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CHECKLIST

Checklist of alien plant species in a natural protected area: Anaga Rural Park (Tenerife, Canary Islands); effect of human infrastructures on their abundance

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Background and aims – Invasive alien (exotic) species are one of the most serious threats to the conservation of biodiversity on the planet. This is especially true on islands, given the fragility of their ecosystems and high levels of endemicity in both species and ecosystems. The problem is particularly acute in the Canary Islands, a biodiversity `hot spot´, where there is widespread high endemicity and unique biodiversity. This paper presents the first comprehensive inventory of alien plant species in Anaga Rural Park (ARP) (Tenerife, Canary Islands, Spain) a Natural Protected Area, currently proposed as a UNESCO Biosphere Reserve. Anaga is also outstanding for including a relict Tertiary era laurel-forest ecosystem that hosts a large number of palaeoendemics.
Methods – Surveys were conducted along itineraries through the different ecosystems of ARP to determine the alien plant species in areas with different levels of human impact.
Key results – Two hundred and sixteen alien species were identified, belonging to 53 families and 141 genera, especially concentrated in the most anthropic areas, noting the possibly competitive coexistence of aliens and local endemics of importance in the ecosystem. This is the first overall comprehensive study on the importance of alien species in ARP. Surveys confirmed how human infrastructure and activities significantly favour the presence and diversity of exotic species. Using multivariate statistical analysis, significant differences were found between the species diversity of alien flora and the proximity of anthropic areas. The presence of *Cuscuta campestris* Yunck was detected, being a second record for the Canaries and the first for ARP.
Conclusions – A large number of alien plant species inhabit ARP, affecting all its ecosystems. This is largely the result of the human activities within it, and poses a risk to its conservation and the survival of numerous endemic taxa s. str.

Key words – Invasive plants, endemic species, Rural Park, interspecific coexistence, anthropogenic influence, subtropical areas, Macaronesia, Canary Islands.

INTRODUCTION

Anaga Rural Park is located at the northeastern end of the island of Tenerife (figs 1 & 2). It covers an area of 14418 ha, with about 2000 inhabitants distributed among twenty villages and hamlets. Anaga is a volcanic massif arising from Tertiary era volcanic activity, which because of its origin and intense erosive activity presents a very steep and rugged terrain. It is spread around well-defined summits stretching from east to west, between 800 and 1000 m in altitude. Because of its height and orientation, it is an area heavily influenced by the cool moist trade-winds regime blowing from the NE Atlantic, often forming a 'sea of clouds' encountering the islands. Consequently, the northern and northeastern slopes are wetter than the south, especially at mid-altitudes and the summit. The steep slopes induce a significant thermal gradient and relief rainfall, which has led to the establishment of numerous mesoclimates and thus ecosystems and habitats. The main ecosystems are as follows:
(1) Non-coniferous (largely broadleaf) evergreen forest or 'monteverde' – a general term for both laurel forest (laurisilva) s. str. and the *Morella faya* (formerly *Myrica faya*) – *Erica arborea* thicket. 'Monteverde' is distributed over the summit and upper slopes of the north slope of Anaga be-

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tween 600 and 1000 m a.s.l., within the influence of the sea of clouds caused by the moist trade winds encountering the islands. These formations are a relic of subtropical vegetation that millions of years ago inhabited the Mediterranean basin, disappearing long ago due to climate change. They only survive on some islands of Macaronesia.
(2) Thermophilic forest occupies the range between 300 and 600 m a.s.l. It is composed of Mediterranean-type vegetation, consisting of shrubs or tree species forming dense open canopy evergreen-sclerophyllous thickets, shrubland and undergrowth. This ecosystem has profoundly deteriorated in the past, and is currently relegated to very few relicts and only poorly represented. They are listed in the Habitats Directive of EU as habitats of community and priority interest.
(3) The coastal scrub extends from sea-level to 300 m; it is characterized by species adapted to water stress and high insolation, mainly shrubs of the Euphorbiaceae family (Bramwell & Bramwell 2001).

It has recently been estimated that about 13 168 vascular plants have become naturalized in at least one of the 843 non-overlapping regions, covering approximately 83% of the planet's surface, including 362 islands (van Kleunen et al. 2015). This study has allowed us to perceive the seriousness of the problem, in terms of accumulation of non-native plants at a global level. The total number of vascular plants cited for the island of Tenerife is 1468, of which 297 are endemic, representing more than 50% of Canary Island endemics. In the whole of the Canary Islands, the total number of vascular plants is 2091, of which 539 are endemic.

Oceanic islands in tropical and subtropical latitudes are among the areas most affected by biological invasions, especially when subjected to strong anthropic pressure. Generally, island regions are more prone to biological invasions (Vitousek et al. 1987) and also their consequences are more serious there than on continents. Due to its isolation, insular flora is often poorer in number of taxa, which means the evolution of these species progresses under conditions of reduced competition (Loope & Mueller-Dombois 1989). Thus the native flora has a lower resistance to invasion by aliens, deriving from its lower adaptive capacity, along with the buffering effect of the sea (Sobrino-Vesperinas et al. 2002). Furthermore, intense anthropic pressure and the empty ecological niches left after destruction of the original vegetation lead to a lack of competition among the native flora, which facilitates the establishment of invasive species. Added to this there is often intense commercial activity that operates as input vector (gardening, agriculture, plant imports, etc.).

The Canary Islands along with the other North-East Central Atlantic islands (Azores, Madeira and Cape Verde) make up the Macaronesian region (fig. 1), a first-order biogeographical unit, established on the basis of its rich flora and unique habitats (Rivas-Martínez 1987). The archipelago is home to a large number of native species and constitutes a global diversity hotspot. The endemic vascular flora amounts to about 680 taxa (Reyes-Betancort et al. 2008), over a now greatly reduced area, resulting from processes of natural colonization and subsequent evolution over at least the last 20 million years.

Several factors led to the evolution of this unique flora. Firstly, the isolation of the Canaries, given their oceanic character with a wide diversity of habitats and ecological niches has facilitated the development of many local and island neoendemic taxa. Secondly, their geographical location has afforded them the appropriate conditions to host a wide representation of palaeoendemic or relict species, which in the past had much wider distribution. However, migration occurs in both directions; recent studies indicate that there are plants settled on the African coast whose DNA lineages

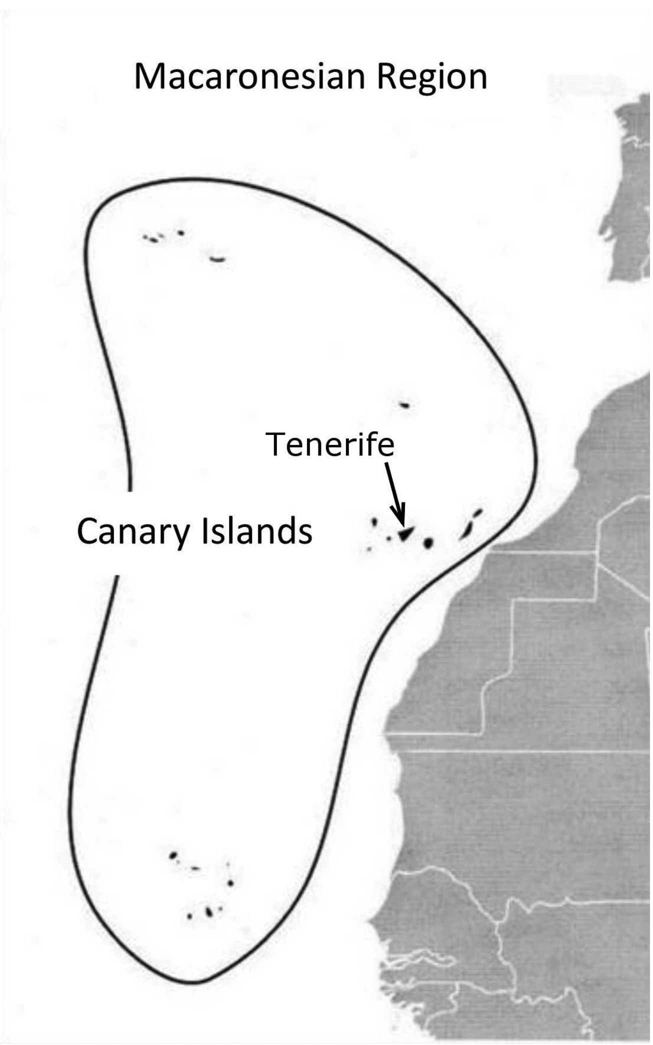

Figure 1 – Position of Tenerife, the Canary Island and the Macaronesian Region in the North Atlantic.

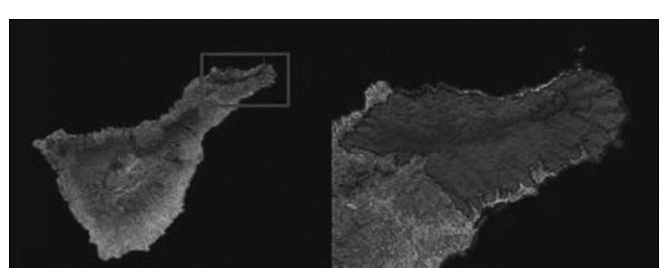

Figure 2 – Location of Anaga Rural Park on Tenerife (Canary Islands).

descend from others on the Canaries. So, elements of the Canary endemic or native biodiversity also contribute to the floristic composition of the African continent. This is in contrast to the idea of islands as biodiversity sinks, and shows that the islands can also be sources of biodiversity for mainland territories (Caujapé-Castells 2011).

The Canary flora is distributed over a series of bioclimatic belts in which ecosystems are located depending on altitude and exposure to trade wind humidity (del-Arco et al. 2006). Up to six such zonal ecosystems are distinguishable on the islands (Aguilera et al. 1994). Not all ecosystems have the same environmental conditions, thus neither do they have the same susceptibility to be invaded ('invasibility'). In general, the more ecologically diverse islands are more easily invaded, because new plants are more likely to find there niches appropriate to them.

The threats to native Canary plants are not new, but date from the first arrival of humans in the islands, between two and three millennia ago. Although the first North-African settlers caused less disruption to the environment, the period of large-scale destruction of natural habitats began in the late 15th century, following the European conquest and colonization. To this was added the introduction of rabbits and other game animals together with the new livestock and agricultural species of European origin, and the acclimatization of many other species arriving from America and elsewhere for subsequent introduction into Europe. Anaga Rural Park (ARP; fig. 2) is a protected natural area of great ecological importance, recently nominated as a Biosphere Reserve and known for its unique biodiversity and role in the conservation of laurel forest, in particular a relict Tertiary era ecosystem. The Canary Island Rural Parks are protected natural areas (PNA) in which conservation itself coexists with traditional land uses. They are aimed at the conservation of the whole and in turn promote the harmonious development of the local people and their living conditions. In the international nomenclature they correspond to spaces in categories V and VI of the IUCN.

The aims of this study were to: (1) make the first global inventory of alien plants species in the ARP to determine the number of introduced alien plants, so as to propose plans for control; (2) document cases of coexistence between alien and Canary endemic species; (3) study the similarities and differences between the alien flora occupying different localities; and (4) evaluate the effect that the anthropic areas have on species presence and diversity in these localities.

MATERIAL AND METHODS

The study covers a total surface area of about 15 000 ha with large ecological diversity. To prepare the inventory of plant species, a series of predetermined botanical itineraries (14) were carried out, visiting different areas of natural vegetation, villages, recreational areas, roadsides and paths in the ARP (fig. 3). These permitted us to study whether the various infrastructures can act as pathways for disruption in the ecosystem, through the introduction and spread of alien plants. Fourteen areas plus two stretches of road were prospected, distributed between different altitudes, ecosystems and human impact levels, and establishing UTM coordinates us-

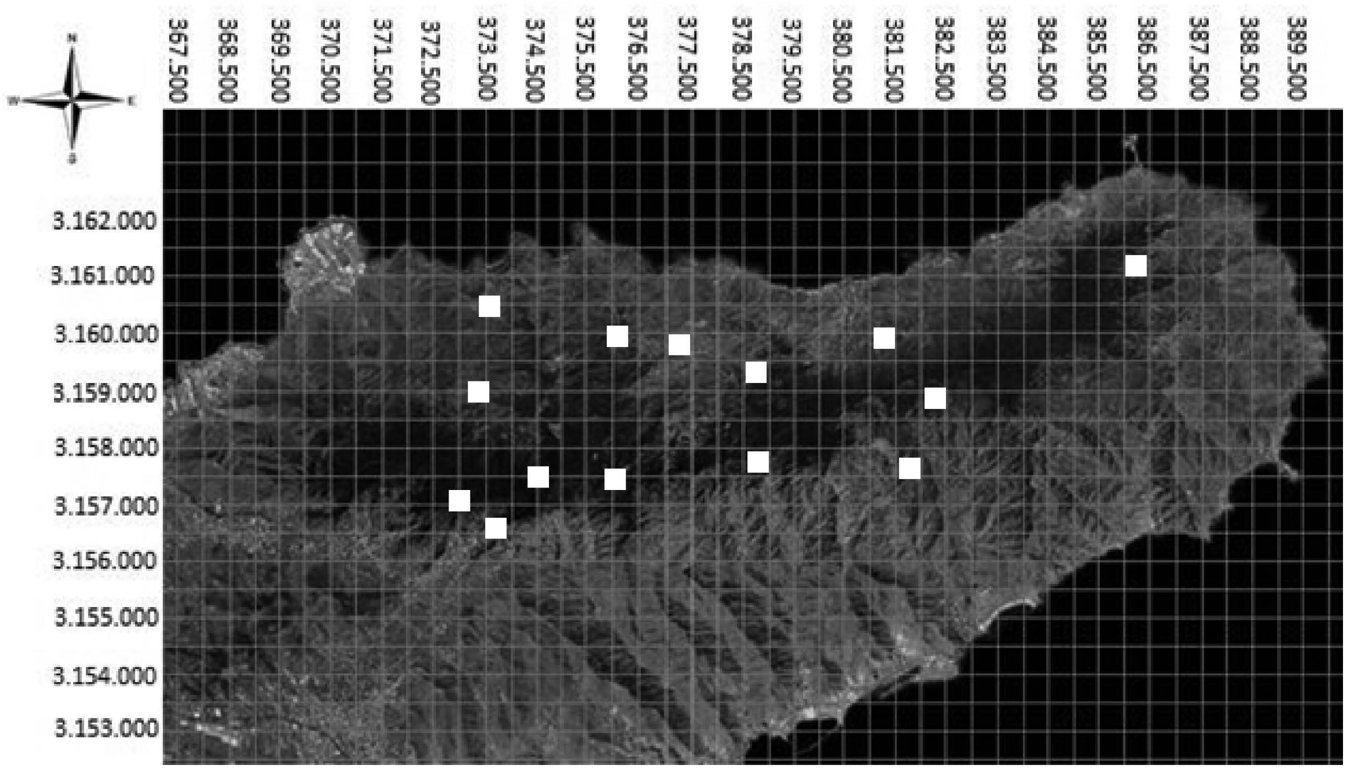

Figure 3 – Map showing the localities prospected (UTM coordinates) for the study and inventory of exotic plants in Anaga Rural Park (Tenerife, Canary Islands).

Table 1 – Botanical families and alien species collected in Anaga Rural Park (Tenerife, Canary Islands).

Nº	Family	Species	Nº	Family	Species
1	Agavaceae	1	28	Fabaceae	18
2	Aizoaceae	2	29	Fumariaceae	3
3	Amaranthaceae	3	30	Geraniaceae	8
4	Anacardiaceae	1	31	Hypolepidaceae	1
5	Apiaceae	2	32	Iridaceae	2
6	Apocynaceae	2	33	Lamiaceae	2
7	Araceae	2	34	Lilliaceae	2
8	Arecaceae	1	35	Malvaceae	3
9	Asphodelaceae	1	36	Mimosaceae	2
10	Asteraceae	27	37	Moraceae	1
11	Balsaminaceae	1	38	Myrtaceae	1
12	Basellaceae	1	39	Oxalidaceae	2
13	Bignoniaceae	1	40	Papaveraceae	5
14	Boraginaceae	1	41	Plantaginaceae	2
15	Brassicaceae	7	42	Poaceae	47
16	Cactaceae	4	43	Polygonaceae	8
17	Campanulaceae	1	44	Polypodiaceae	1
18	Cannaceae	1	45	Primulaceae	1
19	Caprifoliaceae	1	46	Rosaceae	3
20	Caryophyllaceae	6	47	Rubiaceae	3
21	Chenopodiaceae	4	48	Scrophulariaceae	4
22	Commelinaceae	1	49	Solanaceae	5
23	Convolvulaceae	3	50	Tropaeolaceae	1
24	Crassulaceae	3	51	Urticaceae	3
25	Cyperaceae	5	52	Valerianaceae	1
26	Equisetaceae	1	53	Verbenaceae	1
27	Euphorbiaceae	3	**Total families 53**		**Total species 216**

ing a GPS Garmin eTrex vista HCX. Preference was given to those in laurel forest areas, given the uniqueness of this ecosystem.

To evaluate the effect of anthropogenic factors on the presence and diversity of alien taxa, twenty transects (30 m × 1 m) were conducted through anthropic areas vs. non-anthropic (or less disturbed) laurel and thermophilic forests. To test the effect of roads on alien species abundance a distance-based permutational ANOVA (Anderson et al. 2008) was fitted, with two distances from roadside as fixed factor. In order to determine the species that contribute most to the differences between both treatments, a SIMPER procedure was performed (Clarke 1993). This method is widely used in ecological research to determine the species that are creating significant differences among treatments (Fernández-Lugo et al. 2013). Primer 6 and PERMANOVA+ were used to perform all statistical analyses (PRIMER-E Ltd., Plymouth, UK). Multi-Dimensional Scaling (MDS) was used to explore the distribution of samples with regard to alien species composition.

The species collected were distributed between the Herbarium of the Royal Botanic Garden of Madrid and the Herbarium of the Phytopathology and Genetic Laboratory of EPSI (Section of Agricultural Engineering) of the ULL. They were identified by consulting the specific literature (Voggenreiter 1989, Kunkel 1991, 1992, Hansen & Sunding 1993, Arechavaleta et al. 2010), and resorting to local floras for their source areas when species were not mentioned, as well as comparison with herbarium material. The classification of Mediterranean species as native or exotic/alien uses the criteria used by Kunkel (1991, 1992) in his pioneering studies of introduced plants on Tenerife. With the data obtained for each taxon, a checklist of exotic flora was drawn up to include: family, introduction route, chorology, biotype and affected ecosystems.

RESULTS

Two hundred and sixteen (216) exotic species belonging to 53 families and 141 genera (electronic appendix 1) were identified. This represents 14.7% of the total vascular plants cited for Tenerife (Arechavaleta et al. 2010). The most widely represented families were Poaceae (21.8%), Asteraceae (12.5%) and Fabaceae (8.3%) (table 1, fig. 4). Prevalence coincides with the results of other studies of alien flora conducted in other regions (Sanz-Elorza et al. 2004, Campos & Herrera 2009, Garcillán et al. 2014). Another seven families especially represented were Geraniaceae (3.7%), Polygonaceae (3.7%), Brassicaceae (3.2%), Caryophyllaceae (2.8%), Cyperaceae (2.3%), Papaveraceae (2.3%) and Solanaceae (2.3%) (fig. 4). In terms of origin, 43.5% of these species occur in the Mediterranean region, 17.6% in the Americas, 12.5% in Africa – especially South Africa, 11.1% in Eurasia, and the rest is from palaearctic, non-Mediterranean European, cosmopolitan and palaeotropical sources. Their life forms consist of 50.0% of therophytes, 19.0% of hemicryptophytes, 8.3% of chamaephytes, 6.0% of geophytes, 5.1% of macrophanerophytes, 3.2% of phanerophytes, lianas and hydrophytes being represented by only 2.3% and 1.4% of the identified taxa (fig. 5). Among the taxa, 51.9% have been introduced into the Canaries unintentionally and 20.4% as weeds associated with farming. The rest was introduced for use in gardening (20.8%) and agriculture (6.9%) (fig. 6).

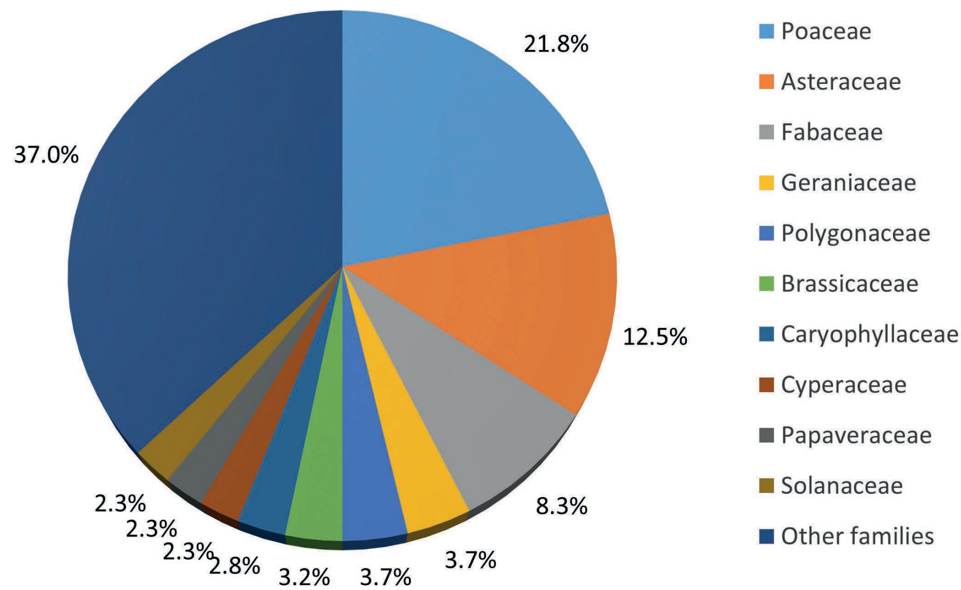

Figure 4 – Relative proportion of families of alien plant species in Anaga Rural Park, Tenerife. The set of families with low representation (43) represent 37.0%.

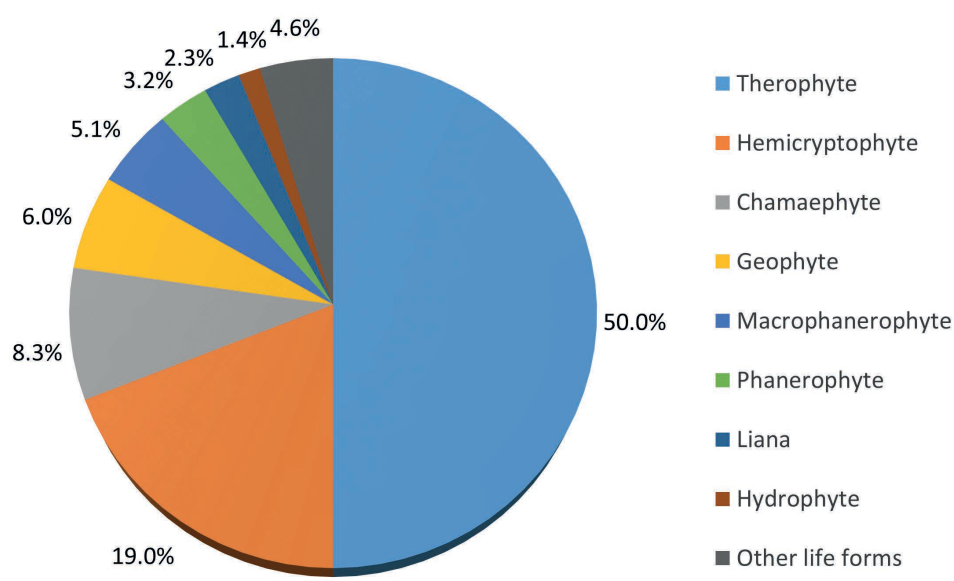

Figure 5 – Relative proportion of life forms shown by alien plant species present in Anaga Rural Park (Tenerife, Canary Islands).

Table 2 – Interspecies coexistence of exotic plants with endemic plants in Anaga Rural Park (Tenerife, Canary Islands).

Endemic species	Exotic species
Aeonium urbicum	*Crassula lycopodioides* *Crassula multicava* *Aloe arborescens* *Asphodelus aestivus* *Dactylis glomerata* *Opuntia ficus-indica*
Aeonium lindleyi	*Crassula lycopodioides* *Opuntia ficus-indica*
Aichyson laxum	*Cymbalaria muralis*
Artemisia canariensis	*Pennisetum purpureum* *Acacia farnesiana*
Bryonia verrucosa	*Ipomea indica*
Canarina canariensis	*Boussingaultia cordifolia* *Rubus ulmifolius* *Vinca major* *Oxalis pes-caprae*
Dracaena draco	*Arundo donax*
Erica platycodon	*Ipomea indica* *Solanum laxum*
Euphorbia canarienis	*Opuntia ficus-indica* *Pelargonium zonale*
Euphorbia lamarckii	*Austrocylindropuntia subulata* *Opuntia ficus-indica* *Rubus ulmifolius* *Pelargonium zonale*
Hypericum canariense	*Rubus ulmifolius* *Arundo donax* *Ipomea cairica*
Kleinia neriifolia	*Austrocylindropuntia subulata* *Opuntia ficus-indica* *Crassula lycopodioides*
Phoenix canariensis	*Agave americana* *Phoenix dactylifera*
Pericallis echinata	*Oxalis pes-caprae* *Lathyrus tingitanus*
Ranunculus cortusifolius	*Zantedeschia aethiopica*
Salix canariensis	*Arundo donax* *Boussingaultia cordifolia* *Rubus ulmifolius*
Phyllis nobla	*Vinca major* *Cyperus eragrostis* *Ageratina adenophora*
Monanthes anagensis	*Crassula lycopodioides* *Dactylis glomerata*
Monanthes laxiflora	*Crassula lycopodioides*
Urtica morifolia	*Oxalis pes-caprae*

The diversity of ecosystems and habitats in ARP is reflected in the wide variety of alien species identified. The presence of these species affects all ecosystems in the Park: laurel forest, *Morella–Erica* thicket, thermophilic woodland and *Euphorbia* shrubland (electronic appendices 1 & 2).

Numerous cases of interspecific coexistence (McNaughton & Wolf 1984) between exotic and native elements involve more than twenty plants endemic to Anaga, the Canaries and Macaronesia. Figures 7 & 8 explicitly illustrate the severity of this problem.

A significant number of the exotic plants establishing relationships of coexistence, which in some cases could even be interpreted as interspecific competition, have been introduced into the Canary Islands for use in gardening. At least twenty-five exotic species coexist on the same substrate, sharing sunlight, nutrients and water resources with the 20 species listed as narrow Canary endemics (table 2). Some of them are locally emblematic plants like *Canarina canariensis* or *Salix canariensis* or as unique as *Aeonium urbicum*, *Aeonium lindleyi* and *Aichryson laxum*. In the case of *Phoenix dactylifera*, individuals or more generally segregating hybrids from previous hybridization are now hybridizing with endemic *P. canariensis* in the transition from *Euphorbia* shrubland to thermophilic woodland. The largest diversity of aliens was concentrated near roads, human settlements and other major humanized environments. In general, the prospected areas with the largest number of aliens are located where the ecosystem units were in 'monteverde', now or in the past before human impact on the environment. The village with the highest number of exotic species with the most invasive behaviour was also the most populated.

As table 3 shows, the treatment – roadsides vs. 10 m from road – has significant effects on floristic composition in the study areas compared to the contribution from alien species. The transects along the roadsides within the 'monteverde' showed that few exotics are found away from the areas showing human impact. This is not the case in the thermophilic forest, where they remain present, because of the high degree of environmental degradation this ecosystem has undergone throughout most of ARP. It is thus clear that anthropogenic disturbance favours naturalization and settlement of alien plants. The promoting effect of such disturbance on the presence and abundance of exotic species is shown by the statistically significant difference in their presence (table 4), depending on the proximity of human activities to the site. Roadsides are characterized by higher abundance of *Conyza bonariensis*, *Sporolobus indicus*, *Rhynchelytrum repens* and *Bidens pilosa*, whereas transects located 10 m away from the road show lower abundance (table 3). However, *Rubus ulmifolius*, *Pteridium aquilinum* and *Ipomea cairica* are more abundant outside roadside areas (table 3).

The presence of *Cuscuta campestris*, recently reported for the first time in the Canaries (Santos-Guerra et al. 2013), is detected for the first time in ARP according to the literature.

DISCUSSION

Presented here is what we consider the first overall comprehensive study of the alien flora of Anaga Rural Park (Tenerife, Canary Islands) and the influence of human environmental impact on its invasibility. The diversity of ecosystems and habitats present in ARP is reflected in the wide variety of exotic species identified. These species are present in all the ecosystems of the park: laurel forest, *Morella–Erica* thermophilic woodlands and *Euphorbia* scrub. From a conser-

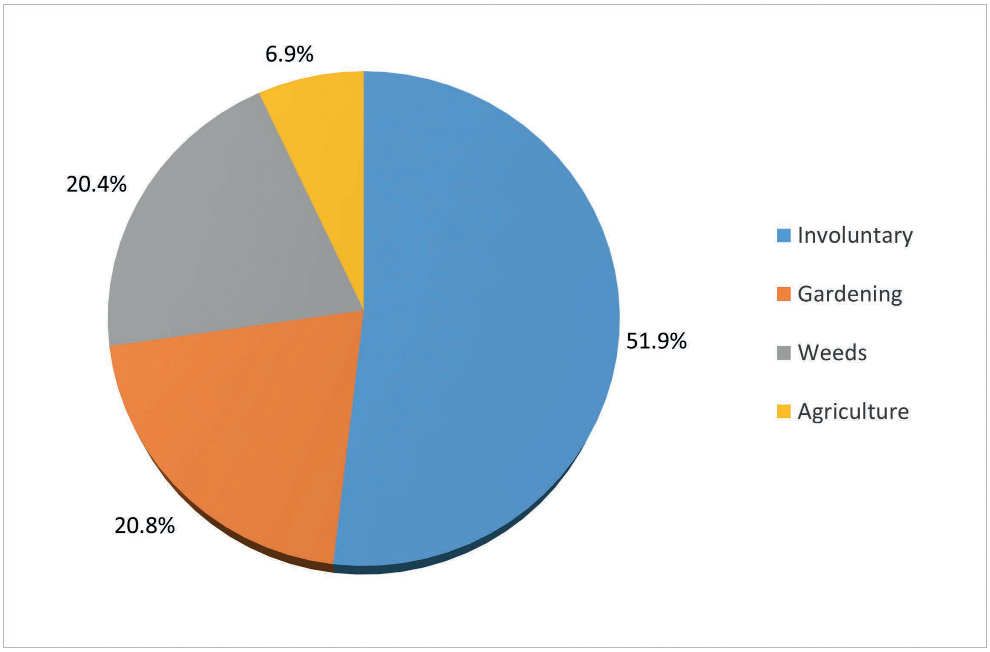

Figure 6 – Relative importance of alien plant introduction routes into Anaga Rural Park (Tenerife, Canary Islands).

Figure 7 – Invasive exotic species in Anaga Rural Park (Tenerife, Canary Islands): A, aerial tubers of *Boussingaultia cordifolia* over Canary-Madeira endemic *Salix canariensis*; B, *Vinca major* and *Oxalis pes-caprae* coexisting with the Canarian endemic *Canarina canariensis*; C, *Ipomoea indica* and *Senecio angulatus* coexisting with the endemic *Bryonia verrucosa* (see fruits on the right); D, *Oxalis pes-caprae* surrounding the endemic *Pericallis echinata*, apparently competing for water, nutrients and light.

Figure 8 – Exotic invaders and endemic species in Anaga Rural Park. A, *Dracaena draco* in an area invaded by *Arundo donax*; B, *Lathyrus tingitanus* together with *Erica platycodon*; C, *Austrocylindropuntia subulata* growing together with the endemic species *Euphorbia lamarckii* and *Phoenix canariensis*; D, *Cymbalaria muralis* introduced with ornamental intentions, coexisting with the Canarian endemic *Aichryson laxum*; E, several invaders apparently competing amongst each other: *Boussingaultia cordifolia*, *Ipomoea cairica* and *Opuntia ficus-indica*; F, *Solanum laxum* in the habitat of *Erica platycodon*, a Canarian endemic; G, invasion of *Senecio angulatus*, an exotic liana, in interspecific coexistence with *Opuntia ficus-indica*, another exotic alien; H, *Crassula multicava* at a roadside location as dominant species.

Table 3 – Results of the SIMPER procedure conducted to determine species contribution to differences between anthropic areas (roadsides) and non-anthropic (10 m from the roadside), in areas of laurel and thermophilic forest in Anaga Rural Park, (Tenerife, Canary Islands).
Av. Value: average contribution of each species; Av. Sq. Dist.: average square distance (as dissimilarity measure) between the two 'treatments'; Sq. Dist. /SD.: mean distance to standard deviation ratio of species; Contrib. %: percentage of species contribution to total distance between treatments; Cum. %: Cumulative percentage of total distance between treatments. Species are ranked according to their percentage contribution to total distance between treatments.

Taxon	Roadside Av. Value	10 m from road Av. Value	Av. Sq. Dist	Sq. Dist/SD	Contrib.%	Cum.%
Rubus ulmifolius	1.720	1.890	16.60	0.57	13.2	13.2
Conyza bonariensis	2.250	0.000	12.10	0.69	9.62	22.81
Pteridium aquilinum	0.996	1.320	9.17	0.54	7.29	30.11
Sporobolus indicus	1.960	0.100	9.11	0.57	7.24	37.35
Rhynchelytrum repens	1.410	0.573	7.88	0.6	6.26	43.61
Ipomea cairica	0.000	0.762	5.80	0.33	4.61	48.22
Bidens pilosa	1.890	0.100	5.52	0.67	4.39	52.61
Crassula lycopodioides	0.534	0.893	5.45	0.47	4.33	56.94
Pennisetum setaceum	0.000	0.728	5.30	0.33	4.21	61.16
Cyperus eragrostis	0.972	0.000	5.20	0.42	4.13	65.29
Hyparrhenia hirta	0.200	0.624	4.05	0.36	3.22	68.51
Paspalum dilatatum	0.557	0.000	3.10	0.33	2.46	70.98
Bromus catharticus	0.895	0.000	2.90	0.54	2.31	73.28
Oxalis corniculata	0.831	0.000	2.80	0.39	2.23	75.51
Opuntia ficus-indica	0.316	0.605	2.12	0.55	1.68	77.19
Carex divulsa	0.765	0.000	2.10	0.55	1.67	78.86
Foeniculum vulgare	0.854	0.141	2.06	0.63	1.64	80.5
Arundo donax	0.245	0.487	1.96	0.44	1.56	82.06
Briza minor	0.446	0.000	1.30	0.36	1.03	83.09
Polypogon viridis	0.361	0.000	1.30	0.33	1.03	84.12
Hypochoeris glabra	0.361	0.000	1.30	0.33	1.03	85.16
Tropaeolum majus	0.332	0.000	1.10	0.33	0.87	86.03
Gnaphalium luteo-album	0.316	0.000	1.00	0.33	0.8	86.83
Sonchus asper	0.538	0.000	1.00	0.59	0.8	87.62
Cenchrus ciliaris	0.538	0.000	1.00	0.59	0.8	88.42
Boussingaultia cordifolia	0.100	0.300	0.94	0.36	0.75	89.16
Picris echiodes	0.565	0.000	0.90	0.59	0.72	89.88
Echium plantagineum	0.418	0.000	0.90	0.47	0.72	90.59

Table 4 – Summary of permutational ANOVA fitted for abundance of alien taxa.
Main factors are: Treatment (roadsides vs. 10 m from the roadside), Unit (laurel and thermophilic forest), and their interaction. Altitude is included as covariate. Anaga Rural Park, (Tenerife, Canary Islands). Values followed by ** indicate highly significant differences ($p < 0.01$); followed by *, significant difference ($p < 0.05$); followed by "ns", non-significant difference.

Source	df	SS	MS	Pseudo-F	P(perm)
Altitude	1	159.61	159.61	3.12	0.0001**
Treatment	1	106.55	106.55	2.09	0.0112*
Unit	1	39.68	39.68	0.78	0.6750 ns
Treatment × Unit	1	79.18	79.18	1.55	0.0859 ns
Residual	15	766.29	51.09		
Total	19	1151.3			

vation perspective, the Canarian endemic flora is considered highly vulnerable to environmental change, the disturbing action of humans and invasive species (Bramwell 1990). Established to promote conservation, Protected Natural Areas (PNAs) now constitute almost 40% of the area of the archipelago. However, this has not guaranteed a lower presence of invasive species, as the human pressure from outside the protected areas can often act as a source of dispersal of these species. In fact, the number of protected areas that are threatened by biological invasions is increasing globally (Foxcroft et al. 2011). These circumstances have made it necessary for protected area management plans to include alien flora control programmes. For the plans to be effective and economically sustainable, updated information is necessary on the species present, their distribution, impacts, status, expansion risk, etc. (Pyšek & Richardson 2010). This was one of the targets of this research, and the starting point to accurately define the risks and propose specific remedial measures.

The results for ARP show a high number of alien species. The total of 216 exotic plants is impressive compared to the total number of 297 endemic species on the island of Tenerife This means that the number of exotic species present in Anaga Rural Park reaches 72% of the total endemic island flora.

Alien plants are especially concentrated in the vicinity of anthropic areas, and their presence is favoured by this proximity as much as by surrounding ecosystem degradation. This directly points to the effect of the villages and the activities therein as a cause of the high presence of such exotics. This effect has already been mentioned (Green & Baker 1997), considering these areas as the immediate sites of introduction and naturalization of exotic species. The possible competition between endemic and exotic species for the same niches is a point of particular importance in ARP, given its particularly high endemism, not only because of the risk it poses to the survival of these native species, but also since many of the xenophytes suspected to be in competition with them were introduced through gardening activities. Even more necessary in such a unique vulnerable territory as the Canaries, this should lead to decisive measures to prevent the introduction of new potentially invasive ornamental plant species and restrict their use by Park residents, so as to limit their release into the wild. In the long term, education of adults and children should also be employed as a conservation strategy.

Considering the citation frequency of exotic species and/or worrying coexistence with the endemic species (table 2), control measures are needed at least for the 21 following invasive species: *Achyranthes sicula*, *Agave americana*, *Ageratina adenophora*, *Arundo donax*, *Austrocylindropuntia subulata*, *Bidens pilosa*, *Boussingaultia cordifolia*, *Conyza bonariensis*, *Crassula lycopoides*, *Crassula multicava*, *Crocosmia × crocosmiiflora*, *Cyperus involucratus*, *Foeniculum vulgare*, *Ipomea indica*, *Ipomea cairica*, *Opuntia ficus-indica*, *Oxalis pes-caprae*, *Pennisetum setaceum*, *Phoenix dactylifera*, *Senecio angulatus*, *Tradescantia fluminenesis.* These measures should not be taken in isolation, but followed by the immediate commencement of restoration of natural vegetation and monitoring of the whole.

Given the difficulty in choosing a method for effective protection of the uniqueness of these ecosystems and the numerous local endemics hosted by Anaga Rural Park, establishment of a perimeter protection belt around the park should be considered. This could then also be applied around the villages and isolated buildings within the Park.

SUPPLEMENTARY DATA

Supplementary data are available in pdf at *Plant Ecology and Evolution*, Supplementary Data Site (http://www.ingentaconnect.com/content/botbel/plecevo/supp-data) and consist of the following: (1) checklist of exotic species identified in Anaga Rural Park; and (2) alien species collected in the different localities studied in Anaga Rural Park.

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