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Opuntia fragilis (Nutt.) Haw. (Cactaceae) in the Bulgarian flora

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Abstract: *Opuntia fragilis (Nutt.) Haw. (Cactaceae) is the smallest and most cold-hardy species of genus Opuntia in North America. In Bulgaria it is grown as an ornamental plant, but in 2019 a population of this species was discovered by other researchers in natural habitats in Lozenska Mt (Western Bulgaria) at 630–660 m a.s.l. on an area (extent of occurrence) of ca. 100 m^2. In July 2020, we established a population of this species on the Black Sea coast near the town of Primorsko (Eastern Bulgaria) at 5 m a.s.l. on an area of ca. 300 m^2. The distance between the two populations is 360 km in a straight line and their origins are independent of each other. The two localities of this species are so far the only ones described not only for the territory of Bulgaria, but also for Europe.*

Data are given on the conditions characterizing each of the localities. The possible reasons for the appearance in natural habitats of this alien plant species for the Bulgarian flora are considered. The impacts and threats this species may have on biodiversity in natural habitats are indicated. Measures have been proposed to control the populations of the species.

Keywords: *Opuntia fragilis*, Cacti, Europe, Bulgaria, Black Sea coast floristic region, potential invasive alien plants

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Introduction

For many people, the word "cactus" is necessarily associated with sandy or stony desert spaces, where the sun's rays are so strong that few plants like them are able to survive the heat. In the Journal of Archibald Menzies, who sailed in 1791–1795 with Captain George Vancouver, and was the first European botanist to set foot on the Vancouver Gulf Islands (on the territory of today's Canada), in May 1792 is written: "I was not a little surprised to meet with the Cactus *Opuntia* thus far to the northward, it grew plentifully but in a very dwarf state on the eastern point of the Island which is low flat and dry sandy soil" (Ribbens, 2007).

The species he saw and for unknown reasons did not describe is most likely *Opuntia fragilis* (Nutt.) Haw. It was first described 27 years later by Thomas Nuttall in 1819. He named it *Cactus fragilis*, and Haworth later transferred it to *Opuntia fragilis*. The specific name ‘fragilis’ refers to the ease with which the terminal joint is detached, an adaptation for asexual reproduction and dispersal (Ribbens, 2007).

What made an impression on this researcher 230 years ago continues to make a strong impression today. Today we know that cacti of the genus *Opuntia* Mill. are the most cold-resistant genus of cacti in the world. That is why they have the largest range among the other genera of cacti. Although it seems incredible, they are naturally distributed in the north even in western and southern Canada. Among them, the most cold-resistant species is O. fragilis. The northernmost point of distribution of this species is at 56°17'N latitude along the Peace River valley between Fort St. John, British Columbia and Peace River, Alberta, Canada (Gorelick, 2015). Therefore, it is not surprising that they are transported and grown outdoors in many places around the world, including in the temperate climate zone. Their transfer to new territories is not always for decorative purposes. In the fall of 1961, the Cuban military planted a 13-kilometer strip of *Opuntia* cactus along the borders of the US naval base at Guantanamo Bay to prevent the large number of Cubans wishing to flee the country and resettle in the US. The facility was called the "Cactus Curtain" by analogy with the Iron Curtain in Europe and the Bamboo Curtain in East Asia (Guantanamo Bay Naval Base and Ecological Crises).

Cacti of the genus *Opuntia* were first described in Bulgaria in the 1920s and 1930s. They were imported to the country to be grown as ornamental plants in the parks of the royal palaces in Euxinograd and Krichim (Website of MOEW). The first cacti became part of the Bulgarian flora in 1933, when two species were planted on the island of Saint Thomas (then known as Snake Island): *Opuntia humifusa* (Raf.) Raf. (syn. *O. vulgaris* Mill., *O. compressa* (Salisb.) MacBr.) and *O. macrorhiza* Engelm. (syn. *O. tortispina* Engelm.). Both species were introduced by order of Tsar Boris III from the botanical garden in Bratislava (now Slovakia). Conditions proved to be favorable and the deposit rapidly expanded to cover most of the area of the small island, which is about 0.12 ha (Petrova et al., 2012). The mentioned two species are the only ones that for decades have been known to be widespread in natural habitats on the territory of Bulgaria.

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In 2019, data were published on the natural distribution of two new species for the flora of Bulgaria: *O. engelmannii* and *O. fragilis* (Naydenova et al., 2019).

So far, there are known data on the distribution of species of the genus *Opuntia* in a large number of localities in Bulgaria: south of the town of Beloslav (Beloslav municipality), Sveti Toma island (Zmiyski ostrov), Sinemorets village (Tsarevo municipality), the Lipite beach area, Butamiata beach area, east of Pushevo village (Veliko Tarnovo municipality), southeast of German village (Stolichna municipality), Harmanli town (Harmanli municipality), southwest of Lucky village (Hajidimovo municipality), Valley of River Struma (Southern). (Kenderova, 2012, Tashev, 2012, Glogov et al., 2019, Naydenova et al., 2019). *O. humifusa* is most widespread, which, in addition to the listed places, is also found in the region of Chirpan, Plovdiv, and Yambol (Delipavlov et al., 2011).

The presence of cacti is well received by the local people. They easily turn into attractive objects, which, especially during their flowering and fruiting, stimulate tourism and nature outings. This is most pronounced in the area of the Veliko Tarnovo village of Pushevo, where they have been turned into a real tourist attraction. Locals organize a Cactus Festival, held for the first time in 2013 in the first half of June - the time when cacti are in full bloom.

From another point of view, cacti are an aggressive and easily adaptable competitor of native plants, even under difficult environmental conditions. They spread very easily through parts of the stems and fruits. They are resistant to drought because they economically use the reserve water contained in their stems. They survive fires and can survive extreme cold – with temperatures reaching -30°C. At the beginning of colonization of a territory, a few scattered individuals usually develop. In a few tens of years, a rapid increase in numbers to hundreds and thousands of closely spaced plants was observed. The spread of cacti in natural habitats can lead to the following impacts and threats (Website of MOEW):

- They occupy large areas in the pastures, form impassable parts for animals and significantly limit the available grazing area;
- They obstruct hiking trails and the paths of wild and farm animals, and local residents;
- They attract bees and thus deprive native plants of pollinators, reducing their ability to reproduce;
- They harm biodiversity by suppressing populations of rare and protected species and medicinal plants;
- They cause significant financial losses and a large human resource is needed to limit their spread.

The extent of the problem cacti can create is exemplified by their introduction into Australia. Their distribution there was so successful that by the year 1900, 10,000,000 acres were estimated by cacti. In the next 20 years the weed advanced so rapidly that a survey in 1920 indicated that 58,000,000 acres were affected. This represented an annual increase of almost 2,500,000 acres. The peak of the invasion was reached in 1925, when the infested area must have been greater than 60,000,000 acres. Approximately one-half, or roughly 30,000,000 acres, was occupied by dense growth, completely covering the ground to the exclusion of all grass and herbage. Farmers were forced to leave their homes and lands because of

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what they called the "green hell". In 1919, the Australian government approved a federal cactus control program. This is the reason for the slow spread in the period 1920-1925. Initial attempts to destroy cacti by mechanical or chemical control failed. This forced the government to look for biological means. It turned out that the larvae of the South American moth *Cactoblastis cactorum* (Berg, 1885) feed on prickly pears. After the moth was introduced to Australia in 1925, the cactus population began to decline rapidly (Dodd, 1959).

What will be the situation in Bulgaria in the future depends on the measures we will take today. The purpose of our research is not only to show the increasing spread of another species of the genus *Opuntia* in Bulgaria, but also to warn about its consequences.

Material and Methods

The present study was conducted by the route method in the July 2020. The type of bedrock and soil is defined in the GIS environment under the Bedrock and Soils layers. In determining the associated species with *O. fragilis*, was used Plant Determinant in Bulgaria (Delipavlov et al., 2011). The names of the taxa are according to The World Flora Online. Life forms are represented by the Raunkiaer system (Raunkiaer, 1934). The floristic elements are according to Assyov et al. (2012). The cover abundance of the accompanying species is according to Braun-Blanquet (Westhoff & Maarel, 1973). The marking of the population of the species was done with the help of a GPS receiver Garmin Oregon 450. The WGS 84 UTM 35N coordinate system was used. The distances from the locality to neighboring sites were measured over the air using software Google Earth Pro Portable ver. 7.1.5.

Results and Discussion

Morphology

Shrubs, low, forming mats, 2-10 cm (Fig. 1A). Stem segments easily detached when terminal, dark green, subspheric to subcylindric, to flattened and elliptic obovate, (1.5-)2-5.5 × (1-)1.5-3 cm, low tuberculate (pronounced when dried), glabrous; areoles 3-5 per diagonal row across midstem segment, oval, 3 × 2.5 mm; wool white. Spines 3-8 per areole, in most areoles spreading, gray with brown tips, straight, ± acicular, terete, the longest 8-24 mm; depressed spines at base of areoles 0-3, 1-3 mm. Glochids in crescent at adaxial margin of areole, tan to brown, inconspicuous, to 3 mm. Flowers (Fig. 1B): inner tepals yellow, sometimes basally red, 20-26 mm; filaments white or red; anthers yellow; style white; stigma lobes green. Fruits tan, 10-30 × 8-15 mm, dry, glabrous; areoles 12-22, distal areoles bearing 1-6 short spines. Seeds tan to gray, flattened, warped, oblong to subcircular, 5-6 mm diam.; girdle protruding 1-1.5 mm. 2n = 66. Flowering summer (late June - early July) (Flora of North America, Website).

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The entire plant is prostrate, less than 10 cm tall, and larger plants can form dense clusters of 200 or more pads, although whether these plants are still physiologically integrated is doubtful. It is the smallest species of genus *Opuntia* in North America (Ribbens, 2007).

A **B**

Figure 1. Habitus of *O. fragilis*: A. Vegetative individual (Photo D. Zahariev, July 24, 2020), B. Flowering individual (Photo EOL − Tony Frates, June 19, 2010, Pl@ntNet™)

Reproduction

Although the plants can flower, they form fruits with viable seeds only in the central parts of the natural areal. In the peripheral parts of the areal does not appear to be sexually reproducing. Reproduction is primarily vegetative. The rate of vegetative reproduction is very high. About 50% new cladodia are formed per year. However, this is not a reliable method for determining the age of plants.

Since second Latin name "fragilis" refers to the tendency of terminal cladodes to break away easily, it is not surprising that the plant using animals as a dispersal vector. In the grazing teritories in North America it is a most troublesome weed, for the joints easily break off and become attached by their spines to passing animals (epizoochory). The individual stem segments (cladodia) have also been known to disperse via gravity, by the wind and by floating in the water (Ribbens, 2007).

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Identification

Key to the determination of the species of the genus *Opuntia* Mill. (Stoyanov et al., 2021):

1. Tall trees 2-6 m, with a trunk up to 45 cm in diameter. Stem segments 25-60 cm. Spines inconspicuous, up to 2 mm. Fruits 50-100 × 40-90 mm. Seeds 3.7-5 × 3.7-4.3 mm ..... ***O. ficus-indica***

1*. Shrubs - prostrate or in tufts. Stem segments rarely to 20-30 cm. Spines 2 mm 2

2. Shrubs, usually up to 10-15 cm; forming mats; terminal stem segments subcylindric, easily detached. Flowers with a diameter 25-35 mm. Fruits dry, 10-30 × 8-15 mm ….... ..... ***O. fragilis***

2*. Shrubs, usually up to 10-15 cm; prostrate or forming clumps but not mats; terminal stem segments flat, not easily detached. Flowers with a diameter of over 35 mm. Fruits juicy or fleshy ... 3

3. Spines absent, rarely 1-3 per areole. Fruits red, elongated. Flowers with a diameter ca. 40-60 mm. Stem segments light green, wrinkled at unfavorable conditions, up to 15-17 cm in diameter. Fruits 30-50 × 12-20 mm. Seeds 3.5-4.5 mm ..... ***O. humifusa***

3*. Areoles with 1-6 spines each. Fruit purple, ovoid to barrel-shaped. Flowers over 50 mm in diameter 4

4. Stem segments green, distinctly wrinkled under stress, with a length of up to 15-17 cm. Flowers with a diameter 60-100 mm. Fruits 25-40 × 15-28 mm. Seeds 4-5 mm ..... ***O. macrorhiza***

4*. Stem segments blue-green, usually wrinkled under stress, up to 40 cm in diameter. Flowers with a diameter 50-80 mm 5

5. Stem segments ± warty, on borders with scales between border areoles; Fruits 40-60 mm, juicy, barrel-shaped, downward narrowed, purplish .... ***O. stricta***

5*. Stem segments with margins entire, without scales; fruits juicy or fleshy 6

6. Spines scattered, unevenly long, surrounding the areolae, also in the subapical region, often enclosed in hairs. Fruits 35-90 × 20-40 mm. Seeds 2.5-6 × 2-5 mm ..... ***O. engelmannii***

6*. Spines nearly equal or increasing in length towards adaxial margin, dense also in subapical region. Fruits 30-50 × 20-30 mm. Seeds 4-5 mm ..... **O. phaeacantha**

Worldwide distribution

Native to North America. Barren areas in grasslands, woodlands, sandy or gravelly soils, on outcrops of granite, limestone, or quartzite at 0-2400 m a.s.l. (Gorelick, 2015). It grows on south-facing rocky outcrops and like many cactus species, *O. fragilis* is a stress tolerator (Ribbens, 2007). **USA**: Alta., B.C., Man., Ont., Sask.; Ariz., Calif., Colo., Idaho, Ill., Iowa, Kans., Mich., Minn., Mont., Nebr., N.Mex., N.Dak., Okla., Oreg., S.Dak., Tex., Utah, Wash., Wis., and Wyo. (Flora of North America, Website), **Canada**: British Columbia, Alberta, Saskatchewan, Manitoba, and Ontario (Gorelick, 2015).

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Distribution in Europa and Mediterranean Basin

In Europe and Mediterranean Basin (Euro+Med PlantBase Website), this species is described only on the territory of Bulgaria (Fig. 2).

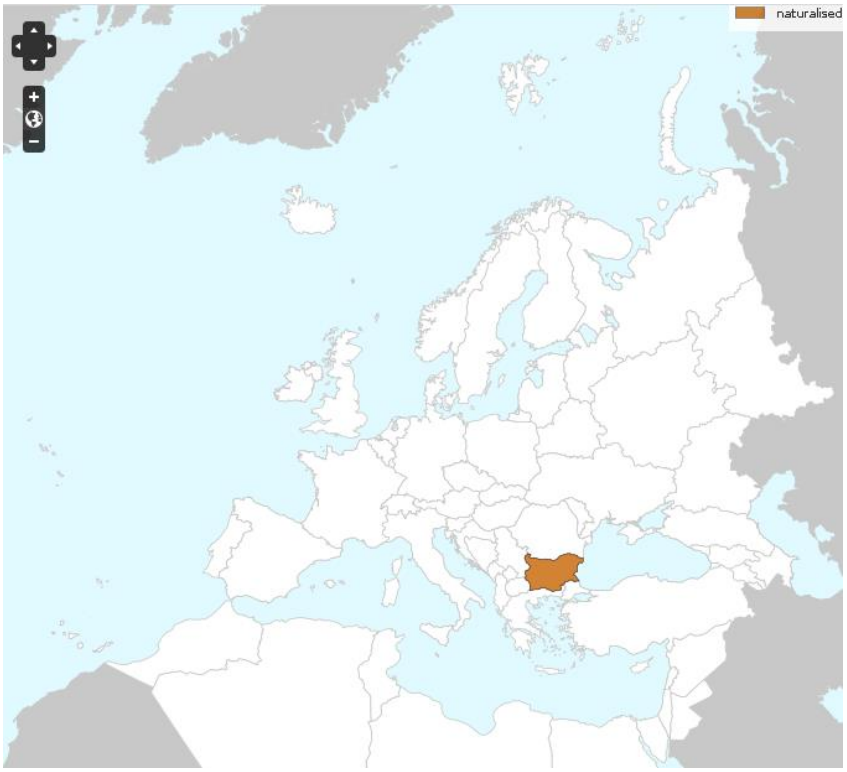

Figure 2. Distribution of *O. fragilis* in Europa and Mediterranean Basin (Euro+Med PlantBase, Website)

Distribution in Bulgaria

The only published data on the establishment of *O. fragilis* in natural habitats on the territory of Bulgaria are in the Lozenska Mt (Fig. 3). The mountain is small and represents the westernmost part of Ikhtimanska Sredna gora Mt. It is located in close proximity to the city of Sofia, the capital of Bulgaria. The cactus population was described for the first time by Vasil Belchinski from German village, Stolichna municipality on a steep slope above the Pancharevo dam near a tourist trail. The first published data on the presence of the species in this mountain are from Naydenova et al. (2019). The information was also confirmed during the inventory of the anthropophitic flora on the territory of Lozenska Mountain (Glogov et al., 2019). Since the site is located in a difficult-to-access location on a very steep and stony slope with ca. 40–50° inclination, it is logical to assume that the plants were not artificially planted, but spread and settled this territory naturally. This is so only at first glance. It is more likely that this reason is not applicable in this case because a total of three species of cacti have been established at the locality: *O. humifusa*, *O. engelmannii*, and *O. fragilis* (Naydenova et al., 2019). Their simultaneous distribution in the

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same territory is unlikely. The proximity to a hiking trail, which is located a few tens of meters up the slope, is also an important detail.

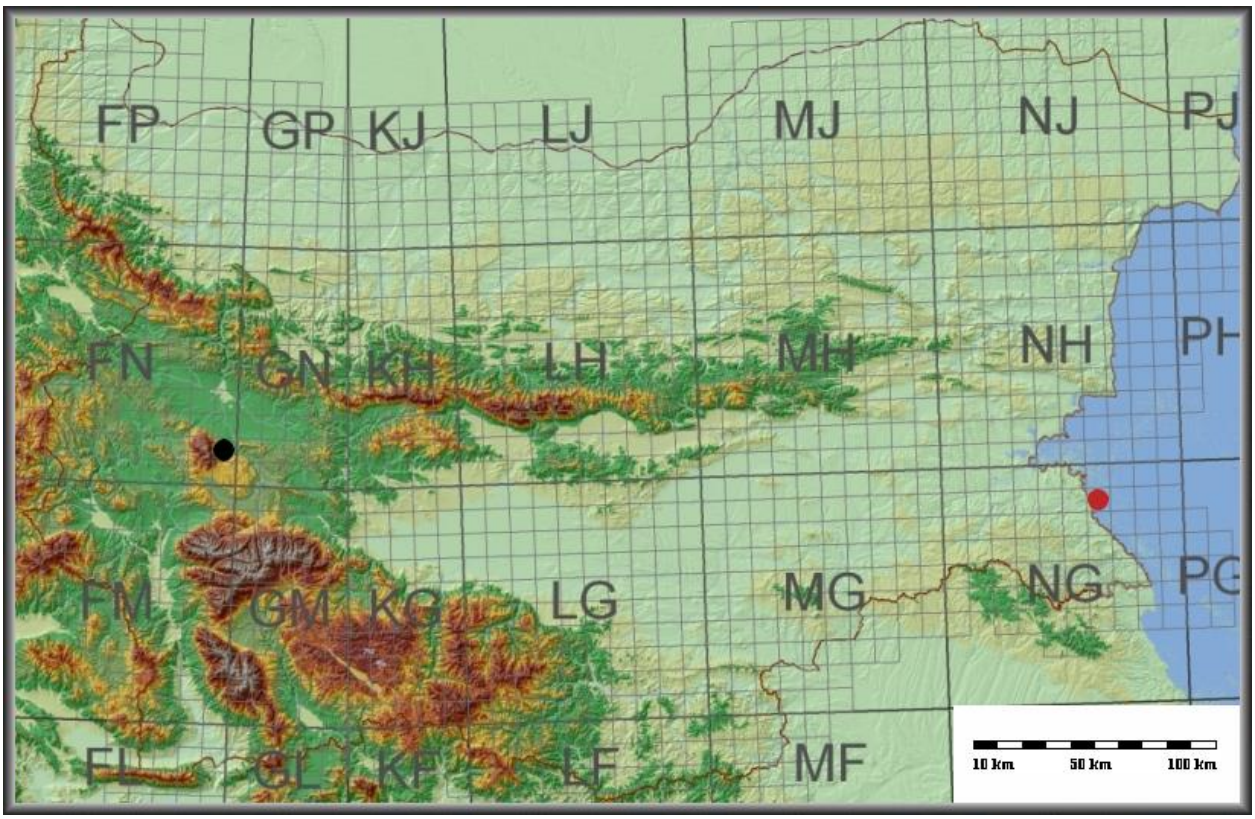

Figure 3. Distribution of *O. fragilis* in Bulgaria
(black spot - known locality in the Lozenska Mt, red spot - new locality in town of Primorsko)

Characteristics of the known population

It is located in the westernmost part of the Lozenska Mt, in the Sredna Gora Mt (Western) Floristic region. The habitat includes open stony and eroded places on a slope with siliceous bedrock and ca. 40–50° inclination, southwest exposition, 630–660 m a.s.l. The population occupying an area (extent of occurrence) of ca. 100 m^2, mainly around 42.59668°N, 23.41803°E, and about 10 mats near 42.59676°N, 23.41878°E. Several dozen mats of varying size were observed – from individual recently rooted stem segments to mats of ca. 0.3 m^2, and height of ca. 10 cm. The accompanying species were following: *Astragalus onobrychis* L., *Bothriochloa ischaemum* (L.) Keng, *Cleistogenes serotina* (L.) Keng, *Clinopodium graveolens* subsp. *rotundifolium* (Pers.) Govaerts (syn. *Acinos rotundifolius*), *Comandra umbellata* subsp. *elegans* (syn. *Comandra elegans*), *Cota tinctoria* (L.) J. Gay, *Euphorbia cyparissias* L., *Linaria genistifolia* (L.) Mill., *Opuntia humifusa* (Raf.) Raf., *O. engelmannii* Salm-Dyck ex Engelm., *Sanguisorba minor* Scop., *Satureja montana* subsp. *kitaibelii* (Wierzb. ex Heuff.) P.W.Ball, *Sedum hispanicum* L., *Sideritis montana* L., *Silene* sp., *Stachys recta* L., *Teucrium chamaedrys* L.,

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Verbascum banaticum Schrad., *Viola arvensis* Murray, *Xeranthemum annuum* L. Considering the local spread of the species, it can be assumed that they have been present there for at least 30–40 years or even longer (Naydenova et al., 2019).

Characteristics of the newly established population

During our field work, a new population of the species was established in the area of the town of Primorsko, Southern Bulgaria. This gives us reason to list the species as new for the Black Sea coast (Southern) Floristic region (Fig. 3). The population was established on July 24, 2020 and is located 2.4 km northeast in a straight line from Perla beach and 4.2 km in a straight line from the center of town of Primorsko (Primorsko municipality) (Fig. 4).

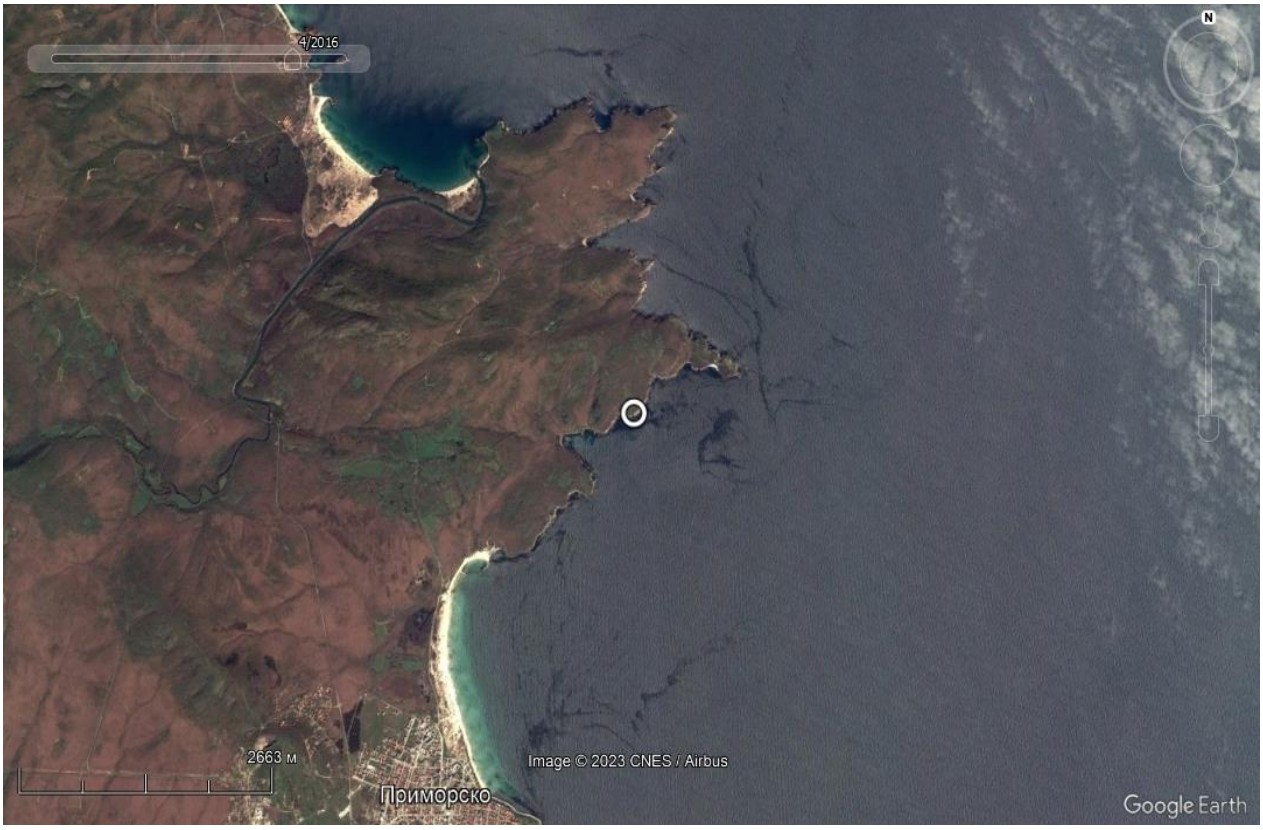

Figure 4. The location of the new population of *O. fragilis* near the town of Primorsko, Bulgaria

The substrate includes skeletal soil and rock material crushed into small pieces (Fig. 5). The base rocks in the area are represented by: basalts, andesitobasalts, in extrusive, explosive and subvolcanic facies; rare packets of sediments - sandstones, siltstones, shales. The soil is strongly leached to slightly podzolized (lessive) cinnamonic forest. Inclination is ca. 20°. The exposure is southeast. The altitude is on average about 5 m a.s.l.

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Figure 5. View of the habitat of *O. fragilis* near the town of Primorsko, Bulgaria

The population occupying an area of ca. 300 m^2, between GPS points with coordinates: 42.302717°N, 27.777369°E and 42.303795°N, 27.780044°E. The individuals are distributed across the ecotone between the cliff top and inshore grassland habitats. They are distributed in groups over tens of meters with different densities – denser groups (Fig. 6A) or less dense groups (Fig. 6B).

A **B**

Figure 6. View of the population of *O. fragilis* near the town of Primorsko, Bulgaria

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Associated plant species (Table 1) are described in GPS point with the following coordinates: 42.303123°N, 27.779409°E. The habitat includes a very small number of plant species due to the proximity to the waterfront of the sea and the thin and poor sandy soil. The total vegetation cover within the locality is ca. 15%. The habitat is in a continuous process of succession, because due to the proximity to the waterfront there is no possibility of reaching a climax state. It is this characteristic of the habitat, combined with the shallow and easily warmed soil, the south-east exposure and the lack of competition from other perennial herbaceous and woody species that form mosaics further inland, that enable the existence and future favorable prospects for population growth and the projected population coverage.

Table 1. Associated species of *O. fragilis* in the population near the town of Primorsko
Life Form: Th – therophyte, H – hemicryptophyte, Cr – cryptophyte, Ph – phanerophyte
Floristic Elements: Adv – Adventive, Am – American, As – Asian, Boreal – Boreal, Eur – European, Med – Mediterranean, Pont – Pontic, N – North, S – South
Braun-Blanquet Cover Abundance Scale: 2a – from 5 to 12.5%, 2m – projective cover less than 5% and number over 50 individuals, 1 – projective cover less than 5% and number among 6 and 50 individuals, + – projective cover less than 5% and number among 2 and 5 individuals, r – projective cover less than 5% and only one individual

No.	Plant Name	Family	Life Form	Floristic Elements	Cover Abundance
1	*Bothriochloa ischaemum* (L.) Keng	Poaceae	H	SMed-As	2a
2	*Sanguisorba minor* Scop.	Rosaceae	H	subBoreal	2a
3	*Trifolium angustifolium* L.	Fabaceae	Th	Med	2m
4	*Avena barbata* Pott ex Link	Poaceae	Th	Med	1
5	*Dactylis glomerata* L.	Poaceae	H	Eur-As	1
6	*Psilurus incurvus* (Gouan) Schinz & Thell.	Poaceae	Th	subMed	1
7	*Cionura erecta* (L.) Griseb.	Apocynaceae	Ph	Med	+
8	*Opuntia macrorhiza* Engelm.	Cactaceae	Ph	Adv (NAm)	+
9	*Pyrus elaeagnifolia* Pall.	Rosaceae	Ph	Med	r
10	*Ephedra distachya* L.	Ephedraceae	Ph	Pont-Med	r
11	*Convolvulus cantabrica* L.	Convolvulaceae	Cr	Pont	r

The reasons for the spread of cacti in territories that were not previously inhabited by them are not natural. It is easiest to make a connection with climate change and global warming (Bratanova-Doncheva

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& Gocheva, 2018, Glogov & Dimitrov, 2021). The warming of the climate in Bulgaria is a fact and has a beneficial effect on the development of cactus populations, but this does not explain why species of the genus *Opuntia* are found in such different places in the country. If the spread is in a natural way, then colonization of neighboring, closely located territories should be observed from already existing localities. However, the localities are isolated and very far from each other, and it is not possible to transfer individuals between them.

The most likely reasons for the spread of cacti in Bulgaria are two: 1. Throwing away by people of grown or already unwanted plants near the settlements and 2. Intentional planting by people in nature, which is motivated by noble goals. These are the same reasons that lead people to release their domesticated ornamental animals into the wild. In our opinion, it is the deliberate planting of foreign plants to "ennoble" the territory that explains the appearance of *O. fragilis* populations in the two localities: in Lozenska Mt and near the town of Primorsko. In both cases, from the time the plants were deliberately planted to the time the sites were established by botanists, tens of years have passed, and the cacti have managed to conquer a significantly larger area than the original - from a few square meters at the beginning to several hundred square meters at the present moment.

There is a forest road that connects the town of Primorsko with Cape Maslen nos a few tens of meters northwest of the newly established locality of *O. fragilis*. During the active tourist season, the road is used intensively by people who wish to spend a few days in nature at a campsite. Adjacent to the site are two temporary buildings. In the area, the forest is thinned out and forms a mosaic of grassy spaces of varying sizes, providing suitable places for parking and pitching tents. The coast is low and offers opportunities for a wild and peaceful beach. All this makes the place accessible and attractive. People's desire to add extra exoticism to the place by planting cacti proved to be decisive - the flowering period of cacti coincides with the first half of the active season along the Black Sea coast. The simultaneous presence of two species of the genus *Opuntia* is further indirect evidence of the intentional planting of cacti in this area. The situation is very reminiscent of that near the village of German and the Pancharevo dam. This reason for the emergence of cacti sites is also shared by other researchers in Bulgaria (Naydenova et al., 2019, Glogov et al., 2020).

The new locality is located within the boundaries of the BG0001001 Ropotamo Protected Area of the European Ecological Network "Natura 2000", declared under the Habitats Directive. Relatively close to the locality is the Ropotamo Reserve. Within the framework of the project Improvement of the conservation status of natural habitat 2130 *Fixed coastal dunes with herbaceous vegetation (grey dunes) by parameter "Structure and functions" and "Future perspectives" and natural habitat 2180 Wooded dunes by parameter "Area", Structure and Functions and Future Prospects, BG16M1OP002-3.021-0005-C01 in 2020, several localities of *O. humifusa* and *O. macrorhiza* were destroyed in Ropotamo Reserve, created specifically by humans. The time and effort invested in this is not small.

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Of the three groups of control methods that can be applied: mechanical, chemical and biological methods, the most suitable for small populations, such as those of *Opuntia* species in Bulgaria, are mechanical methods. Their application needs to be carried out as soon as possible, since the mechanical removal of foreign plants is a relatively slow method and requires a lot of labor and financial costs.

Conclusions

The established new population of *O. fragilis* in a new floristic area is not in favor of the biological diversity of Bulgaria. The increasing number of new populations and the introduction of more and more species of the genus *Opuntia* into natural habitats is a threat to the biodiversity in their locality. Turning these exotic species into a tourist attraction in the short term will bring benefits to local communities. The growth of the problem after decades, however, will lead to huge costs of extermination of the cacti or the abandonment of the territories conquered by them, which will become unsuitable for economic activities, including logging, grazing, cultivated areas, tourist routes and sites.

The species is not included in the list of invasive or potentially invasive alien species in Bulgaria, as it was discovered several years after the publication of this list. Taking into account the data on the reproduction ecology of the species and the consequences of its spread in the grassy areas in the USA and Canada, it can be declared a potentially invasive alien species and preventive measures can be taken to prevent its future spread on the territory of Bulgaria. The example of Australia is more than indicative. We hope that it will not be repeated, even on a very small scale, in the vicinity of settlements on the territory of Bulgaria.

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References

1. Asyov, B.; Petrova, A.; Dimitrov, D.; Vasilev, R., Conspectus of the Bulgarian vascular flora. Distribution maps and floristic elements. Bulgarian Biodiversity Foundation, Sofia, **2012** (in Bulgarian).
2. Bratanova-Doncheva, S.; Gocheva K., Advisory Services on a National Climate Change Adaptation Strategy and Action Plan, Appendix 2: Assessment of the Biodiversity and Ecosystems Sector, World Bank, Ministry of Environment and Water, **2018**.
3. Delipavlov, D.; Cheshmedzhiev, I.; Popova, M.; Teriyski, D.; Kovachev, I., Handbook for Plants in Bulgaria. Publishing House of Agricultural University, Plovdiv, **2011** (in Bulgarian).

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4. Dodd, A.P. The Biological Control of Prickly Pear in Australia. In: Keast, A., Crocker, R.L., Christian, C.S. (eds) Biogeography and Ecology in Australia. Monographiae Biologicae. Springer, Dordrecht, **1959**, https://doi.org/10.1007/978-94-017-6295-3_34.
5. Euro+Med PlantBase, Website: https://europlusmed.org/cdm_dataportal/taxon/b0ff1130-9671-412b-bf68-08fe9096d62f.
6. Flora of North America, Website: http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=242415221.
7. Glogov, P.; Dimitrov, D. Influence of climate change on the spread of invasive alien plant species in the territory of the Lozenska Mountain. *Ecological Engineering and Environment Protection*, **2021**, *1*, 78-82.
8. Glogov, P.; Georgieva, M.; Pavlova, D.; Gyudorova, S.; Dodev, Y., Characteristics of the locality of *Opuntia humifusa* (Raf.) Raf. (Cactaceae) on the territory of the Lozenska Mountain, *Forest Science*, **2020**, *1*, 29-44 (in Bulgarian).
9. Glogov, P.; Pavlova, D.; Georgieva, M.; Kachova, V., Analysis of Anthropophitic Flora on the Territory of Lozenska Mountain, Bulgaria. *Ecologia Balcanica*, **2019**, *11(2)*, 181-191.
10. Gorelick, R. Northern range llmjt of *Opuntia fragilis* and the Cactaceae is S6°N, not S8°N, *Madroño*, **2015**, *62(2)*, 115-123. JSTOR, http://www.jstor.org/stable/44577548. Accessed 14 Mar. 2023.
11. Guantanamo Bay Naval Base and Ecological Crises, Website: https://web.archive.org/web/20090327053019/http://www.american.edu/TED/guantan.htm.
12. Kenderova, R. Report 49. In: New floristic records in the Balkans, Compiled by Vladimirov, V., F. Dane & K. Tan. *Phytologia Balcanica*, **2012**, *18(2)*, 205-230.
13. Naydenova, T.; Vladimirov, V.; Bancheva, S., Contribution to the knowledge of naturalised *Opuntia* species (Cactaceae) in the Bulgarian flora. *Phytologia Balcanica*, **2019**, *25(1)*, 39-46.
14. Petrova, A.; Vladimirov, V.; Georgiev, V., Invasive alien plant species in Bulgaria, Institute of Biodiversity and Ecosystem Research, BAS, Sofia, **2012**.
15. Raunkiaer, C., The Life forms of plants and statistical plant geography, Oxford, Clarendon Press, **1934**.
16. Ribbens, E., *Opuntia fragilis*: Taxonomy, distribution, and ecology. *Haseltonia*, **2007**, *14*, 94–110.
17. Stoyanov, K.; Raycheva, Ts.; Cheschmedzhiev, I., Key to the native and foreign vascular plants in Bulgaria. Agricultural University Plovdiv Academic Press, Plovdiv, **2021** (in Bulgarian).
18. Tashev, A., Characteristics of the *Opuntia humifusa* (Cactaceae) locality in the Harmanli district, South Bulgaria. *Phytologia Balcanica*, **2012**, *18(1)*, 11-16.
19. The World Flora Online, Website: http://www.worldfloraonline.org/.

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20. Website of the Ministry of Environment and Water of the Republic of Bulgaria, *Opuntia* – the treacherous cactus with beautiful flowers and delicious fruits, https://www.moew.government.bg/static/ media/ups/tiny/filebase/Nature/Biodiversity/IAS/opuncia.pdf (in Bulgarian).
21. Westhoff, V.; Maarel, E., The Braun-Blanquet Approach In: Handbook of vegetation science (ed. Tuxen, R.), Dr. W. Junk b. v. Publishers the Hague, **1973**.

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