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ALIEN PLANT SPECIES TURNOVER IN CONSTANŢA HARBOR (ROMANIA) IN THE LAST DECADE

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Abstract: Previous studies indicate Constanţa Harbor as an important entrance point of alien species in Romania, defining it as an ideal place for studying alien plant species. The monitoring of vegetation over a decade (2004-2014) underlines the turnover in specific composition of alien species, many of them with invasive character. The species accumulation curve is not nearing a plateau for native species, suggesting that the inventory is incomplete, but indicates an almost complete inventory for alien species. This result is supported by the incidence-based estimators of species richness that indicate an incomplete inventory, but show a higher percentage of missing native species compared to alien species. The estimated invasion rate during for the studied period was 2 species year^{-1}. Our study highlights the efficiency of long term extensive monitoring program, as a measure for rapid detection of invasive species.
Key words: species turnover, alien plant species, harbors.

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Introduction

One of the European Union strategic objectives for 2020 is represented by prevention and management of alien species (EC 2011 in Gallardo & Aldridge 2013). Becoming invasive (sensu Richardson et al. 2000) alien species can cause ecosystem degradation, loss of biodiversity and homogenization of regional biotas (Pysek & Richardson 2010, Vila et al. 2011, Macer et al. 2012, Jeshke et al. 2014).

Changes in environmental conditions and dispersal limitations generates species turnover in space and time (Whittaker 1972). The response of plant communities to this kind of changes can be quantified analyzing species turnover (Ulrich et al. 2014).

Transport corridors and especially hubs – harbors, airports, train stations – are the main routes for entrance and spreading of alien species (Bax et al. 2003, Anastasiu et al. 2011). Environmental instability and maritime traffic make the harbors more susceptible to invasion by exotic species (Çinar et al. 2006). This hypothesis was confirmed by previous studies in Constanţa harbor (Costea 1996, Anastasiu et al. 2009, 2011) that reported a high proportion of alien plant species therefore entail a continuous and sustained research of this area.

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Historical traffic values, current data and prognosis for the next years for Constanţa harbor (Fig. 1) show that despite a slowdown caused by the economic crisis, the predicted recovery period followed by rapid growth represents a major risk and is correlated with a higher probability of alien species emergence and an increasing invasion rate.

The aim of this study is to evaluate species turnover and estimate the rate of invasion, based on a decade of monitoring alien plant species in the harbor.

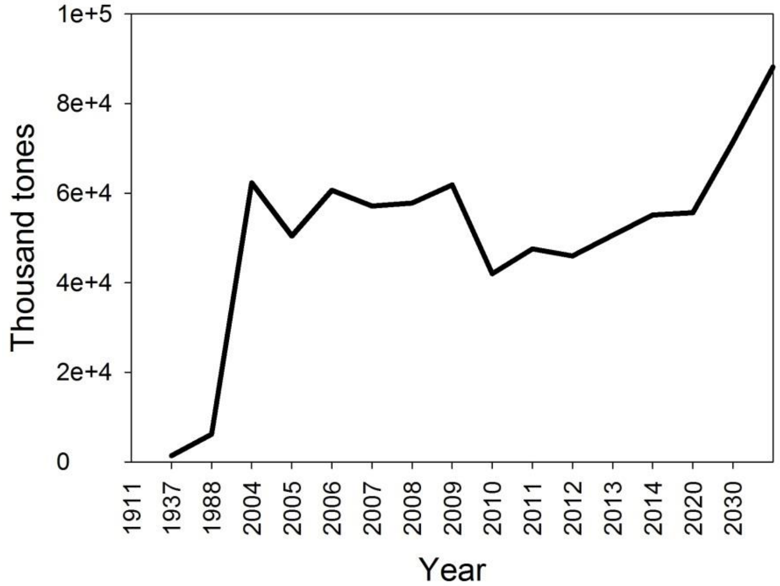

Fig. 1. Traffic values in Constanţa harbor (source: Constanţa Port Administration - http://www.portofconstantza.com/).

Material and methods

Study area. Constanţa harbor is the largest port at the Black Sea and the second, taking into account the capacity, from Europe. Together with two smaller satellite harbors, Midia and Mangalia, the Port of Constanţa (Fig. 2) can be considered the main eastern gate of Europe, both for goods, but also for alien species accidentally transported.

With an area up to 3,626 hectares, from which 1,094 inland and 2,532 waterway, the harbor has 140 functional berths, from a total number of 156.

Vegetation inventory. Based on a previous study that was considered a baseline for our inventory, we conducted repeated visits to the harbor during 2004-2014. The inventory was done along linear transects. This method was favored by existence of extended communication network (roads, railroads), which were used by following their lines. For comparing the data with previous studies (Anastasiu et al. 2011), selected areas were monitored, respectively 11 areas, seven of them in old harbor – area with most alien species abundance (Fig. 3a), three areas in oil products terminal and ore berths – area with constant traffic (Fig. 3b), respectively one area in Constanţa Sud – Agigea – the container terminal – area with the most intense traffic (Fig. 3c).

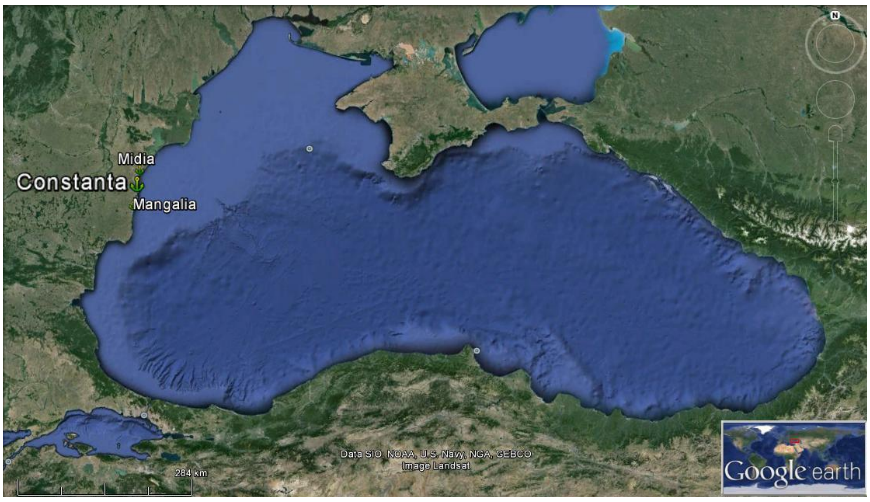

Fig. 2. The location of Constanţa harbor and its satellites, Midia and Mangalia on the western side of Black Sea. Map data: Google, SIO, NOAA, U.S. Navy, NGA, GEBCO. Image: Landsat.

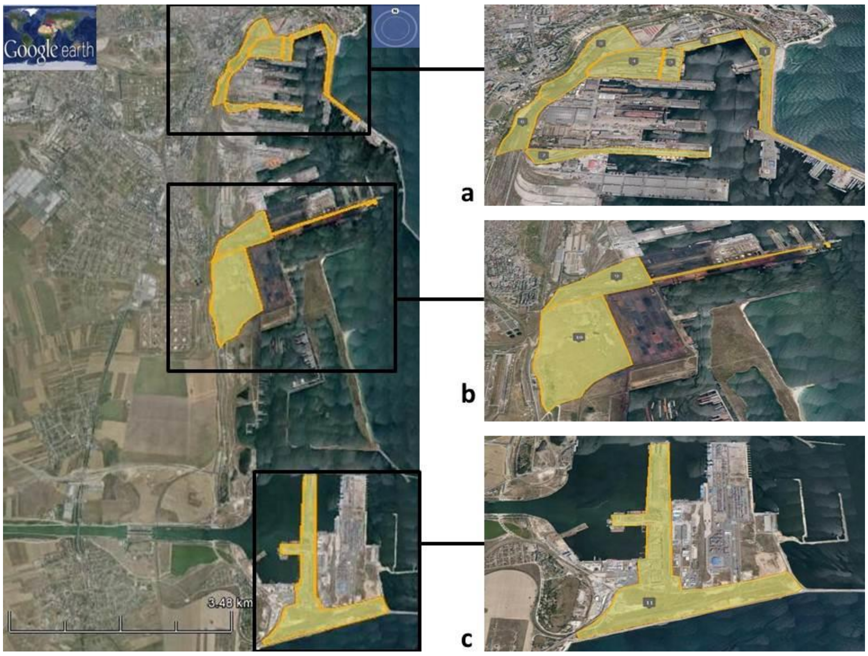

Fig. 3. Study areas in Constanţa Harbor. Map data: Google, SIO, NOAA, U.S. Navy, NGA, GEBCO. Image: Terra Metrics.

We extended the monitoring to the northern satellite Midia harbor, due to large areas of disturbed lands with high amount of alien species identified here. We did not consider the southern satellite harbor of Mangalia, because of the low traffic.

To present the invasive status for alien plant species, definitions provided by Richardson et al. (2000) were used:

Casual alien plants – Alien plants that may flourish and even reproduce occasionally in an area, but which do not form self-replacing populations, and which rely on repeated introductions for their persistence;

Naturalised plants – Alien plants that reproduce consistently and sustain populations over many life cycles without direct intervention by humans (or in spite of human intervention); they often recruit offspring freely, usually close to adult plants, and do not necessarily invade natural, seminatural or human-made ecosystems.

Invasive plants – Naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants and thus have the potential to spread over a considerable area.

Data analysis. Due to the specific activities in the harbor during the study period access was at times restricted in areas visited previously. Also the management of the vegetation in the port was not consistent over time. Thus the transects used in the inventory varied between visits. To limit the bias we decided to pool the data for each year, and use as sampling year the species inventoried during a year, disregarding the length of the transects and the number of visits.

Estimators of species richness and species accumulation curves were used to estimate if our inventory was complete and were computed using EstimateS 9.1 (Colwell 2013). We used the following species richness incidence-based estimators: Chao 2 - wich uses the number of uniques (species detected in only one sample) and duplicates (species detected in only two samples) (Chao 1987); ICE - Incidence Coverage-based Estimator of species richness, assumes that the detection probabilities vary among species) (Lee & Chao 1994); Jackknife 1 (First-order jackknife estimator) use the frequency of uniques and Jackknife 2 (Second-order jackknife estimator) uses the frequency of uniques and duplicates to estimate the number of undetected species (Burnham & Overton 1978). Bootstrap richness estimator is a reliable method related to the jackknife and has a wider applicability (Smith & van Belle 1984). We used the Bootstrap estimator as reference since it is more stable and less influenced by sample size (Smith & van Belle 1984).

Species turnover was calculated as β diversity (Magguran 2004), using Wilson and Shmida (1984) equation: $\beta_T = \frac{[g(H)+l(H)]}{2S_j}$

where g(H) = the number of species gained; and l(H) = the number of species lost.

Invasion rates were estimated by dividing the number of established non-indigenous species discovered over a decade by the length of that time interval (Ricciardi 2006).

Results and discussion

Between 2004 – 2014 we identified 526 plant species (see Annex), 412 of them native and 114 alien species (Fig. 4). We can see high species occurrence between 2004-2009. An explanation for this may be due to changes after 2010 in Constanţa harbor administration, management measures regarding natural vegetation within an industrial area being regulated by authorities with responsibilities in emergency situations (e.g. fire). Thus, after 2010 some of the areas investigated were mowed, so the identified species list was shorter.

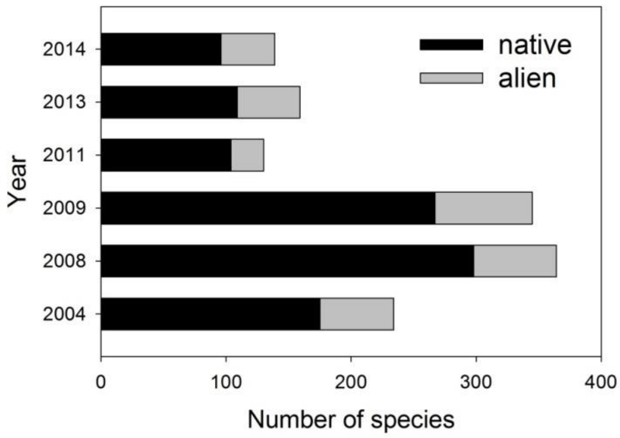

Fig. 4. Plant species from Constanţa Harbor during 2004-2014.

From 412 native species identified, 238 of them (57.76%) are incidental species, and only 67 are constant species, being inventoried in almost every year.

Regarding the alien species, from 114 species identified (Fig. 5), 14 are naturalized (12%), 57 casual (50%) and 43 (38%) of them having characteristics of invasive species. From the total number of alien species, 60 of them are incidental and only 23 species were constantly inventoried.

Our long term monitoring program enabled the identification of a new alien species for the flora of Romania, *Conyza sumatrensis* (Retz) E. Walker (Anastasiu & Memedemin 2012), providing evidence for the utility and efficiency of such a program.

Species accumulation curve (Fig. 6) for native species shows an incomplete inventory, this fact being explained by the dynamic environment of the harbor under permanent human pressure. The species accumulation curve for alien species indicates an almost complete inventory, much closer to the plateau. The patterns correspond with field observations.

The estimators of species richness support the conclusions obtained from analyzing the species accumulation curves and indicate that the inventory is still incomplete for both native and alien species, but the differences are higher for native as compared to alien species (Table 1).

Both native and alien species showed a high species turnover during the period of study. The β diversity index as a measure of species turnover had similar values for both native and alien species during the study period: 0.553 for alien species and 0.549 for native species. A positive turnover deviation indicates higher species turnover than expected by chance (Wang et al. 2013).

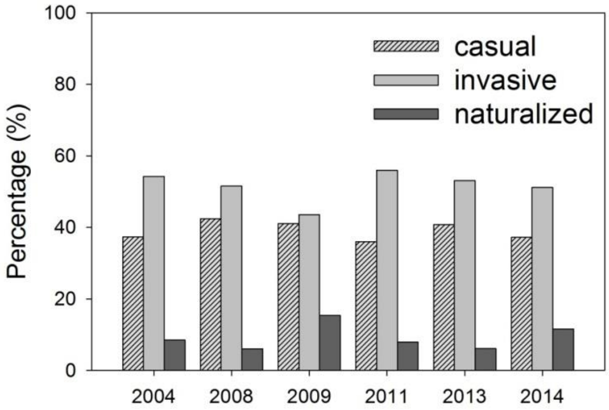

Fig. 5. Percentage of casual, invasive and naturalized plants per year.

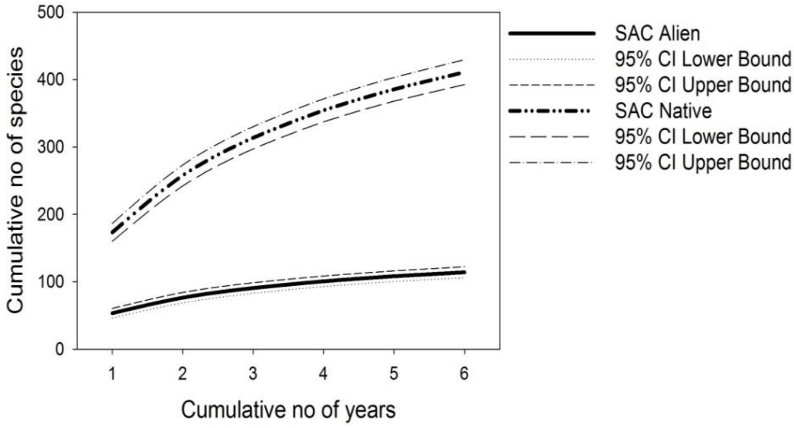

Fig. 6. Species Accumulation Curve with 95% confidence interval.

Table 1. Incidence based estimators of species richness computed separately for native and alien plant species for Constanţa harbor

Estimators	**Native species**		**Alien species**	
Observed species number	413	% increase	114	% increase
Chao 2	522	26	133	17
ICE	558	35	142	24
Jackknife 1	538	30	143	25
Jackknife 2	594	44	153	34
Bootstrap	471	14	128	12

The estimators were computed considering as sample unit years (n=6).

Invasion rate is in direct connection with rate of discovery of alien species, so an increasing discovery rate indicates that a region is becoming more invaded (Ricciardi 2006). In our case, the invasion rate, measured by dividing the number of established alien species inventoried over a decade (2004-2014) by the length of time (i.e. 10 years), was 2 species year^{-1}, having thus one new alien species every 26 week.

Comparing with one of the most invaded estuary, and possibly the most invaded aquatic ecosystem in the world – San Francisco Bay and Delta (Cohen & Carlton 1998) which has a new alien species identified every 14 week, we can conclude that, regarding alien plant species, Constanţa harbor has a medium invasion rate.

Taking into consideration the prognosis of increasing traffic in the next years, we can anticipate a stable estimated invasion rate at least. This fact sustains the necessity of monitoring and implementing an early detection and rapid response program in order to prevent, control and if possible to eradicate the invasive alien plant species.

Conclusions

Our study confirms that Constanţa harbor functions as main entrance and reservoir for alien species. Despite the long-term inventory of plants in the harbor this is still incomplete due to the dynamic environment and the frequent changes in land use that facilitate the persistence of plants. The high probability of new alien species emergence imposes the continuous monitoring of harbor areas. We also recommend the use of species accumulation curves and estimators of species richness as valuable tools to evaluate the success of a monitoring program, based on repeated inventories.

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Annex. List of alien species identified in Constanţa Harbor

Species	**Family**	**Invasive status**	**Origin**	**Persistance (years)**
Acer negundo L.	Aceraceae	I	North America	5
Aesculus hippocastanum L.	Hippocastanaceae	C	Balcanic Peninsula	3
Ailanthus altissima (Mill.) Swingle	Simaroubaceae	I	China	6
Alcea rosea L.	Malvaceae	I	Crete Isl & Eastern Europe	2
Alopecurus myosuroides Huds.	Poaceae	I	Atlantic-mediteranean	1
Amaranthus albus L.	Amaranthaceae	I	North America	4
Amaranthus crispus (Lesp. Et Thevenau) N. Terracc.	Amaranthaceae	I	South America	1
Amaranthus hybridus L.	Amaranthaceae	I	America	1
Amaranthus lividus L.	Amaranthaceae	N	Mediteranean	3
Amaranthus palmeri S. Watson	Amaranthaceae	N	North America	4
Amaranthus powellii S. Watson	Amaranthaceae	N	North America	1
Amaranthus retroflexus L.	Amaranthaceae	I	North America	5
Amaranthus rudis Sauer	Amaranthaceae	N	North America	2
Ambrosia artemisiifolia L.	Asteraceae	I	North America	6
Ambrosia trifida L.	Asteraceae	I	North America	6
Amorpha fruticosa L.	Fabaceae	I	North America	4
Anethum graveolens L.	Apiaceae	C	SW Asia	2
Antirrhinum majus L.	Scrophulariaceae	C	Mediteranean	1
Apium graveolens subsp. *graveolens* L.	Apiaceace	C	Atlantic-mediteranean	1
Artemisia annua L.	Asteraceae	I	Temperate Asia - SE Europe	6
Atriplex hortensis L.	Chenopodiaceae	C	Asia	2
Avena sativa L.	Poaceae	C	Asia Minor	3
Bassia scoparia (L.) A.J. Scott	Chenopodiaceae	I	Asia and Eastern Europe	6
Bidens frondosa L.	Asteraceae	I	North America	1
Brassica rapa subsp. *oleifera* DC.	Brassicaceae	C	Mediteranean	5
Brassica rapa subsp. *sylvestris* (L.) Janchen	Brassicaceae	N	Atlantic-mediteranean	1
Bromus madritensis L.	Poaceae	C	Mediteranean	4

Bromus rigidus Roth	Poaceae	C	Mediteranean	1
Bromus willdenowii Kunth	Poaceae	C	South America	3
Calendula officinalis L.	Asteraceae	C	Mediteranean	4
Catalpa bignonioides Walter	Bignoniaceae	C	North America	1
Cercis siliquastrum L.	Caesalpiniaceae	C	Mediteranean	1
Chamomilla suaveolens (Pursh) Rydb.	Asteraceae	N	N-E Asia and North America	1
Chenopodium ambrosioides L.	Chenopodiaceae	I	Tropical America	1
Chenopodium botrys L.	Chenopodiaceae	C	Southern Europe and Western Asia	2
Chloris barbata Sw.	Poaceae	C	Tropical America	1
Citrullus lanatus (Thunb.) Mansf.	Cucurbitaceae	C	Western Kalahari	3
Cladium mariscus subsp. *martii* (Roem. et Schult.) Soó	Cyperaceae	N	Mediteranean-Central Asia	1
Commelina communis L.	Commelinaceae	N	Temperate Asia	1
Conyza canadensis (L.) Cronquist	Asteraceae	I	North America	6
Conyza sumatrensis (Retz.) E. Walker	Asteraceae	C	South America	3
Cucurbita pepo L.	Cucurbitaceae	C	North America	1
Cuscuta campestris Yunck.	Convolvulaceae	I	North America	6
Cuscuta suaveolens Ser.	Convolvulaceae	N	South America	
Cydonia oblonga Mill.	Rosaceae	C	SW Asia	1
Datura innoxia Mill.	Solanaceae	C	Southern and Central America	2
Datura stramonium L.	Solanaceae	I	Unknown	5
Echinocystis lobata (Michx.) Torr. & A. Gray.	Cucurbitaceae	I	North America	1
Elaeagnus angustifolia L.	Elaeagnaceae	I	Asia	6
Eleusine indica (L.) Gaertn.	Poaceae	I	Tropical and subtropical Asia	5
Erigeron annuus (L.) Pers.	Asteraceae	I	North America	5
Euonymus japonicus Thunb.	Celastraceae	C	Asia	1
Euphorbia maculata L.	Euphorbiaceae	I	North America	4
Fallopia aubertii (L. Henry) Holub	Polygonaceae	C	Eastern Asia	1
Ficus carica L.	Moraceae	C	SV Asia	1
Foeniculum vulgare Mill.	Apiaceae	N	Mediteranean and western Asia	1

Fragaria × *ananassa* Duchesne	Rosaceae	C	Hybrid	2
Fraxinus americana L.	Oleaceae	I	North America	2
Fraxinus pennsylvanica Marshall	Oleaceae	I	North America	3
Galinsoga parviflora Cav.	Asteraceae	I	South America	3
Gleditsia triacanthos L.	Caesalpiniaceae	I	North America	4
Helianthus annuus L.	Asteraceae	C	North and Central America	6
Helianthus tuberosus L.	Asteraceae	I	North America	3
Hemerocallis fulva (L.) L.	Liliaceae	C	Eastern Asia	1
Hibiscus syriacus L.	Malvaceae	C	Eastern and Southern Asia	2
Hordeum distichon L.	Poaceae	C	Eastern Asia	2
Hordeum marinum Huds.	Poaceae	N	Atlantic-mediteranean	1
Hordeum murinum subsp. *murinum* L.	Poaceae	C	Atlantic-mediteranean	5
Hordeum vulgare L.	Poaceae	C	Middle East	4
Impatiens balsamina L.	Balsaminaceae	C	South-eastern Asia	1
Ipomoea hederacea Jacq.	Convolvulaceae	N	Tropical America	2
Ipomoea lacunosa L.	Convolvulaceae	N	North America	2
Ipomoea purpurea (L.) Roth	Convolvulaceae	C	Tropical America	4
Iris germanica L.	Iridaceae	N	East-mediteranean	1
Iva xanthifolia Nutt.	Asteraceae	I	North America	5
Juniperus virginiana L.	Cupressaceae	C	North America	2
Koelreuteria paniculata Laxm.	Sapindaceae	C	Eastern Asia	2
Lemna minuta Kunth	Lemnaceae	I	North America	2
Lepidium virginicum L.	Brassicaceae	I	North America	3
Lonicera japonica Thunb.	Caprifoliaceae	C	Eastern Asia	2
Lycium barbarum L.	Solanaceae	C	Eastern Asia (China)	2
Lycopersicon esculentum L.	Solanaceae	C	Southern and Central America	3
Maclura pomifera (Raf.) Schneid.	Moraceae	C	North America	1
Malus domestica Borkh.	Rosaceae	C	Hybrid	4
Medicago falcata L.	Fabaceae	N	Eurasia	2
Medicago sativa subsp. *sativa* L.	Fabaceae	N	Central and Western Asia	1

Mentha × *piperita* L.	Lamiaceae	N	Hybrid	2
Mentha spicata L.	Lamiaceae	N	Hybrid	1
Mirabilis jalapa L.	Nyctaginaceae	C	Mexic	1
Morus alba L.	Moraceae	I	Eastern Asia (China)	4
Nicotiana alata Link & Otto	Solanaceae	C	South America	2
Oenothera biennis L.	Onagraceae	N	North America	1
Oxalis corniculata L.	Oxalidaceae	I	Southern Europe/Eastern Asia	3
Oxalis stricta L.	Oxalidaceae	I	North America	3
Panicum capillare L.	Poaceae	I	North America	1
Panicum dichotomiflorum Michx.	Poaceae	N	North America	2
Parthenocissus inserta (Kerner) Fritsch	Vitaceae	I	North America	5
Parthenocissus tricuspidata (Siebold & Zucc.) Planch.	Vitaceae	N	Japonia and China	2
Petroselinum crispum (Mill.) Fuss	Apiaceae	N	East Mediteranean	1
Petunia × *atkinsiana* D.Don	Solanaceae	C	Hybrid	1
Phalaris canariensis L.	Poaceae	C	Mediteranean	1
Phytolacca americana L.	Phytolaccaceae	I	North America	1
Prunus armeniaca L.	Rosaceae	C	Central Asia	4
Prunus cerasus L.	Rosaceae	C	Asia Minor and Caucasus	1
Prunus persica (L.) Batsch	Rosaceae	C	Tibet, W China	3
Raphanus sativus L.	Brassicaceae	C	Probably hybrid	2
Robinia pseudacacia L.	Fabaceae	I	North America	6
Salvia splendens Sellow ex Schult.	Lamiaceae	C	South America	1
Satureja hortensis L.	Lamiaceae	C	Mediteranean	1
Setaria faberi Herrm.	Poaceae	C	Eastern Asia	2
Solanum carolinense L.	Solanaceae	N	North America	1
Solanum tuberosum L.	Solanaceae	C	South America	1
Sophora japonica L.	Fabaceae	C	Eastern Asia	4
Sorbaria sorbifolia (L.) A. Braun	Rosaceae	C	Asia	1
Sorghum bicolor (L.) Moench.	Poaceae	C	South-saharian Africa	1
Sorghum halepense (L.) Pers.	Poaceae	I	North Africa , Asia Minor	6
Tagetes patula L.	Asteraceae	C	Mexic	1

Tecoma radicans (L.) Juss.	Bignoniaceae	C	North America	3
Thuja occidentalis L.	Cupressaceae	C	North America	1
Thuja orientalis L.	Cupressaceae	C	Eastern Asia	2
Trigonella caerulea (L.) Ser.	Fabaceae	N	Mediteranean	1
Triticum aestivum L.	Poaceae	C	Middle East	5
Ulmus pumila L.	Ulmaceae	I	Central and esatern Asia	3
Veronica persica Poiret	Scrophulariaceae	I	South-western Asia	3
Viola × *wittrockiana* Gams	Violaceae	C	Hybrid	1
Vitis vinifera L.	Vitaceae	N	SW Asia and Mediteranean	6
Xanthium orientale subsp. *italicum* (Moretti) Greuter	Asteraceae	I	America	6
Xanthium spinosum L.	Asteraceae	I	South America	3
Zea mays L.	Poaceae	C	Central America	4

Invasive status: C – casual; N – naturalized; I – invasive.
Persistance was estimated as the number of years during the inventory period that the species was present, maximum number is 6 years.