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STUDY ON THE THREAT OF INVASIVE NATIVE AND ALIEN PLANT SPECIES IN THE ALEPU SAND DUNES AND MARSHES (BULGARIAN BLACK SEA COAST)

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Abstract

The aim of the present study is to present an actual information about the diversity and distribution of alien and native invasive plant species in the Sand Dunes and adjacent lakes of the Alepu Marsh and to assess the threat these species pose to the NATURA 2000 habitats in question.

The study area is 178.7ha and includes the following habitat types according the Council Directive 92/43/EEC: 1150 Coastal lagoons, 2130 Fixed dunes with herbaceous vegetation ('grey dunes') and 2190 Humid dune slacks. The investigation was held in the period May-June, 2022. Sample plots were set up on each locality of the invasive species for the estimation of species abundance. The size of the sample plots was 10 m^2 for grass-lands and 100 m^2 for woodlands and shrublands. Species abundance is measured by plant cover (%) in a sample plot. To assess the impact of each of the influences and threats from the invasive species, the three-level scale was used: H- High - currently acting and/or affecting a large area (>60%) of the habitat; M- medium- has been active in the past and has a high probability of recurrence and/or affects a small area (<30%) of the habitat; L- Low- did not act, but is likely to affect and/or affect a minor area (<5%) of the habitat.

The following invasive alien species have been found in the study area: *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Amorpha fruticosa* L., *Broussonetia papyrifera* (L.) L'Hér. ex Vent., *Eleagnus angustifolia* L. *Erigeron canadensis* L., *Laburnum anagyroides* Medik., *Parthenocissus quinquefolia* (L.) Planch., *Robinia pseudoacacia* L., *Spartium junceum* L., *Xanthium italicum* Moretti. Among the native plants the following species can be mentioned as invasive: *Phragmites australis* (Cav.) Trin. ex Steud. (this species is not noted in Table 1 because it is widespread in the study area), *Paliurus spina-christi* Mill., *Tamarix ramosissima* Ledeb. and *Rubus discolor* Weihe & Nees. The most dangerous to the habitats invasive alien species is False indigo (*Amorpha fruticosa*) and at the current stage the risk of this species impact is assessed as medium. Among the native species, Common reed (*Phragmites australis*) is the most aggressive species with high level of impact.

The main routes for the spread of invasive alien pant species in the area are determined by the proximity of the hotel complex, where all the established invasive alien species are cultivated; the canal, which is the active water connection between the lakes and the dunes; the coastal road ruderalised in placed and the increased flow of tourists whose vehicles carry seeds and plant parts.

Keywords: habitats, vegetation, dunes, invasive species, NATURA 2000, anthropophytes

INTRODUCTION

Dunes presently comprise only 10% of the entire 412 km long coastline of Bulgaria: they embrace a total length of 38.57 km and a total area of 8.78 km^2 [1]. The conservation status of the dunes in Bulgaria is regulated in a number of laws, including the Protected Areas Act. [2], Biological Diversity Act [3] and Act on the Black sea coast spatial development [4]. The priority for the protection of these natural resources, which are part of the international NATURA 2000 network, is strengthened when their territories are connected to other valuable habitats such as lagoons, dune-slack pools, dune-slack reedbeds, sedgebeds and canebeds etc. Such a combination of unique habitats is the territory of the Alepu area situated on the Bulgarian Black Sea coast, within Burgas Province, south of the resort town of Sozopol. The Sand Dunes were declared a protected area in 1984, and Alepu Marsh – in 1986 in order to protect the habitats of endangered and rare water bird species, the sand dunes, as well as the water chestnut and both sites belong to the category "natural landmark". In 2002 they were granted an international status because they are on the territory of Ropotamo Nature Reserve [5]

The aim of the present study is to present an actual information about the diversity and distribution of alien and native invasive plant species in the Sand Dunes and adjacent lakes of the Alepu Marsh and to assess the threat these species pose to the NATURA 2000 habitats in question.

MATHERIALS AND METHODS

The study area covers the territory of the Sand Dunes, Alepu area (Figs. 1, 3) and the coastal part of the two lakes located between the national road 99 and the road to the Diuni resort village (Figs. 1, objects 1 and 2). The two lakes are part of the Alepu Marsh (and their total area is about 166.7 ha. It is a lagoon marsh and by origin it is a firth and is separated from the sea by a strip of interesting sand dunes [5]. The area of the Sand Dunes is 12 ha. On the eastern side of the road, where the standing dunes are located, a small canal with constant water (Fig. 1, 4) has formed, which is connected to the lakes and at this stage it does not mouth of the sea. The canal enters the dunes and is a potential vector for the spread of invasive species.

Figure 1. Study area (Satelite image).

Legend: 1 Northern Alepu marsh lake; 2 Southern Alepu marsh lake; 3. Alepu sand dunes; 4. Canal.

The study area includes the following habitat types according the Council Directive 92/43/EEC [6]: 1150 Coastal lagoons (Фиг 1, objects 1 and 2), 2130 Fixed dunes with herbaceous vegetation (‘grey dunes’) (Figure 1, object 3) and 2190 Humid dune slacks (Figure 1, object 4).

The current study is focused on invasive plant species (native and alien) in the lakes, canal and sand dune area, species characteristic of these specific habitats and species with conservation status whose localities these invasive species threaten.

The investigation was held in the period May-June, 2022. Sample plots were set up on each locality of the invasive species for the estimation of species abundance. The size of the sample plots was 10 m^2 for grasslands and 100 m^2 for woodlands and shrublands. Species abundance is measured by plant cover (%) in a sample plot [7].

To assess the impact of each of the influences and threats from the invasive species, the following three-level scale was used [8]: H- High - currently acting and/or affecting a large area (>60%) of the habitat; M- medium- has been active in the past and has a high probability of recurrence and/or affects a small area (<30%) of the habitat; L- Low - did not act, but is likely to affect and/or affect a minor area (<5%) of the habitat. The established invasive alien species for the territory of Bulgaria in the studied area are according to Petrova et al. (2013)[9]

Results and Discussion

The following invasive alien species have been found in the study area (Table 1): *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Amorpha fruticosa* L., *Broussonetia papyrifera* (L.) L'Hér. ex Vent., *Eleagnus angustifolia* L. *Erigeron canadensis* L., *Laburnum anagyroides* Medik., *Parthenocissus quinquefolia* (L.) Planch., *Robinia pseudoacacia* L., *Spartium junceum* L., *Xanthium italicum* Moretti.

Among the native plants (Table 1), the following species can be mentioned as invasive: *Phragmites australis* (Cav.) Trin. ex Steud. (this species is not noted in Table 1 because it is widespread in the study area), *Paliurus spina-christi* Mill., *Tamarix ramosissima* Ledeb. и *Rubus discolor* Weihe & Nees.

Table 1.

List of localities of the native and alien invasive species

No of locality	Species name	Geographic coordinates	Sample plot size (m^2)	Cover abundance (%)	Origin of the invasive species
1	*Acer negundo*	42°22'07.6"N 27°42'15.8"E	100	5	alien
2	*Ailanthus altissima*	42°20'47.2"N 27°42'52.2"E	100	<1	alien
3	*Ailanthus altissima*	42°22'22.3"N 27°42'38.1"E	100	10	alien
4	*Amorpha fruticosa*	42°22'11.3"N 27°42'28.3"E	100	80	alien
5	*Amorpha fruticosa*	42°20'45.4"N 27°42'55.4"E	100	40	alien
6	*Amorpha fruticosa*	42°22'11.0"N 27°42'23.6"E	100	10	alien
7	*Amorpha fruticosa*	42°22'02.9"N 27°42'30.0"E	100	40	alien
8	*Broussonetia papyrifera*	42°22'09.5"N 27°42'18.2"E	100	3	alien
9	*Eleagnus angustifolia*	42°22'12.2"N 27°42'25.4"E	100	3	alien
10	*Erigeron canadensis*	42°21'58.1"N 27°42'28.2"E	10	5	alien
11	*Erigeron canadensis*	42°21'57.0"N 27°42'29.1"E	10	3	alien
12	*Laburnum anagyroides*	42°22'22.6"N 27°42'38.4"E	100	5	alien
13	*Paliurus spina- christy*	42°20'56.0"N 27°43'14.1"E	100	10	native
14	*Paliurus spina- christy*	42°20'52.6"N 27°43'14.0"E	100	70	native
15	*Paliurus spina-christy*	42°20'51.3"N 27°43'10.0"E	100	80	native
16	*Paliurus spina- christy*	42°22'11.3"N 27°42'28.3"E	100	5	native
17	*Parthenocissus quinquefolia*	42°22'07.8"N 27°42'14.9"E	100	5	alien
18	*Parthenocissus quinquefolia*	42°22'11.6"N 27°42'25.6"E	100	10	alien
19	*Robinia pseudoacacia*	42°22'09.2"N 27°42'19.4"E	100	5	alien
20	*Rubus discolor*	42°22'07.9"N 27°42'29.3"E	100	30	native
21	*Rubus discolor*	42°22'03.5"N 27°42'28.5"E	100	50	native
22	*Rubus discolor*	42°21'37.8"N 27°42'44.6"E	100	30	native
23	*Rubus discolor*	42°21'30.3"N 27°42'48.8"E	100	30	native
24	*Rubus discolor*	42°20'50.3"N 27°42'50.0"E	100	20	native
25	*Rubus discolor*	42°21'18.0"N 27°42'24.0"E	100	20	native
26	*Rubus discolor*	42°21'37.0"N 27°42'07.4"E	100	20	native
27	*Rubus discolor*	42°21'46.3"N 27°42'02.4"E	100	10	native
28	*Rubus discolor*	42°22'00.3"N 27°42'09.0"E	100	15	native
29	*Spartium junceum*	42°21'14.9"N 27°42'26.3"E	100	15	alien
30	*Spartium junceum*	42°21'39.6"N 27°42'03.2"E	100	10	alien
31	*Tamarix ramosissima*	42°21'07.8"N 27°43'06.8"E	100	<1	native
32	*Tamarix ramosissima*	42°22'02.3"N 27°42'31.4"E	100	30	native
33	*Tamarix ramosissima*	42°22'22.5"N 27°42'38.9"E	100	10	native
34	*Xanthium italicum*	42°21'47.9"N 27°42'35.0"E	10	10	alien
35	*Xanthium italicum*	42°21'37.0"N 27°42'42.8"E	10	10	alien

In the study area, localities of 6 species with nature protection status (Figure 2) were registered, which are under the direct threat of the spread of populations of native and alien invasive species.: *Pancratium maritimum* L., *Stachys maritima* Gouan, *Silene thymifolia* Sm., *Galilea mucronata* (L.) Parl., *Centaurea arenaria* M. Bieb., *Eryngium maritimum* L., which are under the direct threat of native and alien invasive species populations. *Pancratium maritimum*, *Stachys maritima*, *Silene thymifolia* и *Galilea mucronata* are included in the Red Data Book of the Republic of Bulgaria [10] as "endangered species" and the first two of them together with *Centaurea arenaria* are under protection of the Biological Diversity Act [3]

Figure 2 Species with conservation status in the study area:
a) Galilea mucronata, Pancratium maritimum, c) Stachys maritima, d) Centaurea arenaria M. Bieb.,

On the territory of the former lagoon and the dunes associated with it, which are dynamic natural systems, species characteristic of several types of habitats have been established, including: *Jurinea albicaulis* Bunge, ssp. *kilaea* (Aznav.) Kozuharov., *Artemisia campestris* L., *Centaurea arenaria*, *Cionura erecta* (L.) Griseb., *Galilea mucronata*, *Jasione heldreichii* Boiss. & Orph., *Linaria genistifolia* (L.) Mill., *Pancratium maritimum*, *Silene thymifolia*, *Teucrium polium* L. (characteristic of habitat type 2130), *Ammophila arenaria* (L.) Link, *Cakile maritima* Scop., *Eryngium maritimum* L., *Glaucium flavum* Crantz, *Leymus racemosus* (Lam.) Tzvelev subsp. sabulosus (M.Bieb.) Tzvelev, *Salsola kali* subsp. *ruthenica* (Iljin) Soó, *Stachys maritima*, *Xanthium orientale* subsp. *italicum* (Moretti) Greuter (most characteristic of habitat type 2110 Embryonic shifting dunes and 2120 Shifting dunes along the shoreline with Ammophila arenaria ('white dunes')), *Crambe maritima* L., *Eryngium maritimum*, *Salsola kali* subsp. *ruthenica* (Iljin) Soó (1210 Annual vegetation of drift lines), as well as species attached to wet habitats such as *Periploca graeca* L. and *Juncus conglomeratus* L. and such diagnostic for habitat type 1150 *Phragmites australis* (Cav.) Trin. ex Steud., *Lemna minor* L., *Typha angustifolia* L., *Juncus maritimus* Lam., *Schoenoplectus lacustris* (L.) Palla.

Among the established invasive alien species, the greatest danger to the habitats is False indigo (*Amorpha fruticosa*) (Figure 2), and at the current stage the risk of this species impact is assessed as medium (Table 2).

Figure 2. Individuals of Amorpha fruticosa threaten a locality of Crambe maritima

The percentage participation of the populations of the other invasive species in the total area of habitats is small (below 5%), but the experience with species such as Tree of heaven (*Ailanthus altissima*) and black locust (*Robinia pseudoacacia*) in similar areas in the country and their strong invasive strategy is a reason to estimate the danger higher from their distribution in the studied territory.

Table 2.

Assessment of the impact of invasive native and alien species

Species name	Habitat type					
	1150		2130		2190	
	Percentage of the total habitat area that the population of the species affects	Leve of impact of species influences and threats	Percentage of the total habitat area that the population of the species affects	Leve of impact of species influences and threats	Percentage of the total habitat area that the population of the species affects	Leve of impact of species influences and threats
Acer negundo	<1	L	<1	L	<1	L
Ailanthus altissima	<1	M	<1	L	<1	L
Amorpha fruticosa	8	M	10	M	10	M
Broussonetia papyrifera	<1	L	<1	L	<1	L
Eleagnus angustifolia	<1	L	<1	L	<1	L
Erigeron canadensis	<1	L	<1	L	<1	L
Laburnum anagyroides	<1	L	<1	L	<1	L
Paliurus spina-christy	15	M	5	M	10	M
Partenocisus quinqifolia	<1	L	<1	L	10	M
Phragmites australis	80	H	65	H	7	M
Robinia pseudoaccacia	<1	M	<1	L	<1	L
Rubus discolor	10	M	<1	L	15	M
Spartium junceum	7	M	<1	L	<1	L
Tamarix ramosissima	2	L	5	M	<1	L
Xanthium italicum	<1	L	8	M	5	M

Among the native species, Common reed (*Phragmites australis*) is the most aggressive species (Table 2), its population has occupied most of the water area of the two lakes of habitat type 1150 and the canal (habitat type 2190), as well as about 7% of the dune territory (habitat type 2130) (Table 2). Around the monodominant reed communities surrounding the lakes, in the part bordering the dunes, are situated alternating formations of *Juncus maritimus*, *Juncus conglomeratus*, and to a lesser extent *Periploca graeca* and *Cionura erecta*, which although characteristic species for the studied habitats with their dense populations in to a certain extent they threaten the biodiversity in them, by displacing protected species such as *Silene thymifolia* and diagnostic species such as *Jurinea albicaulis, Teucrium polium, Jasione heldreichii*, etc.

Garland thorn (*Paliurus spina-christi*) is particularly aggressive in the south-eastern part of the lakes, where it forms dense communities of about 3000 m^2 and poses a threat to the habitat's biodiversity including several rear localities of *Stachys maritima* situated there.

Populations of Tamarisk (*Tamarix ramosissima*) currently represent a more serious threat to the biodiversity of habitat type 2130 fixed dunes with herbaceous vegetation ('grey dunes'), where some of the populations of this species (Table 1, site No 32) are distributed near the habitats of the protected species *Pancratium maritimum* and *Stachys maritima*, and enter the localities of characteristic species such as *Eringium maritimum, Glaucium flavum, Crambe maritima*, etc. (fig. 3)

Figure 3. Individuals of Tamarix ramosissima threaten locality of Eringium maritimum

Himalayan blackberry (*Rubus discolor*) forms dense impassable stands by the roads, which gradually enter the wetter parts of the habitats, suppress and displace the characteristic species such as some representatives of the genus Carex, *Euphorbia palustris* L., etc. They pose a threat to the wet habitats (type 1150 and 2190) and to the peripheral parts of the dunes.

At this stage, in the western part of the lakes (on the border with national road 99), the smallest number of invasive species and their habitats have been established. In this section, as well as in the northwestern end of the lakes, a part of the autochthonous tree vegetation has been preserved, represented by communities with a well-defined three-layer structure, in which the layer of trees (average cover 75%) is mainly occupied by *Fraxinus angustifolia* Vahl and in more a small extent of *Ulmus minor* Mill., *Populus nigra* L. and *Salix alba* L. The shrub layer has an average cover of 55% and is mainly represented by *Fraxinus angustifolia*, *Ulmus minor*, *Prunus cerasifera* Ehrh., *Crataegus monogyna* Jacq. and *Rosa canina* L.. *Brachypodium pinnatum* (L.) P.Beauv. predominates in the grass leyer (50%), accompanied by *Calystegia sepium* (L.) R. Br., *Geum urbanum* L., *Hypericum perforatum* L. etc.

The northern part of the studied territory borders the "Dunes" hotel complex, where 100% of all established invasive alien species are registered. The hotel complex has preserved a small part of the natural forest communities of *Fraxinus angustifolia*, *Ulmus minor* and *Populus nigra*, but they have been penetrated mainly as undergrowth by non native, including invasive species such as Fraxinus *pennsylvanica* Marshall , *Amorpha fruticosa*, *Partenocisus quinqifolia*, *Robinia pseudoacacia* and native species such as *Tamarix ramosissima* and *Paliurus spina-christy.*

The study confirms the finding of Ivanova et al. (2021)[11] that the main problem of Alepu area is the overgrowing with reeds and the gradual swamping that leads to reduction of the open water areas in the protected area. With regard to invasive alien species, what was found in other habitats of a similar type along the Black Sea coast also applies here, regarding the increased presence and impact of *Amorpha fruticosa* and the danger of invasion of natural and alien shrub and three species as *Paliurus spina-christi*, *Ailanthus altissima*, *Robinia pseudacacia*, *Eleagnus angustifolia* [12].

The main routes for the spread of invasive alien species in the area are determined by the proximity of the hotel complex, where all the established invasive alien species are cultivated; the canal, which is the active water connection between the lakes and the dunes; the coastal road ruderalised in placed and the increased flow of tourists whose vehicles carry seeds and plant parts.

Conclusions

At the current stage, a stronger expansion of native species than of alien invasive species has been established in the study area.

Both specific localities of rare and endangered species, as well as the floristic wealth and structure of each of the studied habitats, are threatened.

Measures are needed for the periodic reduction of aggressive species populations in order to prevent the

formation of monodominant coenoses, and these measures must be consistent with the management regimes of territories falling within the NATURA 2000 zone and the conservation status of the Alepu area.

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