SOCIETÀ TOSCANA
DI
Scienze Naturali
RESIDENTE IN PISA

ATTI
DELLA
SOCIETÀ TOSCANA
DI
SCIENZE NATURALI

MEMORIE • SERIE B • VOLUME CXXIV • ANNO 2017

Edizioni ETS

Con il contributo del Museo di Storia Naturale dell'Università di Pisa

e della Fondazione Cassa di Risparmio di Lucca

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Atti Soc. Tosc. Sci. Nat., Mem., Serie B, 124 (2017)
pagg. 101-108, fig. 3; tab. 1; *doi: 10.2424/ASTSN.M.2017.10*

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ALIEN PLANT INVASIONS IN ASTRONI CRATER, A DECADES-LONG UNMANAGED FOREST IN SOUTHERN ITALY

Abstract - *Alien plant invasions in Astroni crater, a decades-long unmanaged forest in southern Italy.* In this work, we studied the alien vascular flora of the forest of the Astroni crater. The mixed hardwood forest of deciduous species at the crater base have been withdrawn from management for some decades but that have not achieved yet the characteristics of a true old-growth forest. The floristic list based on field investigation and reference data comprises 20 neophytes, representing 5.4% of the whole vascular flora of the Nature Reserve. Data analysis shows that the exotic flora comprises casual (25%), naturalized (50%) and invasive (25%) aliens. The share of invasive species is related both to a low disturbance level and to good conditions of naturalness in the Astroni forest. The invasive aliens are *Ailanthus altissima* (Mill.) Swingle, *Erigeron sumatrensis* Retz., *Oxalis pes-caprae* L., *Phytolacca americana* L. and *Robinia pseudoacacia* L. Interfering with native plant communities, these species could alter the delicate environmental balance and affect its evolutionary dynamics.

Key words - ancient forests, biodiversity, bioindicators, Campania, exotic species, invasiveness

Riassunto - *Invasioni di piante aliene nel cratere degli Astroni, una foresta del sud Italia non gestita da molti decenni.* In questo lavoro è stata indagata la flora vascolare aliena del cratere degli Astroni. Il bosco di latifoglie decidue presente alla base del cratere pur non essendo gestito da molti decenni, non ha ancora raggiunto le caratteristiche di una vera e propria foresta vetusta. L'elenco floristico, basato su indagini sul campo e dati di letteratura, comprende 20 neofite che rappresentano il 5.4% dell'intera flora della Riserva Naturale. L'analisi dei dati evidenzia che la flora alloctona comprende specie casuali (25%), naturalizzate (50%) ed invasive (25%). La bassa incidenza delle invasive è dovuta al basso grado di disturbo e alle buone condizioni di naturalità degli Astroni. Le specie aliene invasive sono *Ailanthus altissima* (Mill.) Swingle, *Erigeron sumatrensis* Retz, *Oxalis pes-caprae* L., *Phytolacca americana* L. e *Robinia pseudoacacia* L. Interferendo con comunità naturali, queste specie possono alterare il delicato equilibrio ambientale e influenzare la sua dinamica evolutiva.

Parole chiave - boschi vetusti, biodiversità, Campania, specie esotiche, invasività

Introduction

The movement of species by man beyond natural dispersal barriers is a still accelerating process, resulting from global commerce and disturbance of natural ecosystems. Species introductions lead to biological invasions, which can have profound impacts on the regional economy and the ecological integrity of natural communities (Mooney & Hobbs, 2000; Pimentel, 2011). Biological invasions constitute a major threat to biodiversity (Sala *et al*., 2000) and cause homogenization in living systems worldwide (Olden, 2006). Invaders alter the balance and function of the colonized ecosystem, making it difficult or in some cases impossible for native communities to become re-established. Not negligible are also economic (Pimentel *et al*., 2001) and health impacts (Belmonte & Vilà, 2004) associated with non-indigenous species. Alien species, probably more frequently than so far known in literature, can be secondary hosts for viruses, insects and fungi harmful to the native flora and agricultural crops (Parrella *et al*., 2013). In addition, some exotic plants cause serious damages to monuments and archaeological areas (Motti & Stinca, 2011).

In forest ecosystems, plant invasion has drawn the attention of researchers, managers and policy-makers worldwide (Traveset & Richardson, 2006). The spread of alien species in forests, even ancient forests, may also induce variation in biogeochemical cycles and structural transformations (Knapp & Canham, 2000). At the landscape scale, forest edges are recognized as a potential starting point for invasions of alien plant species into less disturbed environments (Saunders *et al*., 1991; Brothers & Spingarn, 1992; Cadenasso & Pickett, 2001; Honnay *et al*., 2002). The experiences of years of forest planning and management around Europe may be of considerable assistance in addressing the issue of invasive alien species, through the implementation of appropriate forestry activities, to face the issue of invasive alien species (Sitzia *et al*., 2016). Alien flora has become an important component of wild flora and stands as a real challenge for environmental management (Podda *et al*., 2012).

In this context, alien species lists form the basis for much of the current research on biological invasions,

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for guiding legislation and code of conducts, as input to decision making and risk assessment and in the formulation of management policies and strategies for nature conservation (Jacobs *et al.*, 2017). Considering that an accurate lists of alien species, with data on their introduction status, are crucial resources, not just for the regions for which they are compiled, but also globally (Wilson *et al.*, 2011), in this work we analysed the alien vascular flora of a forest withdrawn from management for several decades grown in the Astroni crater in southern Italy.

Materials and methods

Study area

Astroni crater is located in the Campania region in the NE part of the continental caldera of the Campi Flegrei (Fig. 1). It is a Nature Reserve (instituted by the Italian Ministry of the Environment Decree no. 422 of 24/07/1987), of about 247 hectares classified as a Site of Community Importance and Special Protection Area (code IT8030007). The Astroni is also part of the Campi Flegrei Regional Park and is currently managed as a limited-access nature reserve by the World Wide Fund for Nature (WWF). These represent a large volcanic district located NW of Naples, originated by the collapse of the previous volcanic system called Archiflegreo. This led to a multifaceted polycrateric complex with a heterogeneous physiography.

The Astroni crater is located mostly in the Municipality of Pozzuoli, only a small part belonging to that of Naples. It is an extinct volcano (tuff cone) which formed about 3700 years BP, ranging from 9 to 253 m of altitude. The crater features a typical truncated flipped cone shape, and an elliptical outline with a maximum width of about 2 km at its rim. At the crater base it decreases to about 750 m.

The climate of the Campi Flegrei is influenced by both its geographical position close to the Tyrrhenian Sea and its low altitude, reaching its maximum height at Mt. Sant'Angelo alla Corbara (319 m a.s.l.). Average rainfall and temperature in the area are typical of a Mediterranean climate, with a hot dry period between June and August.

Figure. 1. Digital ortophoto of the Astroni crater (white line) and its location in Southern Italy and Campania region.

Table 1. Alien species surveyed in Astroni crater.

Species	Family	Life form	Invasive current status	Origin area	Previous reports
Ailanthus altissima (Mill.) Swingle ≡ *Toxicodendron altissima* Mill. = *A. glandulosa* Desf.	Simaroubaceae	P scap	Invasive. Common in anthropic areas, tree-fall gaps and in expanding	South Asia (China)	Cavara (1910)
Amaranthus retroflexus L. – *A. strictus* Ten., nom. nud.	Amaranthaceae	T scap	Naturalized. Rare in anthropic areas	North America	Cavara (1910); Motti & Ricciardi (2005)
Artemisia annua L. = *A. annua* L. f. *macrocephala* Pamp.	Asteraceae	T scap	Naturalized. Rare in anthropic areas	East Europe, West and Centre Asia	
Azolla filiculoides Lam. = *A. caroliniana* Willd. = *A. mexicana* C.Presl	Azollaceae	H nat	Naturalized. Rare in the lake	North, Centre and South America	Motti & Ricciardi (2005)
Cestrum parqui L'Hér. = *C. foetidissimum* Jacq.	Solanaceae	NP	Casual. Very rare in anthropic areas	South America	
Datura stramonium L. = *D. tatula* L.	Solanaceae	T scap	Naturalized. Rare in anthropic areas	North America	Cavara (1910)
Dysphania ambrosioides (L.) Mosyakin & Clemants ≡ *Chenopodium ambrosioides* L.	Chenopodiaceae	T scap	Naturalized. Rare in anthropic areas	Tropical America	Motti & Ricciardi (2005)
Erigeron bonariensis L. = *E. crispus* Pourr. = *E. linifolius* Willd. ≡ *Conyza bonariensis* (L.) Cronq.	Asteraceae	T scap	Naturalized. Common in anthropic areas	South America	
Erigeron canadensis L. ≡ *Conyza canadensis* (L.) Cronq.	Asteraceae	T scap	Naturalized. Common in anthropic areas	North America	Cavara (1910)
Erigeron sumatrensis Retz. = *Conyza albida* Spreng. = *C. naudinii* Bonnet ≡ *C. sumatrensis* (Retz.) E.Walker	Asteraceae	T scap	Invasive. Very common in anthropic areas, tree-fall gaps and in expanding	South America	
Eriobotrya japonica (Thunb.) Lindl. ≡ *Mespilus japonica* Thunb.	Rosaceae	P scap	Casual. Very rare in anthropic areas	South-East Asia	
Eucalyptus camaldulensis Dehnh. subsp. ***camaldulensis*** = *E. acuminata* Hook.	Myrtaceae	P scap	Casual. Very rare in anthropic areas	Australia	
Galinsoga quadriradiata Ruis & Pav. = *G. ciliata* (Raf.) F.S.Blake	Asteraceae	T scap	Naturalized. Common in anthropic areas	North, Centre and South America	
Iris albicans Lange ≡ *I. germanica* L. subsp. *albicans* (Lange) O.Bolòs & Vigo	Iridaceae	G rhiz	Naturalized. Very rare in anthropic areas	Temperate Asia	
Oxalis pes-caprae L. = *O. cernua* Thunb.	Oxalidaceae	G bulb	Invasive. Common in anthropic areas and in expanding	South Africa	
Phytolacca americana L. = *Ph. decandra* L.	Phytolaccaceae	G rhiz	Invasive. Very common in anthropic areas and tree-fall gaps	North America (Canada and USA)	Pasquale & Avellino (1841); Cavara (1910); Motti & Ricciardi (2005)
Pittosporum tobira (Thunb.) W.T.Aiton ≡ *Euonymus tobira* Thunb.	Pittosporaceae	NP	Casual. Very rare in anthropic areas	South-East Asia (China, Korea and Japan)	

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Quercus rubra L. = *Erythrobalanus rubra* (L.) O.Schwarz	Fagaceae	P scap	Casual. Rare in the wood	North America (Canada and USA)	Motti & Ricciardi (2005)
Robinia pseudoacacia L. = *R. pringlei* Rose	Fabaceae	P scap	Invasive. Common in anthropic areas, wood edges and in expanding	North America (USA)	Cavara (1910)
Veronica persica Poir. = *Veronica buxbaumii* Ten., nom. illeg.	Scrophulariaceae	T scap (scand)	Naturalized. Common in anthropized areas	West Asia	

The particular micro-climate of Astroni is due both to the presence of small lake at the bottom, namely Lago Grande (33,000 m^2), Cofaniello Piccolo (2,000 m^2) and Cofaniello Grande (1,000 m^2) and to the morphology of the volcanic structure, causing the inversion of vegetation belts. The colder and more humid air at the bottom of the crater has led to the creation of more mesophytic plant communities generally found at higher altitudes in the Central and Southern Apennines. Due to different temperature and humidity conditions, on the internal slopes of the crater there are more thermophile populations, more adapted to such xeric conditions.
From the second half of the fifteenth century, the area was used as a hunting reserve, in the early twentieth century occurred a deep transformation and was intensively exploited for agricultural purposes, while during World War II became military depot. Since 1987 was instituted the Natural Reserve of Astroni crater by the Ministry of Environment.

Field surveys

The study was based on field surveys carried out from 2009 to 2017 and bibliographic data. The plant material collected was deposited in the *Herbarium Porticense* (PORUN, acronym according to Thiers, 2017).
The floristic list of exotic species detected is arranged in alphabetical order (Tab. 1). Nomenclature follows Conti *et al.* (2005, 2007) and Celesti-Grapow *et al.* (2009). The collected specimens were identified with the help of standard literature (Tutin *et al.*, 1964-1980, 1993; Pignatti, 1982; Zhengyi *et al.*, 1994-2009).
For each species found in the study area, the following informations are provided: basionym and most relevant synonyms; plant family (Christenhusz *et al.*, 2011; APG IV, 2016); life form (Raunkiaer, 1934) modified according to Pignatti (1982) and verified by on-field observations; current invasiveness status to be awarded by the monitoring over time of the population, according to the terminology of Pyšek *et al.* (2004); native range; previous plant reports available for the study area.

Results and discussion

The wild flora

Mixed broadleaves forest grown on the Astroni crater bottom show a high variability of the structural characteristics and floristic composition. The upper tree layer consists of both *Quercus robur* L. subsp. *robur* and *Quercus rubra* L. The lower layer is characterized by the presence of *Carpinus betulus* L., *Ostrya carpinifolia* Scop., *Carpinus orientalis* Mill. subsp. *orientalis*, *Fraxinus ornus* L. subsp. *ornus*, *Quercus ilex* L. subsp. *ilex*, *Ulmus minor* Mill. subsp. *minor*, *Castanea sativa* Mill. and *Acer campestre* L. The shrubby layer mostly consists of *Euonymus europaeus* L., *Ruscus aculeatus* L., *Rubus ulmifolius* Schott, *Ligustrum vulgare* L. and tree seedlings. The most representative herbaceous species are *Arum italicum* Mill. subsp. *italicum*, *Asplenium onopteris* L., *Brachypodium sylvaticum* (Huds.) P.Beauv., *Cyclamen hederifolium* Aiton subsp. *hederifolium*, *Drymochloa drymeja* (Mert. & W.D.J.Koch) Holub subsp. *exaltata* (C.Presl) Foggi & Signorini and *Rubia peregrina* L.
Some lianas and climbing species, such as *Clematis vitalba* L., *Hedera helix* L. subsp. *helix*, *Rubus ulmifolius* Schott and *Smilax aspera* L. occur at the same time in different vegetation layers.

Alien species analysis

During this survey 20 neophytes were detected (Tab. 1), representing 5.4% of the whole vascular flora of the Astroni crater constituted by 373 species (Stinca & Motti, unpublished data). From the census it has been excluded the archeophytes, i.e. alien species introduced to the region during the period since the beginning of Neolithic agriculture and the end of Medieaval (discovery of Americas, approximately the year 1500 AD). However, the separation between natives and archaeophytes is sometimes difficult and relies on a combination of palaeobotanical, archaeological, ecological and historical evidence (Preston *et al.*, 2002). Analyses of recent and historical data highlights an

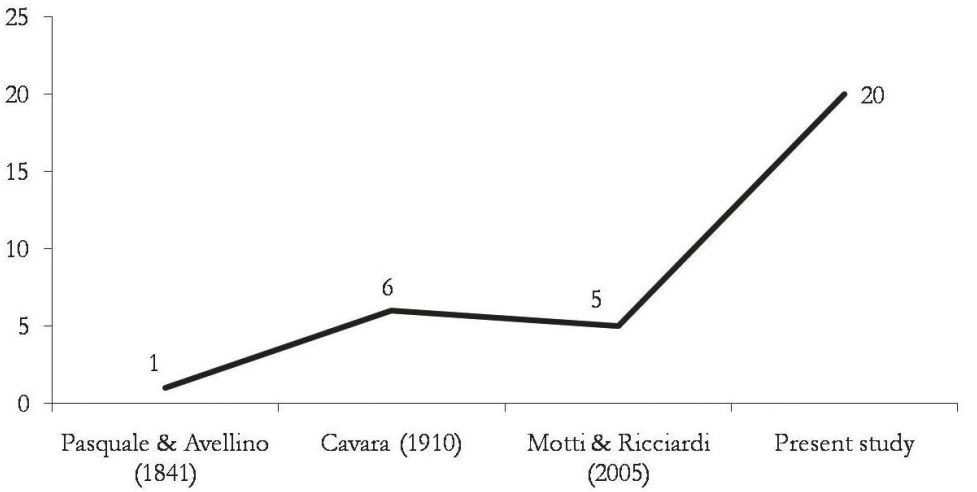

Figure 2. Trend of reports of alien species in Astroni from 1841 to 2017.

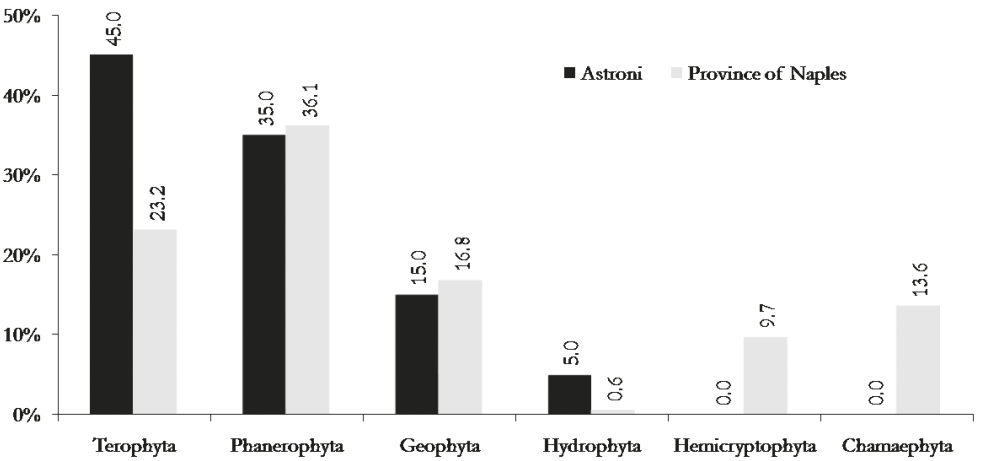

Figure 3. Comparison of alien plant life form percentages at Astroni and the province of Naples.

high increase of reports of alien species over time in Astroni (Fig. 2).

In comparison with the data for the whole province of Naples (Motti & Stinca, 2008), a higher incidence of therophytes is evident in the alien vascular flora of Astroni (Fig. 3). This may be related to the visiting public who accidentally spread exotic species in natural ecosystems (Hemp, 2008). The annual species are found mostly near the trails and clearings with a higher degree of disturbance, so they do not constitute a hazard for woodland plant communities.

The data show that the exotic flora comprises casual aliens (25%), naturalized (50%) and invasive species (25%). This last value is related to minimal disturbance and good conditions of naturalness in the Astroni forest. Given that the presence of available resources makes ecosystems more susceptible to invasion (Davis *et al.*, 2000), the dense forest cover in the crater has led to reduced encroachment by alien plant species (Rejmánek, 1989; Lonsdale, 1999). This occurs even though the site is placed in an area characterized by high levels of urbanization in which large urban cities are the point of introduction and spread of non-native species (Kowarik, 1990).

The invasive aliens are *Ailanthus altissima* (Mill.) Swingle, *Erigeron sumatrensis* Retz., *Oxalis pes-caprae* L., *Phytolacca americana* L. and *Robinia pseudoacacia* L. Of these, *R. pseudoacacia* tends to spread more widely within the forest, while the other four species normally colonize their margins and degraded areas. As observed by Bonanomi *et al.* (in press) in the evergreen Mediterranean forest of the Royal Park of Portici, even to Astroni *Phytolacca americana* is very common in tree-fall gaps. According to Knapp &

Canham (2000), *Ailanthus altissima* saplings colonize also several gaps within forest. Among the exotic species there is *Quercus rubra* L.: this plant was introduced by U.S. army during the World War II when the area was intensively cultivated and have had a quick naturalization process so, at moment, represent one the oldest species in the Astroni forest. The high prevalence of naturalized exotic plants is due to a part of species now permanently established in Astroni flora as, for example, *Azolla filiculoides* Lam.
In the future the invasive and naturalized species, could pose a serious threat to the conservation of the forest at the crater bottom interfering with the forest's natural dynamics.

Conclusions

The recent work conducted by Celesti-Grapow *et al.* (2010) recorded for Campania 284 non-native taxa. However, also in this region, the number of exotic species is steadily increasing especially in anthropic areas (e.g. Stinca & Motti, 2009; Del Guacchio, 2014, 2015; Stinca *et al.*, 2012, 2013, 2014, 2016a, 2016b, 2017a, 2017b; Salerno & Stinca, 2017). The increase of the exotic flora is also evident in the small islands (Celesti-Grapow *et al.*, 2016). The Astroni crater is one of the few areas in the province of Naples that conserves a forest withdrawn from management for several decades and evolving naturally. Although analysis of the various plant species showed little floristic pollution due to anthropogenic release of exotic plants, such species could interact with local plant communities, altering the delicate environmental balance and affecting its evolutionary dynamics. Considering that a disturbance phenomenon (e.g. windstorm, fire) facilitate invasion processes (Bonanomi *et al.*, in press), targeted interventions to eliminate or contain non-native species would be desirable.

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(*ms. pres. 15 maggio 2017; ult. bozze 26 ottobre 2017*)

Edizioni ETS
Piazza Carrara, 16-19, I-56126 Pisa
info@edizioniets.com - www.edizioniets.com
Finito di stampare nel mese di dicembre 2017