Aliens come from the edge: a distribution pattern of focal alien plants in a small coastal reserve

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Abstract

We studied the distribution of nine easily detectable focal alien plant species (one archaeophyte and eight neophytes) in a small coastal nature reserve (Palude di Torre Flavia, Central Italy). On 70 units, 100x100 m each, we obtained evidence of 39 units with at least one focal species. Palms are the most common taxa (> 51% of spatial occurrences). All the species are mainly distributed along the edge of the protected area, near the most anthropized areas. Most of the neophytes have all been actively cultivated in the last decade (voluntary introduction for ornamental purposes) in rural houses and bathing establishments (e.g. *Yucca gloriosa*, palmae such as *Phoenix canariensis*, *Washingtonia robusta* and *Carpobrotus acinaciformis/edulis*), with the exception of *Eucalyptus camaldulensis* historically cultivated along the boundaries of agricultural land reclaimed areas. The only alien species widespread spontaneously in the whole area is an archaeophyte (*Arundo donax*), especially along road margins and, occasionally, along the dunes. Among neophytes, *Carpobrotus acinaciformis/edulis* (invasive), *Yucca gloriosa* and *Phoenix canariensis* are the only naturalized species, located along the dunes (for zoocorous and involuntary anthropocorous dispersion). No species have been found in wet environments (*Juncetalia maritimi* rushbeds and *Phragmites australis* reedbeds). Our results will be used to (i) distinguish which species could autonomously spread in the reserve; (ii) develop appropriate management strategies aimed to control the invasive species.

Keywords: Atlas, invasive species, dunal habitats, management.

Riassunto

Gli alieni vengono dal margine: modello di distribuzione di specie vegetali aliene in una piccola area protetta costiera
È stata studiata la distribuzione a scala locale di nove specie vegetali focali, di facile contattabilità (una archeofita e otto neofite) in un'area protetta costiera laziale dell' Italia centrale. Su 70 unità totali (ciascuna di 100x100 m), abbiamo ottenuto evidenze di almeno una delle specie focali in 39 unità (>51%). Le palme rappresentano uno dei taxa maggiormente rappresentati. Tutte le specie sono distribuite per la maggior parte lungo il confine dell'area protetta, vicino alle zone maggiormente antropizzate. La maggioranza delle neofite è stata coltivata attivamente nell'ultimo decennio (introduzione volontaria per scopi ornamentali) nelle case rurali e negli stabilimenti balneari (es., *Yucca gloriosa*, *Phoenix canariensis*, *Washingtonia robusta*, *Carpobrotus acinaciformis/edulis*), con l'eccezione di *Eucalyptus camaldulensis* coltivato storicamente lungo i confini delle proprietà agricole. L'unica specie aliena diffusasi spontaneamente nell'intera area è un'archeofita (*Arundo donax*), presente specialmente lungo i margini delle strade e, occasionalmente, lungo le dune. Tra le neofite, *Carpobrotus acinaciformis/edulis* (invasiva), *Yucca gloriosa* e *Phoenix canariensis* sono le uniche specie naturalizzate a dispersione zoo-antropocora, rinvenute lungo le dune. Non sono state rinvenute specie aliene in ambienti umidi (giuncheto a *Juncetalia maritimi* e canneto a *Phragmites australis*). I risultati ottenuti saranno utilizzati per (i) individuare quali tra queste specie mostrano maggiore invasività e (ii) per sviluppare opportune strategie di controllo.

Keywords: Atlante, specie invasive, habitat dunali

Introduction

Alien (sin.: allochtonous) species are introduced worldwide. Among them, it is well documented that "invasive" alien species can produce decline of native taxa and damage native communities (Mack *et al.*, 2000; Lloret *et al.*, 2005; Gaertner *et al.*, 2009). Moreover, alien species could impact negatively on local socio-economic systems (Pimental *et al.*, 2000). At a large scale, the principal source of introduction of alien species is the international trade, which depends on the economic globalization (U.S. Congress, 1993; Westphal *et al.*, 2008). In the Mediterranean landscapes, anthropized (i.e. urban and

suburban) areas are the richest habitats in alien species and serve as important source for further spread (Pysek, 1998). But in a smaller scale, the presence of alien species could be due to a voluntary release of pets or ornamental plants in nature from citizens and stakeholders (Padilla & Williams, 2004; Patoka *et al.*, 2016).
The richness of alien species in a protected area is positively correlated with many variables like size, habitat diversity, disturbances and human population density. It is also known that many nature reserves were characterized by a strong human presence before they were established and it has affected the abundance of alien species (McKinney, 2002).
In this note, we analyze the local distribution of a set of nine alien plant species, characterized by their easily detectability, in a coastal nature reserve of central Italy. The results of this study will be used (i) to distinguish which species could autonomously spread in the reserve; (ii) to define appropriate management strategies aimed to control the more invasive species.

Study Area

The study area ["Palude di Torre Flavia" Natural Monument (Central Italy; 41.57' N; 12.02' E; hereafter, TFNM] is a small protected wetland (43 ha) situated on the Tyrrhenian coast. This is a Special Protection Area (code IT6030020), according to the European Bird Directive 2009/147/CE (IGM 140-38-1; see Lucchese, 2017). The study area was officially protected by laws since 1997, and since 2000 it has been managed by the Environmental Service of the 'Città Metropolitana di Roma Capitale' public Agency (Battisti *et al.*, 2013). Torre Flavia is a relict portion of a once larger wetland that was recently drained and transformed. It is also characterized by a semi-natural patchiness with channels, that for some years has been utilized, before the beginning of this study, for mullet (*Mugil cephalus* Linnaeus, 1758, *Chelon ramada* (Risso, 1827), *C. saliens* (Risso, 1810)) pisciculture, reed beds (*Phragmites australis* (Cav.) Trin. ex Steud.), flooded meadows, dune and backdune areas, and rush bed patches with *Carex hirta* L., *Juncus acutus* L., and Cyperaceae plants as dominant vegetation. At the edge of the reserve there are anthropized areas (crops, transitional areas, roads and degraded ecotones; Corine Land Cover categories: 24: heterogeneous agricultural areas, 33: open space with little or no vegetation, 42: maritime wetlands). The water in the wet area is mainly of meteoric and sea-storm origin; water-depth is variable over time, and there is no water in the period June–October. Flow from surrounding areas is scarce (further details in Battisti, 2006).

Methods

We carried out a field survey on July 2019 focused on verifying the presence and local distribution of a set of alien plant species (focal species: Table 1). Among the 468 alien species voluntary or involuntary introduced in Latium (Lucchese, 2017), we selected nine charismatic species of relatively large dimensions, easily detectable and widely cultivated in central Italy (Tab. 1). In the case of the *Carpobrotus* records, the local taxonomic diagnosis at the species level is still uncertain and we preferred to indicate both taxa probably present.
First, we defined a grid of 70 100x100 m units over-imposed on the Torre Flavia wetland nature reserve (each one named using an alphanumeric code). Secondly, we carried out a field sampling to identify alien plants and locating them inside each unit and counting the number of specimens. In each unit we first defined the borders before starting to look for focal species under the grid. However, because of the difficulties in coun-

Species	Family	Neophyte/ Archeophyte	Pollination type	Dispersal type	Source of introduction (general)	Source of local introduction	N total occurrences (and n of sites of local naturalization)	% protected area
Agave americana L.	Asparagaceae	N	Entomophilous	Anemochorous/Autochorous	voluntarily introduction (ornamental)	voluntarily planted along park pathway	2 (-)	2.86 (-)
Yucca gloriosa L.	Asparagaceae	N	Entomophilous	Autochorous	voluntarily introduction (ornamental)	voluntarily planted near bathing facilities and private areas (by private stakeholders)	3 (1)	4.29 (1.43)
Arundo donax L.	Poaceae	A	Anemophilous	Anemochorous	voluntarily/ involuntarily introduction (agriculture)	Present along marginal ecotones (along roads)	5 (5)	7.14 (7.14)

Tab. 1 - Continua

Carpobrotus acinaciformis (L.) L. Bolus/ *edulis* (L.) N.E. Br.	Aizoaceae	N	Entomophilous	Endozoochorous	voluntarily introduction (ornamental)	voluntarily planted near bathing facilities and private areas (by private stakeholders); dispersed along dunes	3 (2)	4.29 (2.86)
Eucalyptus camaldulensis Dehnh.	Myrtaceae	N	Entomophilous	Anemochorous/Autochorous	voluntarily introduction (ornamental/ agriculture)	voluntarily planted at the border of agricultural crops (by Land Reclaimed Agency and private stakeholders)	4 (-)	5.71 (-)
Opuntia ficus-indica (L.) Mill.	Cactaceae	N	Entomophilous	Zoochorous	voluntarily introduction (ornamental/ agriculture)	voluntarily planted near private areas (by private stakeholders)	1 (-)	1.43 (-)
Phoenix canariensis Chabaud	Arecaceae	N	Entomophilous	Zoochorous	voluntarily introduction (ornamental)	voluntarily planted near bathing facilities (by private stakeholders)	11 (2)	15.71 (2.86)
Washingtonia robusta H. Wendll	Arecaceae	N	Entomophilous	Zoochorous	voluntarily introduction (ornamental)	voluntarily planted near bathing facilities (by private stakeholders)	9 (-)	12.86 (-)
Pittosporum tobira (Thunb.) Aiton fil.	Pittosporaceae	N	Entomophilous	Autochorous/ Zoochorous	voluntarily introduction (ornamental)	voluntarily planted near bathing facilities (by private stakeholders)	1 (-)	1.43 (-)
Total							39 (10)	

Tab. 1. Alien plants occurring in the 'Palude di Torre Flavia" Natural Monument. Neophyte/Archeophyte (N/A), pollination type, dispersal type, source of introduction (general and local); N = n total occurrences (and number of sites of local naturalization). % = percentage of distribution in the nature reserve (and % of local naturalization).

ting individuals (due to scarce visibility and detectability) these unreliable numbers have not been reported in the study and it has been considered only their occurrences (i.e. the presence of at least one individual plant in each 100x100 m unit). Each unit has been visited for at least 20 minutes (total research effort: about 30 hours). In each grid, we distinguished if plants have been voluntary cultivated or spontaneously naturalized.
Original data of field survey have been integrated from the local cumulative knowledge obtained in the last two years from the Park Agency operators.

We analyzed the field data obtaining a percentage of occurrence (n. of occupied units by at least one individual/total number of units) both for each focal species and for the total of selected species. For each unit, we obtained a value of species richness (number of focal species normalized to 100x100 m units). We used a χ^2 test to compare frequency of occurrences among them (using a SPSS 13.0 software). Finally, we obtained a map of local distribution for single species and for species richness.

Results and Discussion

We obtained 39 occurrences related to the nine selected focal alien species. In 21 units (30%) we observed the occurrence of at least one non-native species, both causal (voluntarily cultivated) and spontaneously naturalized (Figs. 1-9). Palms (Arecaceae) are the most common target species (20 occurrences on 39: 51.28%) with an occurrence significantly higher when compared to second ranked species (*Arundo donax*; χ^2 = 11.538, p<0.001).

The selected species, already reported in recent works, both at local (Guidi, 2006; Buccomino & Leporatti, 2009) and regional scale (Izzi *et al.*, 2007a, 2007b; Lucchese, 2017), are mainly distributed along the edges of the reserve (Fig. 10), with the highest values in the most anthropized units (including bathing establishments, houses, roads). Most of the neophytes have all been actively cultivated in the last decade (voluntary introduction for ornamental purposes) in rural houses and bathing establishments (even intensively: max: *Yucca gloriosa* L.> 110 plants/unit), except for *Eucalyptus camaldulensis* Dehnh., cultivated some decades ago along the borders of agricultural land with the purpose of windbreak in reclamation areas. The only alien species spontaneously (i.e. not cultivated) distributed in the whole area is an archaeophyte (*Arundo donax* L.) along road margins and, occasionally, along the dunes.

We observed a spontaneous dispersion of *Carpobrotus acinaciformis* (L.) L. Bolus/*edulis* (L.) N.E. Br., *Yucca gloriosa* L. and *Phoenix canariensis* H. Wildpret, mainly naturalized along the dunes (zoocorous and anthropocorous dispersion). These species are known as predominantly naturalized in coastal areas of Latium (Acosta & Izzi, 2017; Lucchese, 2017). In particular, *C. acinaciformis*/*edulis* locally showed a potential invasiveness of new colonized sites in the short term (last year). This species is considered a "habitat transformer" since it can cause profound environmental transformations (Richardson *et al.*, 2000).

The species which showed an independent dispersion are those that should be actively monitored by the Park Agency, in order to define appropriate eradication and control strategies. In particular, the dune and sandy environments represent the most vulnerable environments, while no species have been found in wet ecosystems (*Juncetalia maritimi* and *Phragmites australis* (Cav.) Trin. ex Steud. reedbeds). Since these types of ecosystems are less disturbed, they are more resilient and probably less vulnerable to invasiveness by the alien species.

Further investigations could be focused on other alien species, locally occurring. More specifically: (i) actively cultivated species [casual aliens: e.g., *Gazania rigens* (L.) Gaertner; *Tamarix parviflora* DC]; (ii) indigenous species at regional level but locally introduced and naturalized (e.g., *Chamaerops humilis* L.); (iii) species in the phase of autonomous dispersion (e.g. naturalized aliens as *Phytolacca americana* L.).

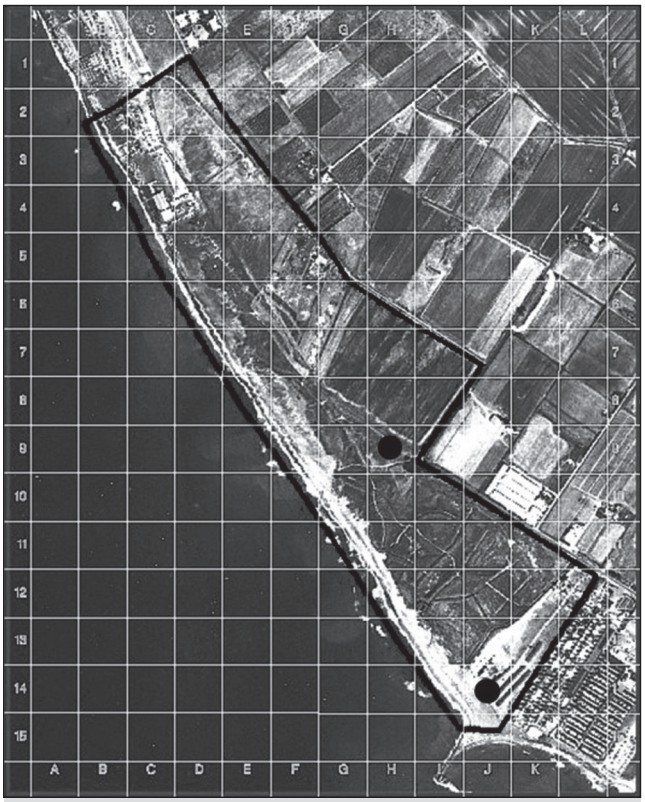

Fig. 1. ***Agave americana*** **L.**

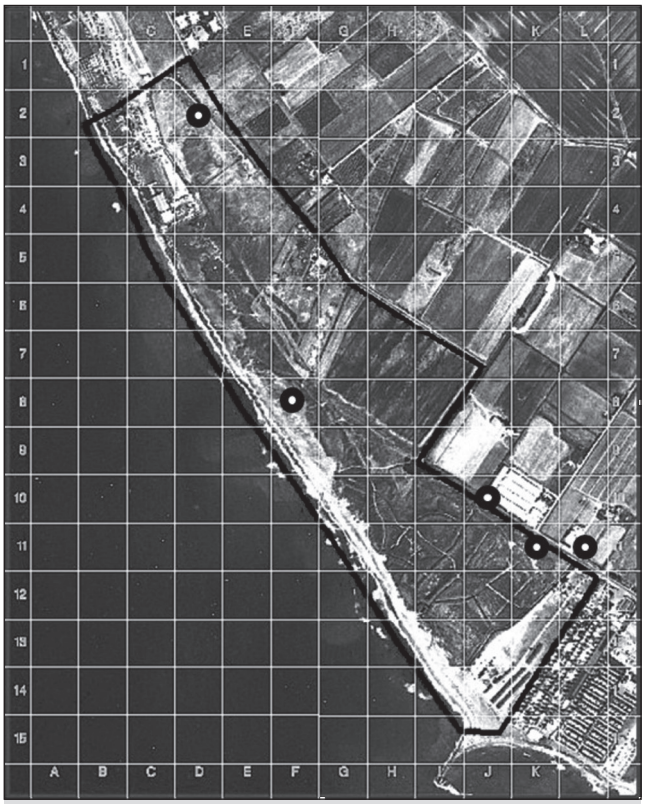

Fig. 2. ***Arundo donax*** **L.**

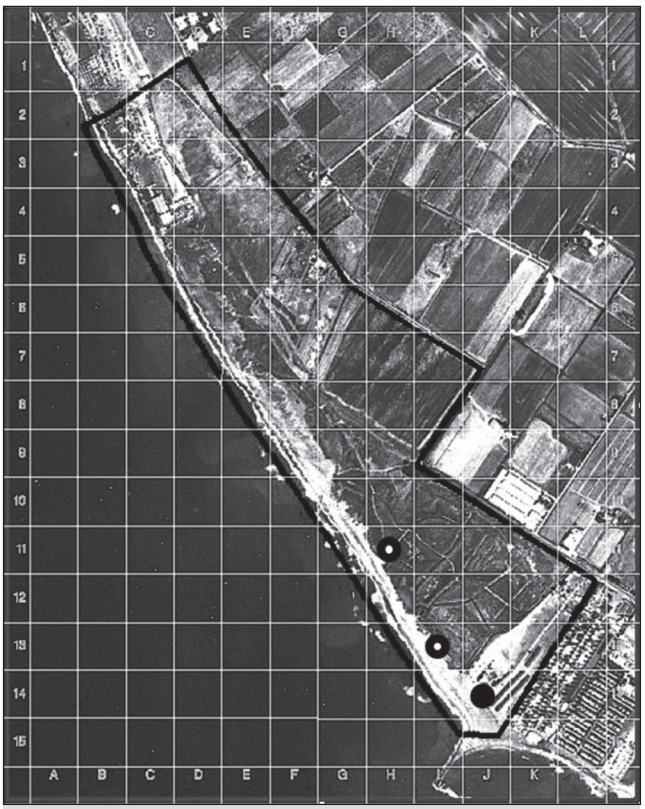

Fig. 3. *Carpobrotus acinaciformis* (L.) L. Bolus/*edulis* (L.) N.E. Br. Black points: cultivated plants; black/white points: spontaneous (naturalized) plants.

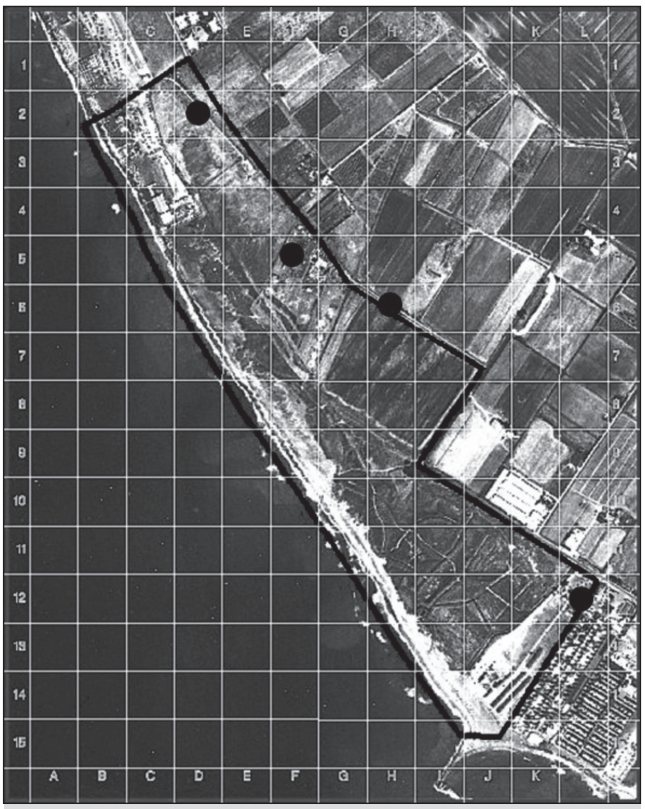

Fig. 4. *Eucalyptus camaldulensis* Dehnh.

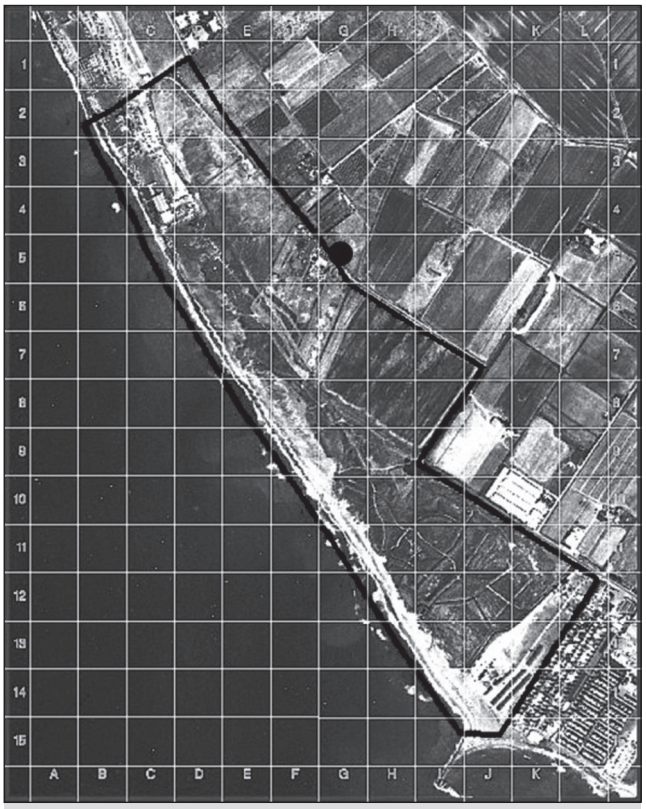

Fig. 5. *Opuntia ficus-indica* (L.) Mill.

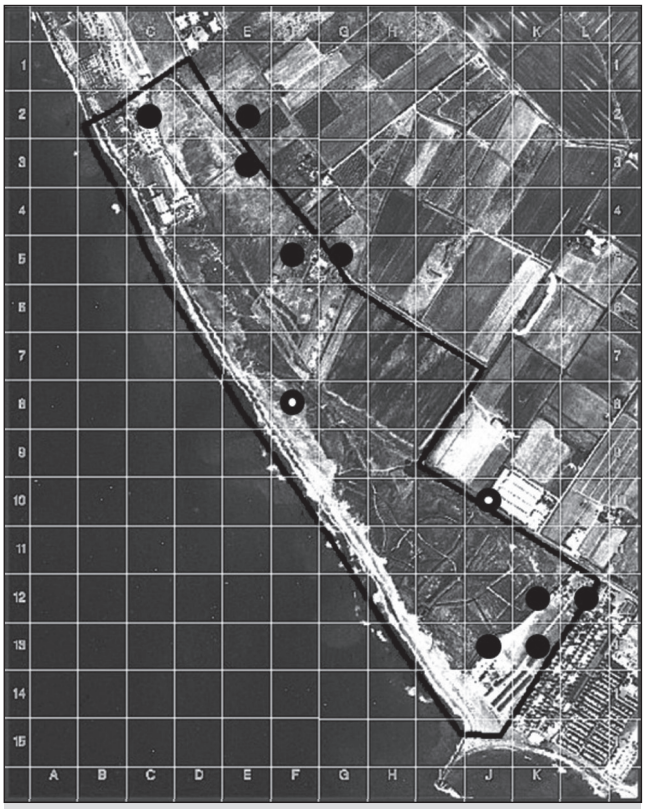

Fig. 6. *Phoenix canariensis* H. Wildpret. Black points: cultivated plants; black/white points: spontaneous (naturalized) plants.

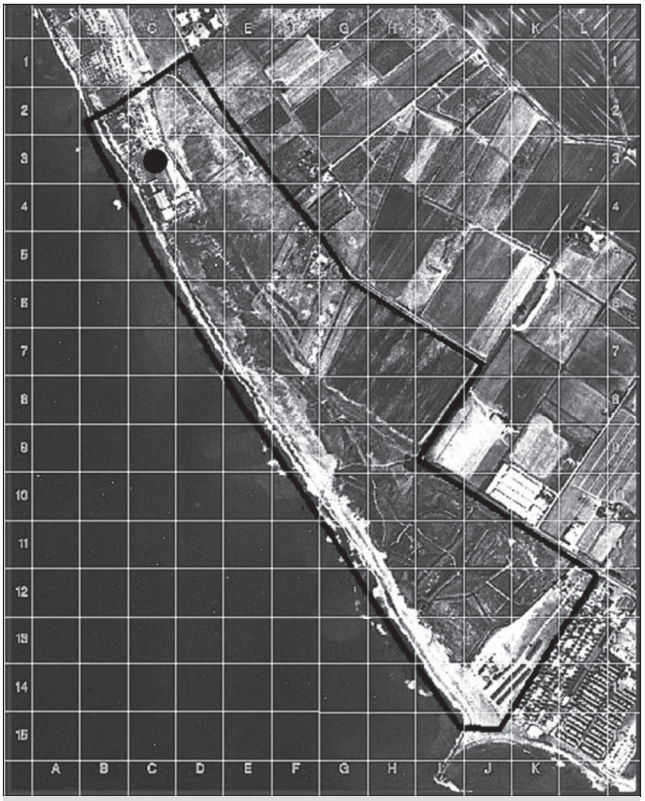

Fig. 7. *Pittosporum tobira* (Thunb.) W.T. Aiton.

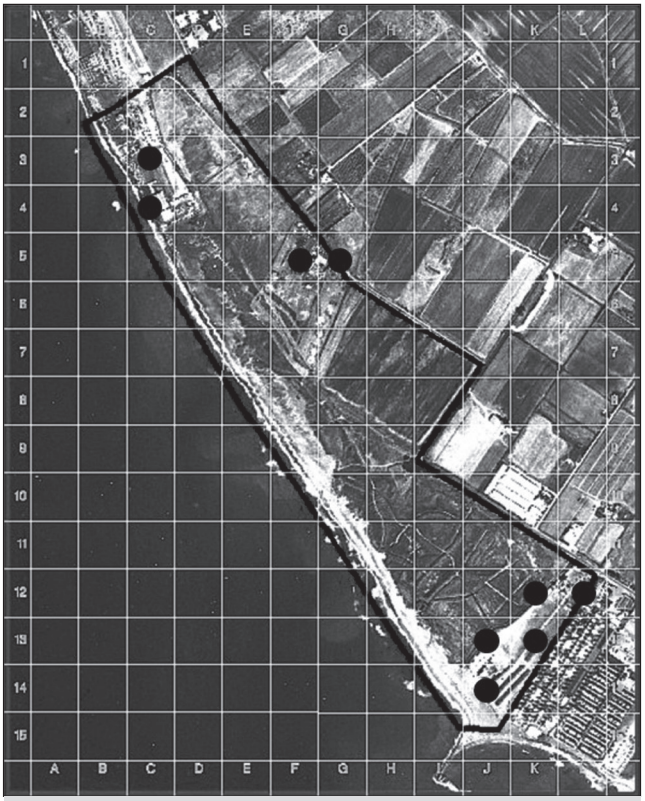

Fig. 8. *Washingtonia robusta* H. Wendl.

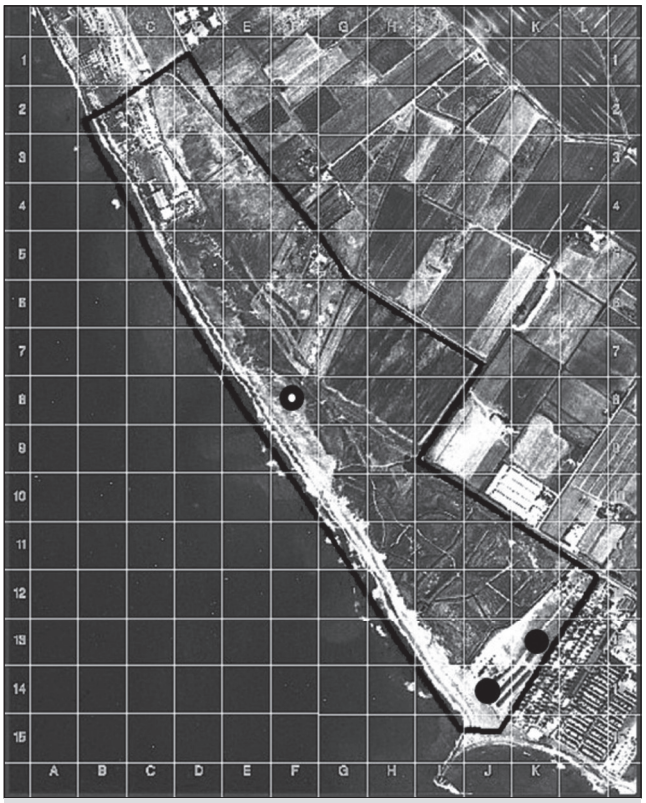

Fig. 9. *Yucca gloriosa* L. Black points: cultivated plants; black/white points: spontaneous (naturalized) plants.

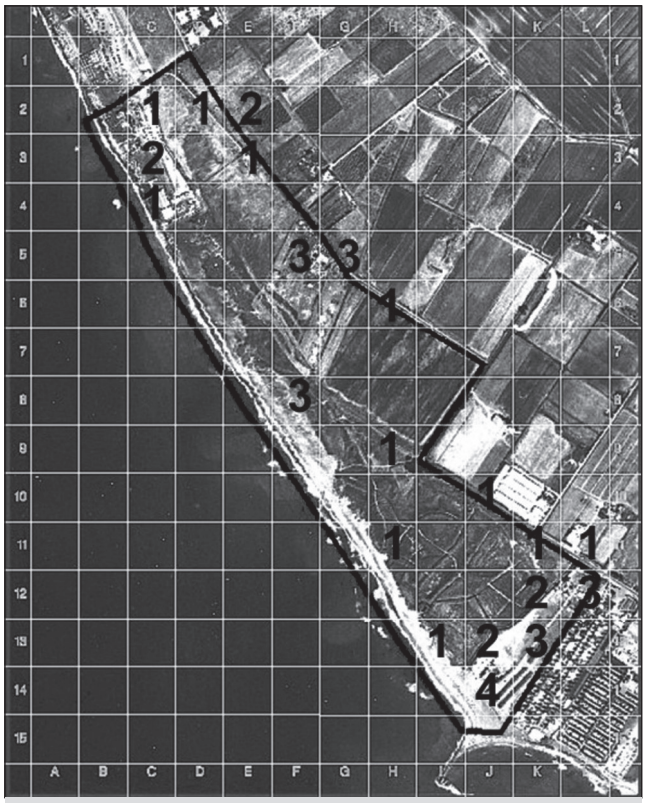

Fig. 10. Map of alien species richness (9 focal species) sampled in 'Palude di Torre Flavia" Natural Monument (grid of 100x100 m units; see Methods).

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