poland	Invasive status and bibliographic sources	Threat to native plants
Asterolecaniidae								
<i>Asterolecanium epidendri</i> (Bouche 1844)	Neotropical	T	1985 (Kawecki, 1985)	L	I	Polyphagous/ <i>Aloe</i> sp., <i>Anthurium</i> sp.	S ₂ (Dziedzicka, 1988a; 1990; Kawecki, 1985; Labanowski, 2009)	R ₂
Coccidae								
<i>Ceroplastes risci</i> (L. 1758)	Oriental	C	1926 (Szulczewski, 1926)	H	I	Polyphagous/ <i>Chaemorops humilis</i> , <i>Azalea mollis</i> , <i>Camellia japonica</i>	S ₂ (Szulczewski, 1926; Labanowski, 2009)	R ₂
<i>Coccus hesperidum</i> (L. 1758)	Oriental	C	1883 (Brischke, 1883)	H	I	Polyphagous/ mainly on Agavaceae, Araceae, Araceae	S ₁ (Dziedzicka, 1990; Lagowska, 2004)	R ₁
<i>Eucalymnatus tessellatus</i> (Signoret 1873)	Neotropical	T	1972 (Koteja, 1972)	H	I	Polyphagous/ mainly on Araceae, Moraceae	S ₂ (Dziedzicka, 1990)	R ₂
<i>Parasaissetia nigra</i> (Nietner 1861)	Afrotropical	T	1985 (Kawecki, 1985)	L	I	Polyphagous/ mainly on <i>Cycas</i> sp., <i>Ficus</i> sp., <i>Platyserium</i> sp.	S ₁ (Dziedzicka, 1990)	R ₂
<i>Parthenolecanium</i> sp.	Cryptogenic	-	2010 (Goliszek <i>et al.</i> , 2011)	L	O	Monophagous of the 2 nd degree/ <i>Rhododendron forrestii</i> , <i>Rhododendron molle</i>	S ₁ (Goliszek, 2014)	R ₁
<i>Parthenolecanium fletcheri</i> (Cockerell 1893)	Nearctic	T	1935 (Kawecki, 1935)	H	O	Monophagous of the 2 nd degree/ Cupressaceae	S ₁ (Kawecki, 1935; 1985)	R ₁
<i>Parthenolecanium perlatum</i> (Cockerell 1898)	Cryptogenic	-	1999 (Dziedzicka and Madro, 1999)	L	I	Monophagous of the 2 nd degree/ <i>Planthycerium weitchii</i> , <i>Davalia solida</i>	S ₂ (Dziedzicka and Madro, 1999)	R ₂
<i>Pulvinaria floccifera</i> (Westwood 1870)	Palaearctic/ Far Eastern	C	1969 (Koteja, 1972)	H	O, I	Polyphagous/ indoors: <i>Acalypha wilkesiana</i> , <i>Citrus aurantium</i> , <i>Camellia japonica</i> , <i>Schefflera arboricola</i> ; outdoors: <i>Ilex aquifolium</i>	S ₁ (Golan <i>et al.</i> , 2010; Labanowski and Sojka, 1997; 2004)	R ₁
<i>Saissetia coffeae</i> (Walker 1852)	Afrotropical	T	1926 (Szulczewski, 1926)	H	I	Polyphagous/ mainly on <i>Asparagus</i> sp., <i>Cycas</i> sp., <i>Hedera</i> sp., <i>Nephrolepis</i> sp., <i>Nerium</i> sp., <i>Yucca</i> sp.	S ₁ (Czyżewski, 1975; Dziedzicka, 1990)	R ₂
<i>Saissetia oleae</i> (Olivier 1791)	Afrotropical	T	1937 (Czyżewski, 1937a)	H	I	Polyphagous/ mainly on <i>Anthurium</i> sp., <i>Aloe</i> sp., <i>Nerium oleander</i> , <i>Monstera</i> sp., <i>Philodendron</i> ssp.	S ₁ (Czyżewski, 1975; Dziedzicka, 1990)	R ₂
Diaspididae								
<i>Abgallaspis cyanophylli</i> (Signoret 1869)	Cryptogenic	T	1961 (Komosińska, 1961)	H	I	Polyphagous/ mainly on <i>Cereus</i> sp.	S ₁ (Komosińska, 1968)	R ₂
<i>Aonidia lauri</i> (Bouche 1833)	Palaearctic/ Mediterranean	R	1968 (Komosińska, 1968)	H	I	Oligophagous of the 1 st degree/ <i>Laurus</i> sp.	S ₁ (Komosińska, 1968)	R ₂
<i>Aonidiella aurantii</i> (Maskell 1879)	Oriental	C	1988 (Dziedzicka, 1988a)	L	I	Polyphagous/ only on <i>Pandanus dubius</i>	S ₂ (Dziedzicka, 1988a)	R ₂
<i>Aspidiotus destructor</i> Signoret 1869	Cryptogenic	T	1992 (Kamkowski, 1993)	L	I	Polyphagous/ <i>Dracaena</i> sp.	S ₂ (Kamkowski, 1993; Lagowska, 2004)	R ₃

(Continued)

(Table 1 Continued)

Family species	Origin	Category of introduction	First record in Poland and valid references	Period of introduction	Environment	Trophic group/ principal hosts in Poland	Invasive status and bibliographic sources	Threat to native plants
Diaspididae (Continued)								
<i>Aspidiotus nerii</i> (Bouche 1833)	Afrotropical	T	1933 (Ruszkowski, 1933)	H I	I	Polyphagous/ mainly on <i>Chrysalidocarpus lutescens</i> , <i>Dracaena</i> sp., <i>Hedera helix</i> , <i>Nerium oleander</i>	S ₁ (Dziedzicka, 1988a; Labanowski, 2009; Labanowski and Soika, 2004; Lagowska, 2004)	R ₁
<i>Aulacaspis rosae</i> (Bouche 1833)	Palaearctic/ Far Eastern	C	1914 (Trzebinski, 1916)	H O	O	Oligophagous of the 1 st degree / <i>Fragaria</i> sp., <i>Rosa canina</i> , <i>Rosa rugosa</i> , <i>Rosa</i> sp., <i>Rubus caesius</i> , <i>Rubus</i> sp.	S ₂ (Lagowska, 2004; Lagowska and Golan, 2002)	R ₁
<i>Aulacaspis yasumatsui</i> Takagi 1977	Oriental	C	2007 (Labanowski, 2009)	L I	I	Oligophagous of the 1 st degree / <i>Cycas revoluta</i>	S ₂ (Labanowski, 2009)	R ₂
<i>Comstockaspis perniciososa</i> (Comstock 1881)	Palaearctic/ Far Eastern	C	1950 (Kawecki, 1950)	H O	O	Polyphagous/ fruit trees	S ₃ (Kawecki, 1985; Lagowska, 1995; 2004)	R ₁
<i>Chrysomphalus aonidum</i> (L. 1758)	Neotropical	T	1937 (Czyzewski, 1937a)	H I	I	Polyphagous/ mainly on <i>Dracena</i> sp.	S ₁ (Dziedzicka, 1987; Dziedzicka, 1988a)	R ₂
<i>Chrysomphalus dictyospermi</i> (Morgan 1889)	Oriental	C	1937 (Czyzewski, 1937a)	H I	I	Polyphagous/ mainly on <i>Cycas</i> sp.	S ₂ (Dziedzicka, 1987)	R ₁
<i>Diaspis boisduvalii</i> Signoret 1869	Neotropical	T	1975 (Czyzewski, 1975)	H I	I	Polyphagous/ mainly on Arecaceae and Palmae	S ₂ (Dziedzicka, 1987)	R ₂
<i>Diaspis bromeliae</i> (Kerner 1778)	Neotropical	T	1985 (Kawecki, 1985)	L I	I	Polyphagous/ mainly on <i>Aechmea</i> sp., <i>Bilbergia nutans</i>	S ₂ (Dziedzicka, 1987; 1988a)	R ₂
<i>Diaspis echinocacti</i> (Bouche 1833)	Neotropical	T	1937 (Czyzewski, 1937a)	H I	I	Polyphagous/ various species of cactus	S ₂ (Dziedzicka, 1988a; Kawecki, 1985)	R ₂
<i>Dynaspidiotus britannicus</i> (Newstead 1898)	Palaearctic/ Mediterranean	R	1926 (Szulcowski, 1926)	H I	I	Polyphagous/ <i>Eugenia australis</i> , <i>Laurus nobilis</i>	S ₂ (Szulcowski, 1926)	R ₂
<i>Fiorinia florinae</i> (Targioni Tozzetti 1867)	Oriental	C	1937 (Czyzewski, 1937b)	H I	I	Polyphagous/ no data	S ₂ (Lagowska, 2004)	R ₃
<i>Furchadaspis zamiae</i> (Morgan 1890)	Afrotropical	T	1968 (Komosińska, 1968)	H I	I	Oligophagous of the 2 nd degree / only on <i>Cycas</i> sp.	S ₂ (Komosińska, 1968; Dziedzicka, 1988a; Kawecki, 1985)	R ₂
<i>Gymnaspis aechmeae</i> Newstead 1898	Oriental	C	1961 (Komosińska, 1961)	H I	I	Oligophagous of the 1 st degree / only on <i>Aechmea</i> sp. and <i>Bilbergia</i> sp.	S ₂ (Komosińska, 1961)	R ₂
<i>Hemiberlesia glivicensis</i> (Komosińska 1965)	Cryptogenic	-	1959 (Komosińska, 1965)	H I	I	Monophagous of the 1 st degree/ <i>Bilbergia nutans</i>	S ₂ (Komosińska, 1965; Dziedzicka, 1989)	R ₃
<i>Hemiberlesia lataniae</i> (Signoret 1869)	Cryptogenic	T	1937 (Czyzewski, 1937a)	H I	I	Polyphagous/ <i>Archontophoenix cunninghamiana</i> , <i>Ficus bengalensis</i> , <i>Ophiopogon japonicus</i> , <i>Pandanus dubius</i> , <i>Sabal</i> sp., <i>Phormium tenax</i>	S ₂ (Dziedzicka, 1988a)	R ₂
<i>Hemiberlesia palmarum</i> (Cockerell 1892)	Neotropical	T	1961 (Komosińska, 1961)	H I	I	Polyphagous/ <i>Aechmea</i> sp., <i>Livistona</i> sp.	S ₂ (Komosińska, 1961)	R ₂

(Continued)

(Table 1 Continued)

Family species	Origin	Category of introduction	First record in Poland and valid references	Period of introduction	Environment	Trophic group/ principal hosts in Poland	Invasive status and bibliographic sources	Threat to native plants
Diaspididae (Continued)								
<i>Hemiberlesia rapax</i> (Comstock 1881)	Cryptogenic	T	1961 (Komosińska, 1961)	H	I	Polyphagous/ <i>Cycas</i> sp., <i>Ficus</i> sp., <i>Palmae</i> sp.	S ₁ (Dziedzicka, 1987; 1988a)	R ₂
<i>Howardia biclavis</i> (Comstock 1883)	Cryptogenic	-	1987 (Dziedzicka, 1987)	H	I	Polyphagous/ only on <i>Ficus</i> sp.	S ₂ (Dziedzicka, 1987; 1988a)	R ₂
<i>Kiwanaspis pseudo-leucaspis</i> (Kuwana 1902)	Palaearctic/ Far Eastern	C	1968 (Komosińska, 1968)	H	I	Oligophagous of the 1 st degree / <i>Arudinaria</i> sp., <i>Bambus</i> sp., <i>Phyllostachys</i> sp., <i>Semiarudinaria</i> sp., <i>Semibambusa</i> sp.	S ₂ (Dziedzicka, 1988a; Dziedzicka and Kamkowski, 2003)	R ₁
<i>Lepidosaphes tokionis</i> (Kuwana 1902)	Cryptogenic	T	2009 (Łabanowski, 2009)	L	I	Oligophagous of the 1 st degree/ <i>Codiaeum variegata</i>	S ₂ (Łabanowski, 2009)	R ₃
<i>Parlatoria pergandii</i> Comstock 1881	Cryptogenic	-	1964 (Komosińska, 1964)	H	I	Polyphagous/ mainly on <i>Croton</i> sp., <i>Cirrus</i> sp., <i>Ficus</i> sp.	S ₂ (Dziedzicka, 1987; 1989)	R ₂
<i>Parlatoria proteus</i> (Curtis 1843)	Cryptogenic	-	1926 (Szulcowski, 1926)	H	I	Polyphagous/ <i>Acalypha hispida</i> , <i>Aloe arborescens</i> , <i>Anthurium magnificum</i> , <i>Anthurium wagnerianum</i> , <i>Bilbergia nutans</i> , <i>Clerodon thomsonae</i> , <i>Croton codiaeum</i> , <i>Latania borbonica</i> , <i>Medinilla magnifica</i> , <i>Pandanus baptistii</i>	S ₂ (Dziedzicka, 1988a)	R ₂
<i>Pinnaspis aspidistrae</i> (Signoret 1869)	Oriental	C	1926 (Szulcowski, 1926)	H	I	Polyphagous/ mainly on fern	S ₁ (Dziedzicka, 1988a; Łabanowski, 2009; Łabanowski and Soika, 2004)	R ₁
<i>Pinnaspis strachani</i> (Cooley 1899)	Cryptogenic	T	1961 (Komosińska, 1961)	H	I	Polyphagous/ <i>Dracena</i> sp., <i>Papiliopteridium insigne</i> and palms	S ₂ (Komosińska, 1961)	R ₂
<i>Pseudaulacaspis pentagona</i> (Targioni Tozzetti 1886)	Palaearctic/ Far Eastern	C	turn of 1940 and 1950 (Dziedzicka and Kamkowski, 1999)	H	I	Polyphagous/ <i>Actinidia</i> sp., <i>Jasminum</i> sp.	S ₂ (Dziedzicka and Kamkowski, 1999)	R ₁
<i>Umbaspis regularis</i> (Newstead 1911)	Aftropical	T	1968 (Komosińska, 1968)	L	I	Polyphagous/ <i>Chamaerops</i> sp.	S ₂ (Komosińska, 1968)	R ₂
Monophlebidae								
<i>Icerya purchasi</i> Maskell 1879	Australasian	T	2002 (Chalańska and Łabanowski, 2002)	L	I	Polyphagous/ <i>Citrofortunella</i> sp.	S ₂ (Chalańska and Łabanowski, 2002)	R ₁
Ortheziidae								
<i>Insignorthesia insignis</i> (Browne 1887)	Neotropical	T	1933 (Ruszkowski, 1933)	H	I	Polyphagous/ <i>Coleus</i> sp.	S ₂ (Ruszkowski, 1933; Łagowska, 2004)	R ₂
Pseudococcidae								
<i>Nipaeococcus nipae</i> (Maskell 1893)	Neotropical	T	1937 (Czyzewski, 1937a)	H	I	Polyphagous/ mainly on <i>Philodendron</i> sp., <i>Phoenix</i> sp.	S ₂ (Dziedzicka, 1988b)	R ₂
<i>Planococcus citri</i> (Risso 1813)	Oriental	C	1926 (Szulcowski, 1926)	H	I	Polyphagous/ mainly on <i>Anthurium</i> sp., <i>Cirrus</i> sp., <i>Dracena</i> sp., <i>Ficus</i> sp., <i>Schefflera</i> sp.	S ₁ (Łagowska, 2004)	R ₂
<i>Pseudococcus longispinus</i> (Targioni Tozzetti 1867)	Australasian	T	1926 (Szulcowski, 1926)	H	I	Polyphagous/ mainly on <i>Ficus</i> sp., <i>Sirelizia</i> sp., <i>Opuntia</i> sp., <i>Clivia</i> sp.	S ₁ (Łagowska, 2004)	R ₂

(Continued)

(Table 1 Continued)

Family species	Origin	Category of introduction	First record in Poland and valid references	Period of introduction	Environment	Trophic group/ principal hosts in Poland	Invasive status and bibliographic sources	Threat to native plants
Pseudococcidae (Continued)								
<i>Pseudococcus maritimus</i> (Ehrhorn 1900)	Neotropical	T	turn of 1920 and 1930 (Dziedzicka, 1988b)	H	I	Polyphagous/ mainly on <i>Ficus</i> sp., <i>Clivia</i> sp., <i>Passiflora</i> sp.	S ₁ (Łabanowski, 2004)	R ₂
<i>Spilococcus mamillariae</i> (Bouche 1844)	Nearctic	T	2004 (Łabanowski, 2009)	L	I	Oligophagous of the 1 st degree/ <i>Gymnocladium mihanowichii</i>	S ₂ (Łabanowski, 2009)	R ₁
Rhizoecidae								
<i>Rhizoecus americanus</i> (Hambleton 1946)	Nearctic	T	2004 (Łabanowski, 2009)	L	I	Polyphagous/ <i>Cycas revoluta</i>	S ₂ (Łabanowski, 2009)	R ₂
<i>Rhizoecus cacticans</i> (Hambleton 1946)	Neotropical	T	1981 (Kawecki, 1985)	H	I	Polyphagous/ various species of cactus	S ₂ (Dziedzicka, 1988a; Goszczyński and Golan, 2011)	R ₂
<i>Rhizoecus dianthi</i> Green 1926	Australasian	T	1999 (Dziedzicka and Madro, 1999)	L	I	Polyphagous/ <i>Acacia longifolia</i>	S ₂ (Dziedzicka and Madro, 1999)	R ₂

However, several alien scale insects live outdoors on roses, wild strawberries and blackberries (*A. rosae*), white-cedars and junipers (*P. fletcheri*), apple trees (*C. perniciosus*), common holly (*P. floccifera*) and rhododendrons or azaleas (*Parthenolecanium* sp.) (table 1).

Of the alien species listed in table 1, 16 are considered to be invasive, of which 13 species occur indoors and 3 species (*P. fletcheri*, *Parthenolecanium* sp., *P. floccifera*) can survive outdoors. The other scale insects form a non-invasive species group of 34 greenhouse species or are considered to be post-invasive (only *C. perniciosus*).

In summary, of the 51 scale insects alien to Poland, 13 species (21.6%) pose a significant threat to our native flora; 34 species are considered to pose little threat, while the status of 4 species is unknown (table 1).

Discussion

About 27,000 insect species has been reported from Poland (Andrzejewski and Weigle, 2003). According to the database of alien species prepared by the Institute of Nature Conservation (INC) in Cracow (Głowaciński *et al.*, 2012), about 137 insect species are non-indigenous (0.5% of native insect fauna), and this number is close to the number listed by the database developed by the Institute of Plant Protection of the National Research Institute (PPNRI) in Poznan (Invasive Species - Database). Both databases include scale insects. That of the INC lists 29 species of scale insects introduced to Poland, while that of the PPNRI lists 18 species, classifying all of them in the invasive group. On the other hand, Delivering Alien Invasive Species Inventories for Europe (DAISIE) database (www.europe-aliens.org) enumerates 24 scale insect species alien to Poland. It needs to be stressed that all of these lists are incomplete or provide incorrect information. For example, in the DAISIE database, there are three species (*Trionymus angustifrons*, *Pulvinaria viburni* and *Parlatoria theae*) that have never been recorded in Poland. Pellizzari and Germain (2010) give a similar number of scale insect species (25) alien to Poland, but they also wrongly reported *T. angustifrons* and *P. theae* from Poland and ignored such alien species as: *C. hesperidum*, *Pseudococcus maritimus* and *Saissetia oleae*, which occur commonly in Polish greenhouses.

The 51 species included in our list (table 1) significantly increases the number of alien Coccoidea that have become established either under cover or in the field in Poland. The percentage of introduced species in Poland (26.7% of total scale insects fauna) is similar to that found in Great Britain (23.6%), France (24.6%), Spain (26.0%), Italy (26.8%) and Bulgaria (23.3%) (Pellizzari and Germain, 2010; Trencheva *et al.*, 2010). Our results also show that the number of alien species of Diaspididae is significantly greater than the number of native species in Poland, as was also noted by Pellizzari and Germain (2010) for the rest of Europe.

Comparing the dates of the first reports on alien scale

insect occurrence in Europe and Poland, it is clear that almost all species were first reported in other European countries (Pellizzari and Germain, 2010), and only later in Poland. The exceptions are *P. fletcheri*, first noted in Poland by Kawecki (1935) and *Pinnaspis strachani*, which was recorded for the first time in Poland in 1961 (Komosińska, 1961), but from Europe (Italy) in 1988 (Tranfaglia and Viggiani, 1988; Pellizzari and Germain, 2010).

In Europe, alien scale insect species mainly colonize ornamental plants in urban ecosystems, but then occasionally spread to natural habitats. It has been suggested (Nentwig and Josefsson, 2010), that alien species have a greater chance for colonizing urban or natural ecosystems when their natural balance has been disrupted (e.g., by fires, floods, erosion, etc) due to their reduced biological diversity and lower biotic resistance compared with undisturbed ecosystems. It needs to be em-

phasized that almost all alien species in Poland have been recorded on ornamental plants in urban areas (botanic and backyard gardens, parks, nurseries, greenhouses) apart from *C. perniciosus*, recorded only in orchards in Poland (Kawecki, 1985). Only *A. rosae*, has invaded natural habitats, having been recorded in residential gardens and xerothermic or forest communities (Golan *et al.*, 2001).

The separation of invasive species from alien or native scale insects is quite complicated, even though there are many definitions and terms relating to this problem. Miller *et al.* (2002) and Miller and Miller (2003), when considering the status of mealybugs and soft scale insects in the United States, concluded that all alien species were invasive, regardless of their economic importance. In another paper about scale insects introduced to the United States (Miller *et al.*, 2005), species that had invaded a habitat and caused harm or had the potential

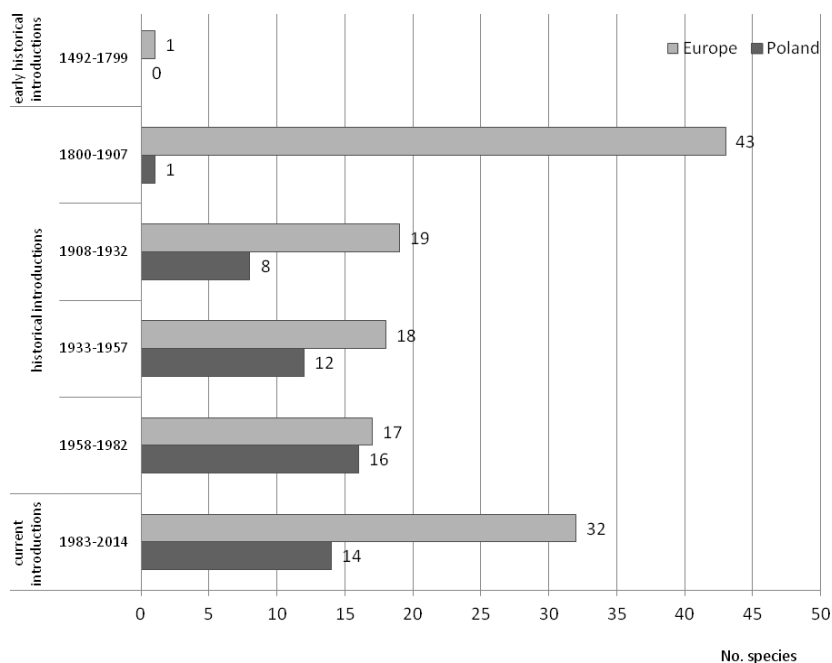


Figure 2. The number of alien scale insect species recorded at time intervals in Poland and Europe. The data relating to Europe taken from Pellizzari and Germain (2010).

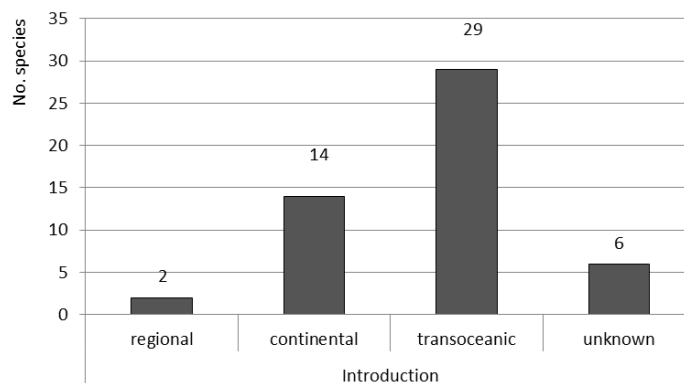


Figure 3. The categories of introduction of scale insect species alien to Poland.

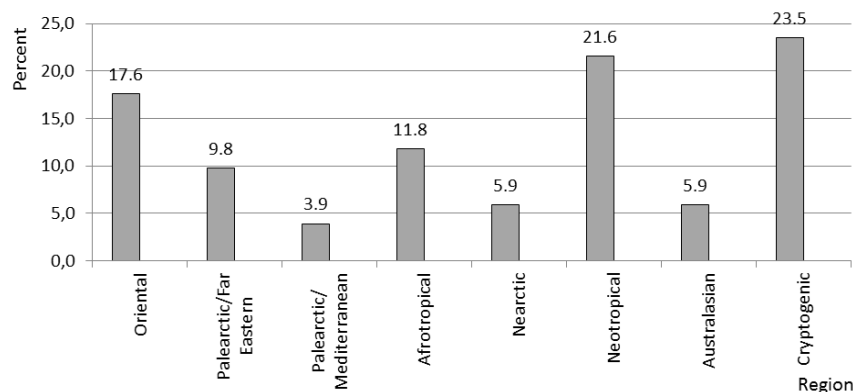


Figure 4. Geographic origin of scale insect species alien to Poland.

to cause harm were recognized as invasive, whereas species that could establish only under cover were excluded. Slightly different criteria for defining an invasive species were applied in France when determining the list of invasive scale insects (Germain, 2008). In this case, all Coccoidea (including those under cover) were regarded as invasive apart from species indigenous to Western Europe. In the present paper, we have used the definition of Miller *et al.* (2005), but have also included species living under cover. Thus, in Poland, we consider 16 species to be invasive, 34 species to be non-invasive aliens and 1 to be a post-invasive species (*C. pernicioso*).

In Poland, two invasive species, *P. floccifera* and *Parthenolecanium* sp., have caused severe damage in recent years. *P. floccifera* has been intercepted twice in Poland since 1971. On the first occasion, this species was imported on potted ornamental plants and recorded only in greenhouses on *Acalypha wilkesiana* Muell. Arg., *Camellia japonica* L., *Citrus aurantium* (L.) and *Schefflera arboricola* (L.) (Koteja, 1972; Kawecki, 1985). More recently, it has been reintroduced to Poland on holly (*Ilex* sp.), imported from nurseries in the Netherlands and is now common outdoors on holly (Chalańska and Łabanowski, 2002). *P. floccifera* is a highly polyphagous insect and may become a dangerous pest on other species of ornamental trees and shrubs cultivated in Poland. This species is currently frequent on common hollies, common yews and other ornamental plants in Croatia, the Netherlands and Germany (Jansen, 1999; Masten Milek *et al.*, 2009; Forster, 2011). Recently, rhododendrons and azaleas in Poland have been attacked by a species of soft scale insect, probably incorrectly identified as *Eulecanium franconicum* or *Parthenolecanium corni* (e.g., Łabanowski and Soika, 2006). An undescribed species close to *P. corni* has been collected on these plants, and was identified based on morphological, biological and molecular studies (Goliszek, 2014). In this paper, it has been classified as an alien species of unknown origin. On the basis of interviews with owners of plant nurseries, it appears that this species has been intercepted in Poland on rhododendrons and azaleas imported from nurseries in the Netherlands and has spread from Polish nurseries into

gardens. It is likely that this species has already been introduced into Lithuania on rhododendrons and azaleas imported from Poland and identified as *P. corni* by Malumphy *et al.* (2008).

Highly polyphagous species dominate the list of alien Coccoidea in Poland. Among them, *Pseudaulacaspis pentagona* poses a potential threat to many plant species cultivated in orchards and recreational urban areas. This species has been intercepted in Poland on kiwi fruits imported from Greece and on unrooted jasmine seedlings imported from Egypt (Dziedzicka and Karnkowski, 2002). It is a dangerous pest of many agricultural and ornamental plants, and is also present in Hungary and Slovakia. According to Dziedzicka and Karnkowski (2002), this pest can survive during the winter in Hungary, with many females overwintering at $-1\text{ }^{\circ}\text{C}$ and some even surviving at $-20\text{ }^{\circ}\text{C}$. These results suggest it is likely that *P. pentagona* could survive on cultivated plants in the field in Poland. Another polyphagous scale insect of tropical origin is *Icerya purchasi*, whose populations appear to have spread northwards during last two decades. In 1999, a severe infestation was reported in Paris and it has also recently been found breeding outdoors in London on ornamental plants belonging to 24 genera, among them on *Cotoneaster* sp., *Geranium* sp., *Pyracantha* sp., *Pyrus* sp. and *Rosa* sp. (Watson and Malumphy, 2004). The establishment of this species outdoors in France and Great Britain, indicates that there is a high probability of its adaptation to similar host plants and climatic conditions in Poland.

Only *C. pernicioso* has been included into the group of the post-invasive species. This species was introduced into Europe from China (Pellizzari and Germain, 2010) and was reported as abundant and economically important in the middle of the last century in Poland, but then it almost disappeared, although recently (1994) it was recorded in two localities in low numbers (Dziedzicka and Karnkowski, 2002). *C. pernicioso* is the only scale insect species listed in the Polish 'List of harmful organisms which are banned from import', and it still poses a potentially high risk to orchards and ornamental plants.

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