IASON BSB-1121

AT1.10 Observatory establishment

D.18: Review on lessons learnt

Part I.

IAS presence in the project sites and proposals for improving management at a Black Sea basin scale

30/04/2023

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Introduction

Invasive alien species (IAS) have become the focus of scientists because of their negative impacts on ecosystems as it is considered that they are among the main drivers of species extinction and global biodiversity loss. In response to these impacts and issues, the European Union issued Regulation 1143/2014 for the prevention and management of their introduction and spread. The aim of this Regulation is to frame specific monitoring programs, objectives and management goals referring to IAS in order to efficiently conserve local biodiversity.

The overall objective of the IASON project is to establish and perform joint monitoring actions on IAS in Black Sea deltaic ecosystems of five countries (Georgia, Greece, Ukraine, Romania and Turkey) and assess their response under current and predicted climatic conditions.

The multifaceted character of the project area – deltaic ecosystems of different biogeographical zones, different protection status & management, cross-border or one-country owned – creates major challenges in regard to IAS management in a climate changing future in the Black Sea region. Under this assumption, IASON project is structured in a way that all challenges are approached in an integrated and cross-border manner.

The scope of the present deliverable is to summarize the IAS presence in the project sites and present proposals for improving management at a Black Sea basin scale.

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1. Invasive Alien Species

Species' geographic distribution is the outcome of the interaction between their niches and environmental conditions. Among these, climatic factors are well known that influence both species growth and their worldwide geographic distribution. Moreover, ecological and biogeographical barriers such as oceans and large mountain ranges allowed ecosystems to evolved independently, and species occurring in these ecosystems are adapted not, only to local climate but also to each other interacting in a delicate balance. Climate change is expected to cause shifts in the current geographic distribution of species as their optimal habitat will likely change as a result of the rearrangement of the climate zones. In addition, the balance of ecosystems can be severely disrupted in cases where species, for several reasons, cross the currently established ecological and biogeographical barriers.

The expansion of plant and animal species outside their natural distribution is a worldwide common phenomenon. This is done either naturally, with a slow gradual way, or more rapidly, assisted by man. These new, alien, species adapt well if they are introduced in sites with similar climate with their natural distribution. In the past, the humankind has greatly benefited from the introduction of alien species (e.g. potatoes and maize in Europe, etc.) and this trend is enhanced in our globalized commerce. As a result, rates of introduction and establishment of alien species are continuously rising. Among these species, a large number has been "naturalized" in their new environments and now they can be found in several natural habitats. Although, many alien species have difficulties growing and reproducing in areas away from their natural range, some others are surprisingly favored by the new environments and they are rapidly expanded as, in most cases, they do not have natural enemies. These species have become invasive, having multiple worrying ecological, economic and human health impacts. Invasive species have an incredible ability to displace and reduce native populations of plants and animals. Invasive plants will compete with and displace native plants by monopolizing resources such as space, light, moisture, nutrients, and pollinators, which native plants require in order to grow. This can impact both natural and commercial areas negatively through increased costs of removing Invasive species can also introduce exotic diseases which native species have little immunity for, e.g. Red-eared slider turtles have introduced exotic diseases which have affected native turtle populations. Non-native plants can breed with native plant species thereby reducing natural genetic variation. This is a particular concern for species-at-risk.

The adaption and thus the distribution of invasive alien species (IAS) is mainly climate driven and this is why they can be found in a number of countries that are far from their native distribution range. Further, in the future, climate change will likely increase the rate of invasive species establishment thereby increasing the cost of land management in addition to negatively impacting native plant communities.

It is well known that invasive alien species are among the main drivers of species extinction and global biodiversity loss. More specifically IAS, represent a threat to native fauna and flora while

they can also result in major disruption to ecosystem health and loss of goods and services. Specifically in Europe, they cause damages amounting to many billions of euros. Increasing pressures on ecosystems, caused mainly by destruction of habitats, spread of IAS, over-exploitation and pollution, are weakening ecosystem resilience and ability to adapt to new conditions under climate change and thus continuously declining capacity for providing ecosystem services.

Deltaic ecosystems are extremely vulnerable to IAS invasion. Moreover, deltaic ecosystems are densely populated all over the world and traditionally support a great number of economic activities. According to reports from the Intergovernmental Panel on Climate Change, climate-related changes during the 21st century will include an acceleration in sea level rise, further rise in sea surface temperature, more extreme weather events and storm surges, altered precipitation and ocean acidification. Deltas are inherently vulnerable ecosystems with their biological communities being adaptable in this situation. However, climate change could result in a 50% increase of delta surface areas that are vulnerable to flooding and in even more warming trends of water temperature. At coastal zones and deltas, these climate-related changes are expected to inflict a range of physical, economic and social impacts.

The monitoring areas of the IASON project consists of five separate deltaic study areas (of the following rivers) which share common characteristics, but also have different environmental management backgrounds.

-Danube (Ukraine & Romania)

-Nestos (Greece)

-Kızılırmak or Halys (Turkey)

-Chorokhi & Kolkheti (Georgia)

The results of the two year monitoring on IAS appearance on the monitoring areas of the IASON project are presented below:

2. Distribution of IAS Species on the monitoring areas of the IASON project and proposals for improving management

2.1 FLORA

2.1.1 Amorpha fruticosa L.

Brief description

Commonly known as false indigo bush, is a shrub native to North America. However, due to its ability to adapt to a wide range of environmental conditions, it has become an invasive species in many parts of the world, including the Danube Delta and Nestos Delta.

Form: loose deciduous shrub with a wide-open crown up to 2.5 m high, legume family, with gray bark, young branches pubescent, later glabrous.

Growth rate: fast growing. At 6 years old, height up to 1.5 m, crown diameter 0.9 m. In case of freezing, the annual growth may exceed 1.5 m.

Leaves: large (up to 30 cm), openwork, alternate, pinnate, consist of 11-25 small elliptical leaves, bright green.

Flowers: small, fragrant, purple or dark cherry with bright golden stamens, collected in dense spike-shaped inflorescences. Located at the ends of the shoots and directed upwards. Blooms profusely in June-August.

Fruits: curved beans, 7-9 cm long, from green to brown in color, contain one small, smooth, brown seed with a dense shell.

Shoots: numerous, directed upwards, initially pubescent, later glabrous. Attitude to light: very photophilous and thermophilic.

Soil: undemanding, normally grows and develops on any, even dry soils. It can tolerate both acidic and alkaline soils, as well as soils with high levels of salts and heavy metals. However, it does not grow well in soils that are too sandy or too clayey.

In terms of light requirements, Amorpha fruticosa can grow in both full sun and partial shade, but it typically prefers areas with at least partial sunlight. It can also tolerate a wide range of temperatures, from -40°C to 40°C, and can grow at elevations up to 2,500 meters above sea level.

The species has a deep root system that allows it to access water and nutrients from deep within the soil. This makes it well-suited for dry environments, but it can also be problematic in wetlands where it can compete with other plants for water resources.

The shrub is also able to fix nitrogen, which means that it is able to convert atmospheric nitrogen into a form that is usable by plants. This ability makes *Amorpha fruticosa* an important plant for soil fertility and ecosystem functioning. The channels levees, after de-siltation process can be colonized by it and this develop a proper habitat for nesting birds, as Alcedo atthis.

According to the existing classification of anthropochores (Rikli, 1904), according to the time of introduction, the species belongs to neophytes (introduced in the recent past), according to the method of immigration, to ergasiophytes ("culture fugitives").

Amorpha fruticosa is able to thrive in a variety of ecological conditions. Mainly, it prefers floodplain forests, channels levees, hydrophilus and meso-hydrophilus meadows, sometimes even sparse common red stands. Also prefers to grow in moist soils, such as those found in wetlands and along streams and riverbanks.

It can outcompete native plants for resources such as light, water, and nutrients, and it can also alter soil chemistry and nutrient cycling. Its dense growth can also create a barrier for wildlife movement and disrupt natural habitats. The plant's ability to produce abundant seeds and root suckers also contributes to its invasive behavior.

It should be taken into account that Amorpha is a valuable ornamental, medicinal, fodder, melliferous and phytomeliorative plant. In most cases, on the territory of the reserve, it inhabits ecotopes with difficult conditions (swamps, sand dunes), where local shrubs cannot grow.

This is one of the best plants for strengthening the soil of slopes, bulk bevels, ravines, erosion control. A powerful root system cobwebs bind large areas of soil around the plant, while the resulting structure is not washed away by rain and does not shrink. Few among native shrubscan withstand flooding for a long time.

The decrease in the species diversity of near-river communities may be compensated by the high bank-fixing ability of amorphous plants, which have a well-developed tap root system. In areas devoid of tree and shrub vegetation, they perform soil protection functions. By shading the soil, they reduce the evaporation of moisture from its surface, suppress weed and steppe grassy vegetation, and improve the growing conditions for the main species. By compacting the plantation in the surface layer, they make it more powerful and thereby contribute to the fight against erosion processes.

Amorpha fruticosa may provide habitat for certain wildlife species, such as birds and insects. Very good honey plant, yields up to 100 kg of honey per hectare. Dried flowers and fruits are used in folk medicine, amorphine has a pronounced calming and cardiotonic effect.

Amorpha has the potential for phytoremediation, which is the use of plants to remove or stabilize pollutants in the soil or water. However, further research is needed to confirm its effectiveness and suitability for this purpose in the Danube Delta.

Amorpha has a fast growth rate, making it a potential source of biomass for bioenergy production. The plant material could be harvested and processed into biofuels or biogas, providing a renewable energy source.

Results of the two-year monitoring in the Danube Delta Biosphere Reserve (Romania)

The spread of *Amorpha fruticosa* in the Danube Delta Biosphere Reserve has been facilitated by human activities such as silviculture, channel de-siltation, road construction, water transport and urban development, which create disturbed areas where the plant can establish and spread rapidly, especially along the channels.

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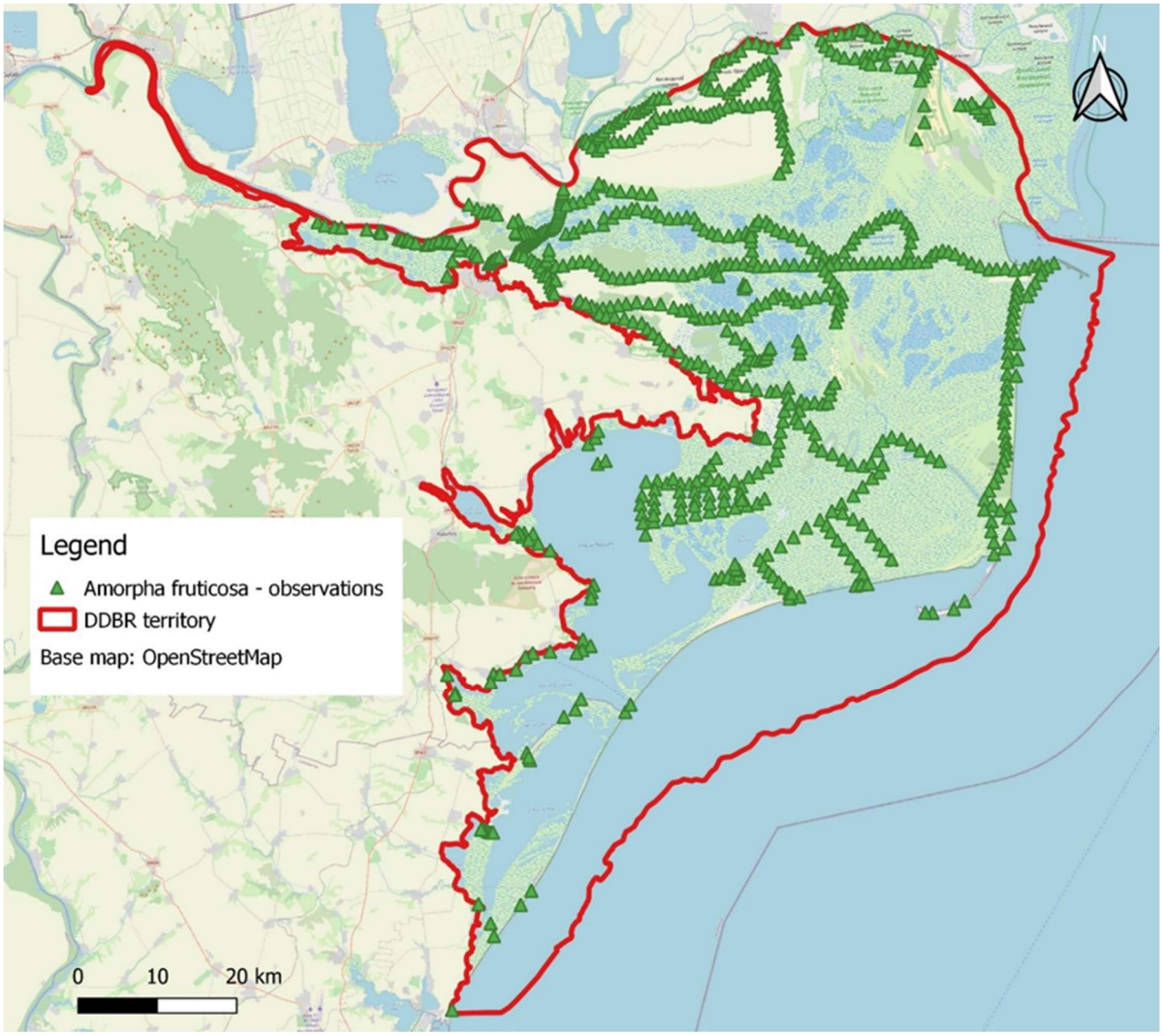

Fig. 1. *Amorpha fruticosa*–monitoring observation points in Danube Delta (Romania)

Results of the two-year monitoring Danube Delta (Ukrainian part)

Amorpha bushes are found on all elements of the relief: on watersheds, slopes of river valleys and gullies, in floodplains. Often these completely independent phytocenoses form a variety of combinations. Obviously, this is due both to optimal soil and climatic conditions and to the dissection of the relief, which creates a large number of diverse ecotopes. Such characteristics as a wide ecological amplitude, high competitiveness in various habitat conditions, active vegetative reproduction, high seed productivity, etc. ensured the introduction of shrub into the undergrowth of willows.

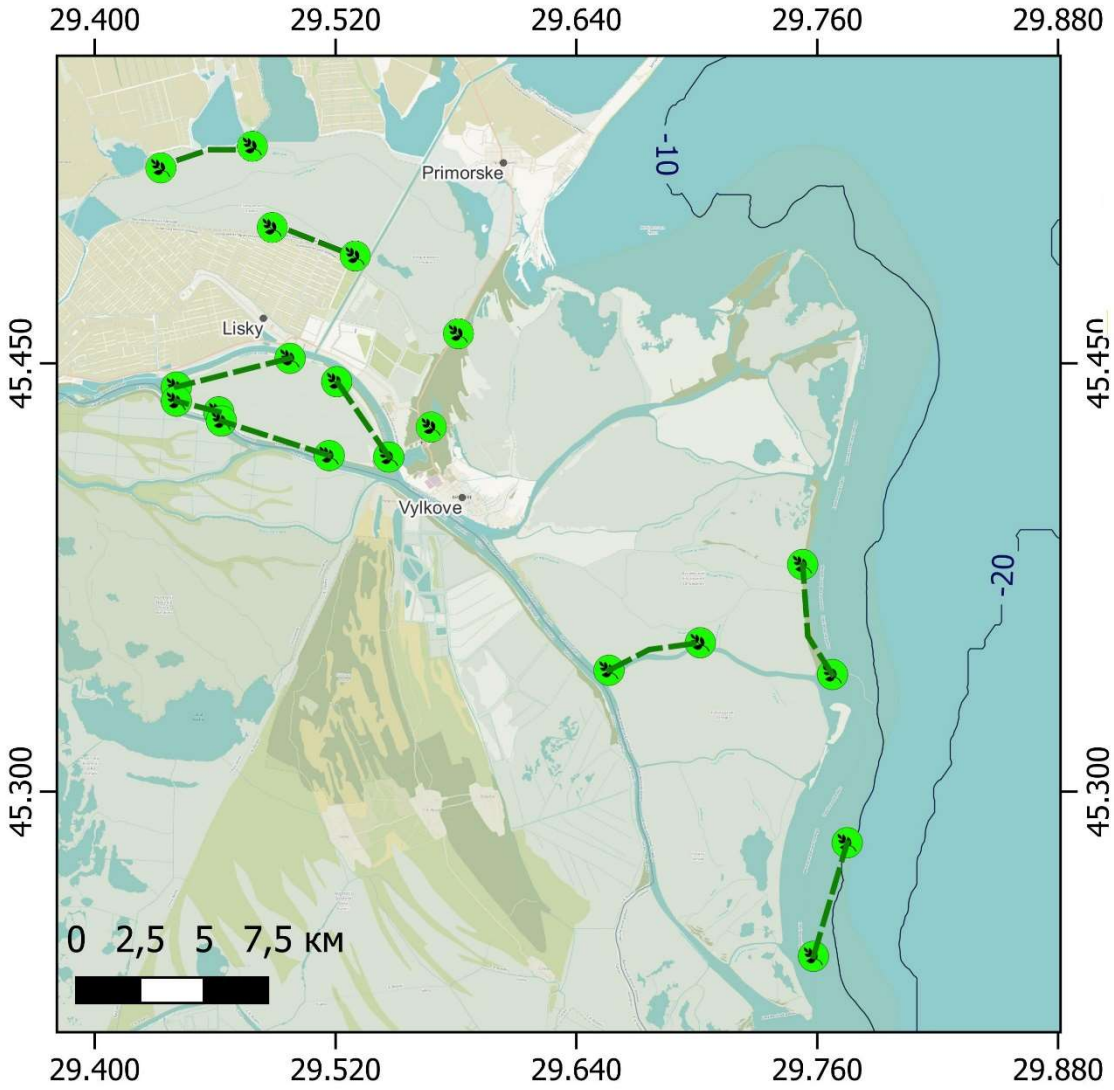

Fig. 2. *Amorpha fruticosa* – monitoring observation points in Danube Delta (Ukraine)

The greatest development of vegetative and generative organs of amorphous shrub was noted in well-lit ecotopes on sandy and sandy loamy soils. In cold winters, freezing of above-ground perennial shoots is observed and the subsequent restoration of the crown due to the growth of new skeletal axes.In the undergrowth and in open places, without woody vegetation, rather powerful thickets of amorphous shrubs are formed. The amorpha height is 2-3 m, and in some places 4-5 m. The average projective cover in some places is 60-70%. Due to the lack of light in the lower tier of vegetation, undergrowth from the main species of riverine forests almost does not develop. The herbaceous cover is poorly developed. The level of florocenotic diversity is low.

Results of the two-year monitoring in the Nestos Delta, Greece

Although *A. fruticosa* was first observed along Nestos River a few years ago, it has rapidly expanded, forming dense thickets and directly affecting plant species richness and distribution patterns. It was found in 63 grid cells (Figs. 2c and 3c, Table 2), mostly in large numbers and primarily in grassland communities where it gradually became the dominant species. However, it has also invaded alluvial forests with *Alnus glutinosa* and native forests with *Populus nigra*. In both cases, the numbers of individuals were smaller than in the open grassland habitats, especially in the alluvial forests with *Alnus glutinosa*. Obviously, the *A. fruticose* populations in open habitats are more dynamic and more disastrous to native vegetation. However, the fact that it was also found in *Populus nigra* forest patches might indicate that these patches could be seriously threatened in the future. *Populus nigra* cannot regenerate under the pressure of *Amorpha fruticosa* and this primary forest tree species would possibly successively be replaced by it after several years.
According to the EUNIS typology, *A. fruticose* has been found in the following habitats of the study area: C1.6: Temporary lakes, ponds and pools; C2.5: Temporary running waters; E3: Seasonally wet and wet grasslands; F9: Riverine and fen scrubs; G1.2: Mixed riparian floodplain and gallery woodland; G1.3: Mediterranean riparian woodland.

Distribution trend

The species is aggressively expanding its range in the Danube Delta Biosphere Reserve and the same is recorded in the Nestos Delta, Greece.

However, although the species continues to spread in the Ukrainian part of the Danube Delta it is showing a trend towards of stabilization.

Estimated damage to the deltaic ecosystems

Invasive species like *Amorpha fruticosa* may have economic consequences, such as costs associated with control measures, decreased tourism due to the degradation of the natural landscape, and negative impacts on agriculture or fisheries.

As a legume, *Amorpha fruticosa* has the ability to fix atmospheric nitrogen in the soil through a symbiotic relationship with nitrogen-fixing bacteria. *Amorph*a can change the nutrient cycling and hydrological processes within the ecosystem. Its nitrogen-fixing capabilities can increase soil fertility, which could potentially favor other invasive species and negatively impact native species adapted to lower nutrient levels.

The spread of *Amorpha fruticosa* in the all deltas that was recorded has been facilitated by human activities such as silviculture, channel de-siltation, road construction, water transport and urban development, which create disturbed areas where the plant can establish and spread rapidly, especially along the channels.

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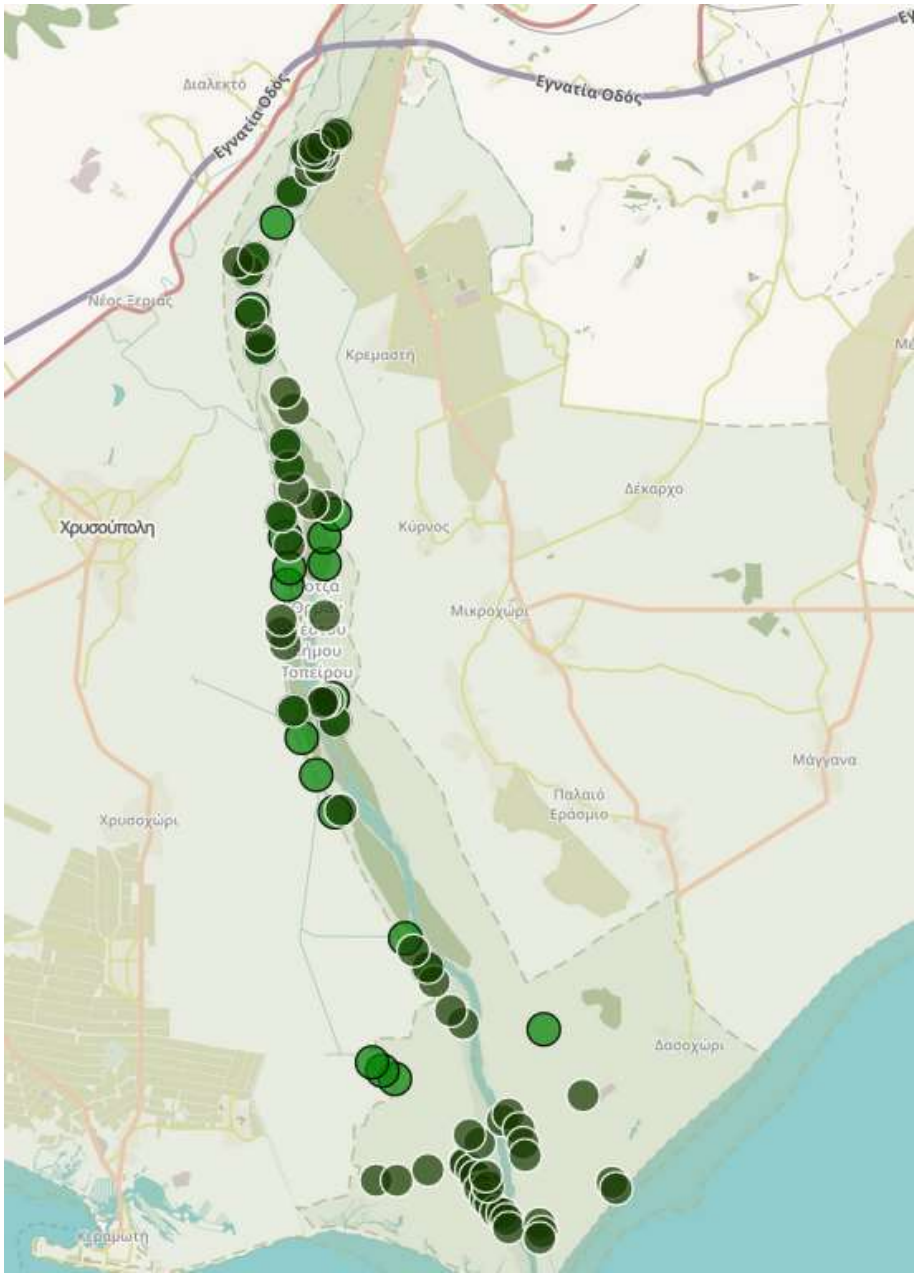

Fig. 3. *Amorpha fruticosa* – monitoring observation points in the Nestos Delta, Greece

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Fig. 4. *Amorpha fruticosa* – monitoring observation points in Kolkheti, Georgia

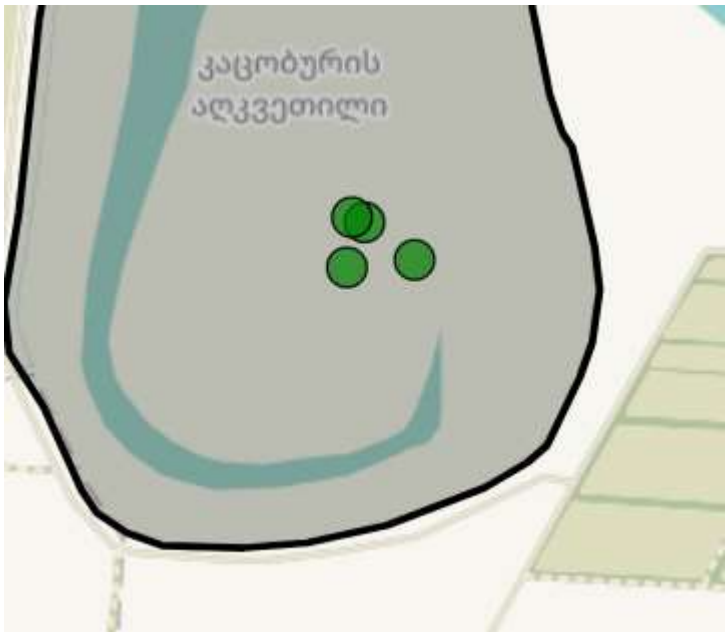

Fig. 5. *Amorpha fruticosa* – monitoring observation points in Katsoburi, Georgia

Possible management

Prevention is often the most effective strategy for managing invasive species. This can involve monitoring and early detection, educating the public about the risks of introducing invasive species, and implementing regulations to prevent the intentional or unintentional introduction of invasive species. In the case of *Amorpha fruticosa*, preventing further disturbances and minimizing human activity in areas where the plant is established can help limit its spread and minimize its impacts on the native ecosystems of the Deltas. Raising public awareness about the threats posed by *Amorpha fruticosa* and other invasive species is crucial for garnering support for control measures. Educational campaigns can inform people about the importance of protecting the Deltas and preventing the spread of invasive species.

2.1.2 Gleditsia caspica

Brief description

It is a species native to western Asia, in the Caucasus region of Azerbaijan and northern Iran, close to the Caspian Sea. It is a medium-sized deciduous tree growing to 12 m tall, with the trunk covered in numerous, 10–20 cm long branched spines. Trees have a light canopy, they come into leaf late in the spring and drop their leaves in early autumn.

The leaves are pinnate or bipinnate, up to 25 cm long, with 12–20 leaflets; bipinnate leaves have six to eight pinnae. The leaflets are up to 5 cm long and 2 cm broad. The flowers are greenish, produced in racemes up to 10 cm long. The fruit is a pod 20 cm long and 3 cm broad.

It is in flower from April to May, and the seeds ripen in October. The species is hermaphrodite (and is pollinated by Insects. It can fix Nitrogen. It prefers well-drained soil but can also be found in sandy, loamy and clays. Suitable pH: mildly acid, neutral and basic (mildly alkaline) soils. It cannot grow in the shade. It prefers dry or moist soil and can tolerate drought. It can tolerate atmospheric pollution.

Gleditsia caspica requires a hot summer if it is to thrive. It is cold hardy, with older trees being able to tolerate temperatures down to around -20°c when fully dormant.

Results of the two-year monitoring in Katsoburi, Georgia

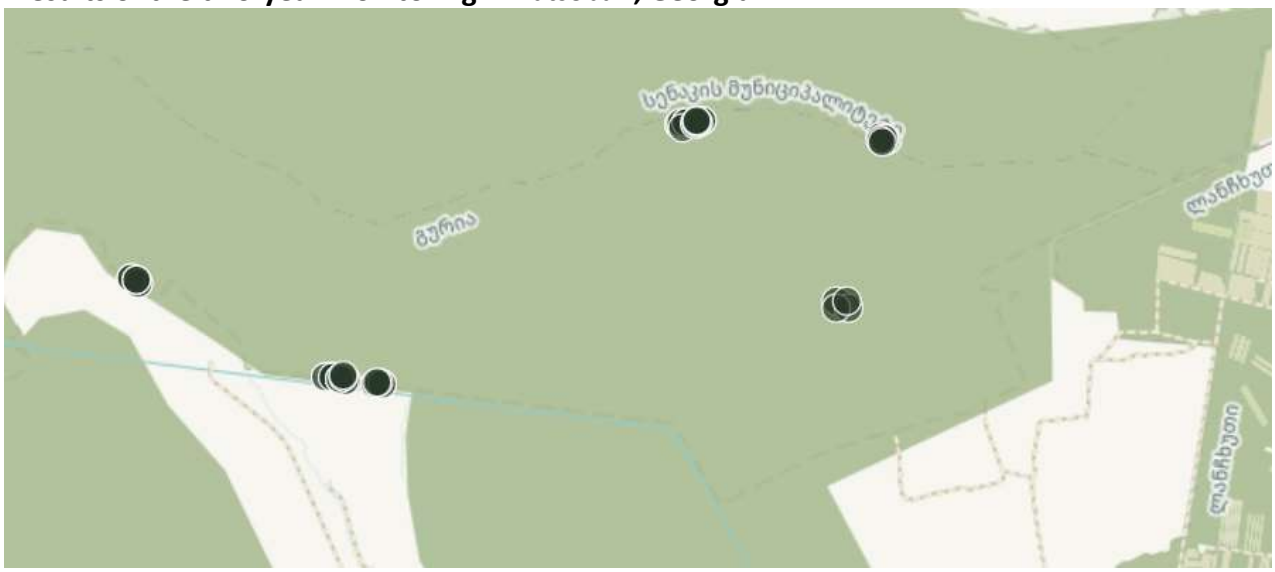

Fig. 6. *Gleditsia caspica* – monitoring observation points in Katsoburi, Georgia

Distribution trend

Fairly low

Estimated damage to the deltaic ecosystems

Fairly low

Possible management

Prevention is often the most effective strategy for managing invasive species. This can involve monitoring and early detection.

2.1.3 Robinia pseudoacacia

Brief description

It is a medium-sized tree (12 to 18 m in height) with an open, irregular crown. It usually produces a shallow and wide-spreading root system that is excellent for soil binding. It has sharp thorns at the nodes of young branches and twigs. The leaves are alternate, deciduous, compound and odd-pinnate; 20- 45 cm long and consist of 7-19 small, oval, alternate leaflets, dull dark green. *R. pseudoacacia* flowers at a relatively early age (3 years). The fragrant, whitish flowers appear in

May or June. Insects, primarily bees, pollinate the flowers. The fruit is a flattened, oblong pod with a narrow wing along the ventral margin. The small pods contain 4-8 hard-coated seeds, which can persist in the soil for many years. Seed crops are high, occur every 1-2 years beginning at age 3; pods open on the tree and seeds are dispersed in winter and early spring. Dry seeds can be stored and retain their viability for as long as 10 years. Trees graft easily and sprout readily from both stump and roots, especially after being cut or damaged, Although seedlings are produced, root suckers are most prevalent in natural reproduction.

The native range of R. pseudoacacia is broad and includes cool temperate moist forest, warm temperate montane moist forest, warm temperate montane wet forest, and warm temperate moist forest life zones It tolerates temperatures from 40°C to -12°C without damage. It is found on a variety of soils with pH ranging from 4.6 to 8.2, but grows best on moist, rich, loamy soils, those of limestone origin. It can also tolerates saline and infertile soils.

Although it prefers mean relatively high annual rainfall, it is adaptable to environmental extremes such as drought. However, it does not tolerate waterlogging. It is also resistant to air pollutants and high light intensities.

R. pseudoacacia was extensively planted for afforestation of bare areas in many countries in Europe as it is fast growing and therefore suitable for the control of soil erosion, land reclamation and rehabilitation of eroded tracts. It is also widely planted as an ornamental plant. It is a nitrogen-fixing species, which improves soil fertility. The trees are lopped for fodder and the flowers provide nectar for honey production.

It has been established on a wide variety of disturbed sites such as old fields or other cleared areas.

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Results of the two-year monitoring in the Nestos Delta, Greece

It is an aggressive colonizer. *Robinia pseudoacacia* is widely distributed in Greece, as it was formerly planted to stabilize soil and to prevent erosion, especially in degraded cropland on slopes, with shallow soils and poor yields caused by surface runoff and subsequent soil erosion. After abandonment of cultivation, a large portion of these areas was restored with *R. pseudoacacia*, following rules of the European Agricultural Fund for Rural Development. In the Nestos area, *R. pseudoacacia* had been grown in plantations to replace natural vegetation formations during the last century. The criteria for its selection were mainly its ability to grow fast and to produce timber of high quality. It was cultivated in several localities, and old plantations still exist in the area. *Robinia pseudoacacia* can easily spread from any place where it has been introduced, and invade natural and semi-natural habitats (mostly dry and mesic grasslands), and affect biodiversity.

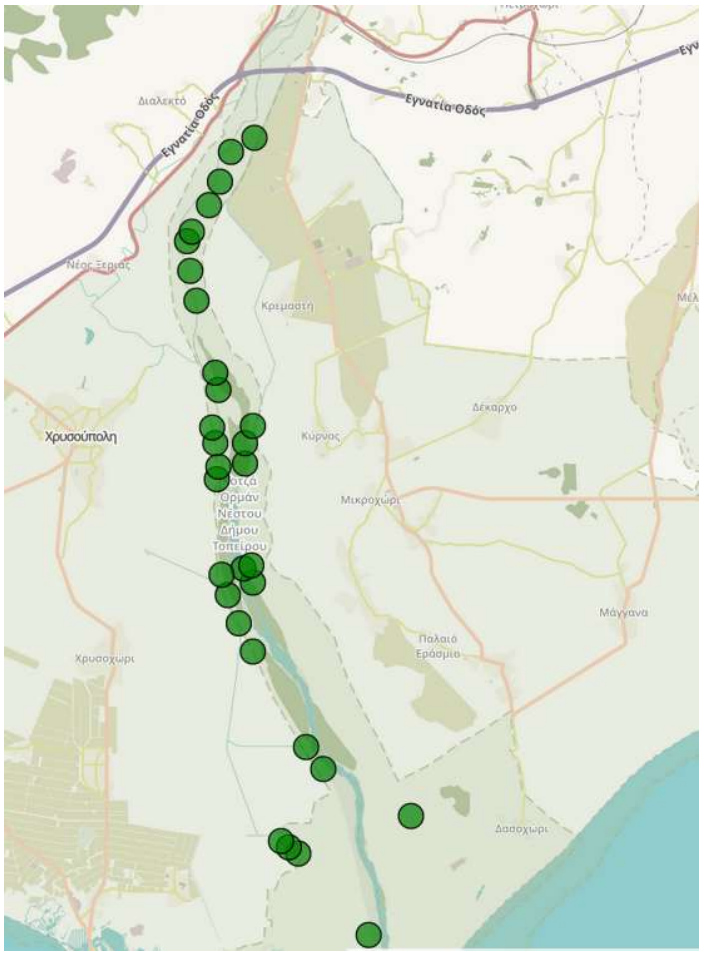

Fig. 7. *Robinia pseudoacacia*– monitoring observation points in the Nestos Delta, Greece

As a result, vital space for other species is being reduced and this causes problems to wild and domestic animals. Despite the species' numerous uses for humans, its negative environmental impacts forced European authorities to list it among the most competitive IAS in Europe.

Distribution trend

The species is aggressively expanding its range as it has been recorded in 67 grid cells along Nestos River. It is the second most widespread IAS in the study area, in terms of the number of occupied grid cells.

Estimated damage to the deltaic ecosystems

According to the EUNIS typology, *R. pseudoacacia* has been found in the following habitats of the study area: E1: Dry grasslands; E2: Mesic grasslands; G1: Broadleaved deciduous woodland. R. pseudoacacia invasion inhibits the growth of native species and plant species composition can be heavily impacted. It can affect ecosystem services.

Possible management

It very difficult and costly to control. Prevention is often the most effective strategy for managing invasive species. This can involve monitoring and early detection. However, it is a pioneer species, dominating in the early stages of a succession but then being taken over by other species as it is intolerant of shade. This attitude may help in controlling.

2.1.4 Acer negundo

Brief description

A. negundo is a fast growing and relatively short lived, multi-stemmed tree reaching a height of no more than 20 m. In open environment, the canopy usually exhibits a broad crown whereas under competition the trunk tends to be straighter. The leaves are 15-35 cm long, pinnate with 3-5 leaflets and light green but paler below. The leaflets are lobed and serrated. Male flowers are born in corymbs with pendent stamens whilst female flowers are in small pendent racemes. Both types of flowers are small and pale yellowish-green in colour. The fruit consists of two fused winged samaras to 4 cm long, diverging at an angle of less than 60 degrees. The samaras separate when shed and contain a single wrinkled seed.
A. negundo is a dioecious species. The tree may start bearing fruit when it is just 5 years old. It is both wind-pollinated and wind-dispersed, although dispersal by birds and squirrels also occurs. Vegetative reproduction is common on damaged individuals. Exposed or damaged roots will produce new shoots. Under natural conditions. It regenerates readily on disturbed and moist soils and does tolerate medium shade but poor establishment occurs under closed canopy.

It is chiefly wind-dispersed. In riparian systems, samaras are probably also dispersed by water but the importance of this dispersal mechanism is unclear.
A. negundo is generally tolerant of a wide range of environmental conditions. It is tolerant to water logging and it is reported as a drought-tolerant tree once established. It is moderately shade-tolerant, resistant to cold.
It is widespread in urban areas throughout much of Europe where it was introduced for landscape planting. It is now also common along many river systems as it is invading in riparian ecosystems.

Results of the two-year monitoring in the Nestos Delta, Greece

Acer negundo was found in the Nestos area in habitat type 91E0 [alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)], in the lower tree layer and more rarely in the understory and the canopy. Although the pressure of *A. negundo* on native tree species is not yet very high, it is expected that its share in the tree layer will increase strongly in the course of succession and affect the habitat type. In total, *Acer negundo* was recorded in 31 grid cells along Nestos River almost always between the two embankments that have been constructed for flood control. In general, *A. negundo* occurs in the form of isolated or

scattered individuals, a fact that could be attributed to the capability of its seeds for long distance dispersal.

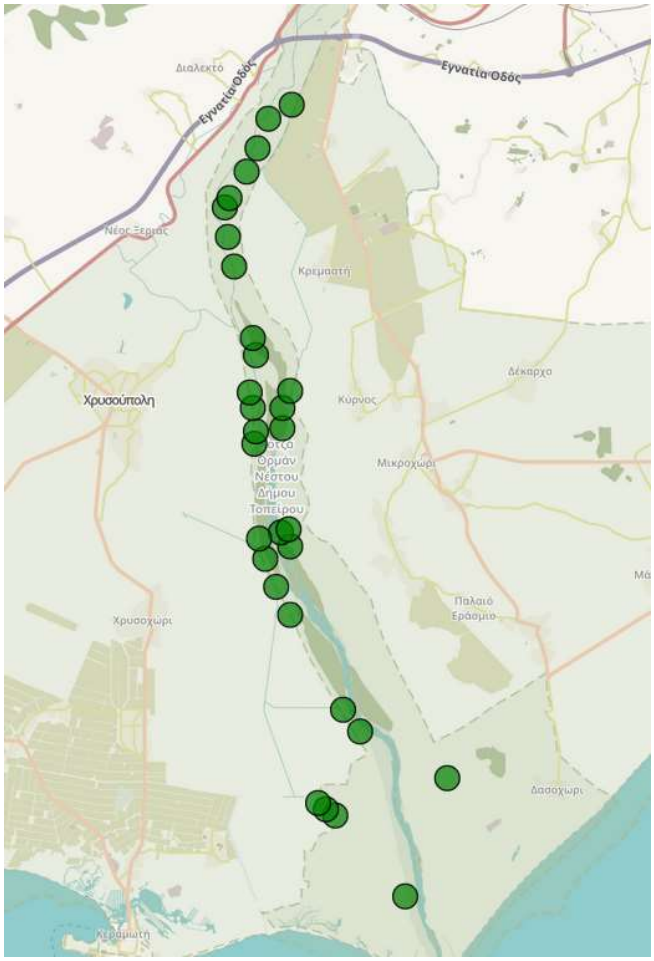

Fig. 8. ***Acer negundo*** – monitoring observation points in the Nestos Delta, Greece

Distribution trend

The species has become one of the most invasive plant species occurring in riparian forests all around Europe.Once established in a riparian area, it is considered that it will affect other dominant tree species and will alter vegetation composition.

Although it was never found in dense thickets, we observed a large number of young plants in the understory of alluvial forests with *Alnus glutinosa* (91E0). This might indicate that the alluvial forests of the area will be strongly affected by the replacement of *Alnus glutinosa* with *Acer*

negundo in the future. Moreover, scattered individuals have been recorded in grassland communities but their effects on these habitats were very limited. This was because the regeneration of *Acer negundo* in grassland communities is not always easy, and thus, its expansion seems to be rather difficult.

Estimated damage to the deltaic ecosystems

According to the EUNIS typology, *A. negundo* has been found in the following habitats of the study area: G1.2: Mixed riparian floodplain and gallery woodland; G1.3: Mediterranean riparian woodland; E2: Mesic grasslands.

Possible management

Mechanical control may prove effective. The cutting of female trees is also suggested in order to eliminate risks of spread in the introduced range.

2.1.5 Phytolacca americana

Brief description

Phytolacca americana is a relatively large wildflower measuring approximately 3m. in height. The white, radially symmetrical flowers of pokeweed are very small, measuring 6 mm. in width. Each bloom has a small, green, central fruiting structure, surrounded by white stamens, five rounded petals and five, white, petal-like sepals. Flowers are arranged as elongated clusters along the length of the reddish-brown stems. The berries are rounded, dark purple, in heavy, drooping elongated clusters. The leaves are large, measuring 12.5-30 cm. in length, and lanceolate with tapered tips and bases. They have wrinkled margins, are conspicuously veined.

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It is an aggressive plant that self-seeds easily and can become weedy. The plant grows easily in average, medium moisture, well-drained soils in full sun to part shade. It prefers consistently moist soils but will tolerate short periods of drought. .It grows best in, disturbed habitats), forest edges in open woods, damp thickets, around clearings and along roadsides. *Phytolacca americana* is a toxic plant. The berries and roots are poisonous.

Results of the two-year monitoring in the Nestos Delta, Greece

Phytolacca americana was first introduced in the Mediterranean in the 17th century but it now also occurs in several other European countries. Its fruits are eaten by birds and thus, their seeds are dispersed over long distances.

It was recorded in 82 grid cells but it was not as dangerous as other alien species, e.g., *Amorpha fruticosa*. In general, it was mostly found in dry grasslands in isolated individuals or small groups. Although it was also found in the understory of forested areas, the number of individuals was small and, based on our evaluation, not able to cause serious problems to the dominant tree species.

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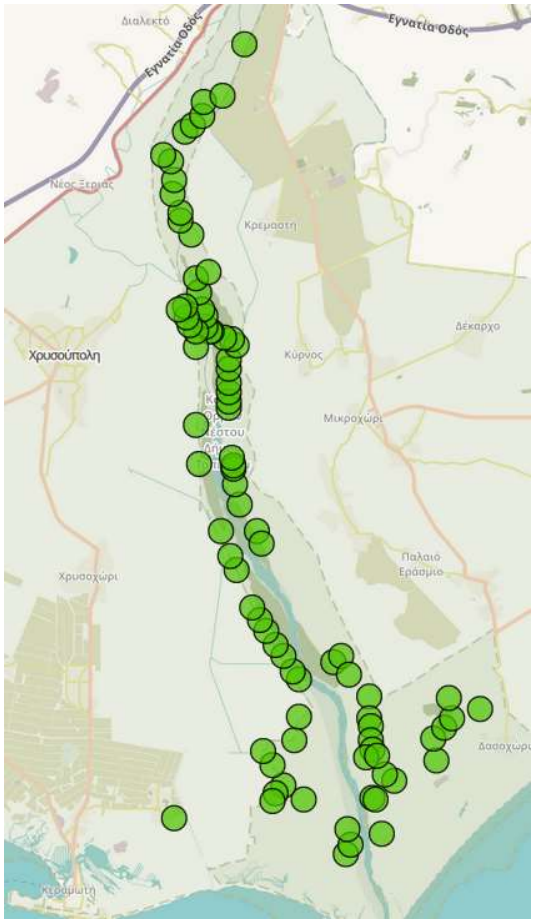

Fig. 9. *Phytolacca americana* – monitoring observation points in the Nestos Delta, Greece

Distribution trend

In terms of the number of grid cells in which it has been recorded so far, *Phytolacca americana* was the most widespread IAS occurring along Nestos River

Estimated damage to the deltaic ecosystems

According to the EUNIS typology, *P. americana* has been found in the following habitats of the study area: E1: Dry grasslands; E2: Mesic grasslands; G1: Broadleaved deciduous woodland; G1.2: Mixed riparian floodplain and gallery woodland; G1.3: Mediterranean riparian woodland

Possible management

Under suitable environment conditions, *P. americana* forms dense populations that can outcompete native vegetation and prevent regeneration of forest species.

2.1.6 Ailanthus altissima

Brief description

Ailanthus altissima is a short to medium-size deciduous tree, usually only 6-10 m tall with bark with pale stripes. Leaves up to 90 cm long, pinnate compound, pubescent or nearly glabrous, the lower pinnae having a blunt tooth near the base together with a large gland, leaflets up to 25, ovate-acute, usually with 1-3 pairs of glandular teeth near the base, otherwise entire. Flowers are unisexual, small and yellow, in large panicles; male flowers having an unpleasant odour. The seeds are contained within one-celled, one-seeded, oblong, thin, spirally-twisted samaras, 3 x 0.8 cm and light reddish-brown. The seeds have no endosperm.

It is native to China, valued chiefly for timber, shade and urban amenity plantings. It is an aggressive pioneer species, characterized by rapid juvenile growth and prolific seed production and has a very high ability to coppice once established. It is tolerant of drought, poor soils and pollution and so can be grown in difficult urban locations. It requires well-aerated and moist soils to produce good, single-stemmed trees. *A. altissima* has colonized disturbed sites along roads and ditches, particularly in the Mediterranean region.

It is found in areas with an annual rainfall of 500-700 mm, can tolerate a 4-8 month dry season.

Results of the two-year monitoring in the Nestos Delta, Greece

Ailanthus altissima was first introduced to Europe (France) in the 1740s and subsequently planted as an ornamental in several European countries. It has spread and been naturalized across large areas of Europe and is now considered as an invasive species that can rapidly spread onto disturbed sites or fragmented landscapes. Moreover, it can invade riparian forests, shrublands, and mesic and xeric woodlands. Therefore, it seriously threatens biodiversity and ecosystem functions.

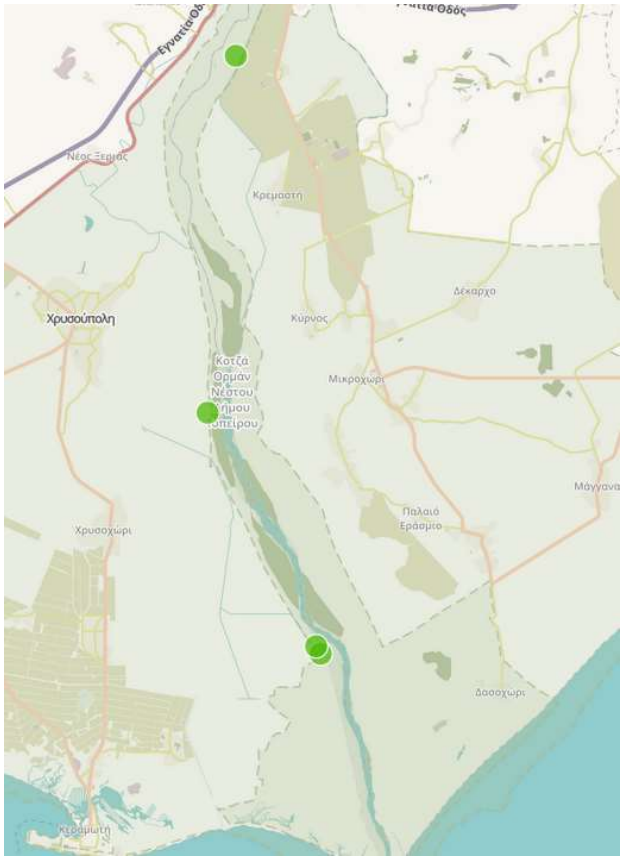

Fig. 10. ***Ailanthus altissima*** – monitoring observation points in the Nestos Delta, Greece

In total, *Ailanthus altissima* has been recorded in 3 grid cells along Nestos River. In three grid cells, only a small number of individuals have been recorded, so far. Thus, for the time being, *A. altissima* can be considered as a rather uncommon alien species in the study area. However, it is only a matter of time that *A. altissima* will expand and establish in other parts of the area where it will affect various natural and semi-natural habitats. It usually forms dense thickets, where all other plant species are going extinct – a quite destructive effect on local species composition and diversity, also due to the allelopathic effects of phytotoxic compounds from roots and leaves.

Distribution trend

Low, at the moment

Estimated damage to the deltaic ecosystems

The species is highly adaptable to different environments. It tolerates, or even benefits from cultivation, browsing pressure, fire etc. It has a negative impact on native biodiversity.

Possible management

A. altissima is very difficult to be removed once has been established. The plant can persist after burning, cutting and herbicide treatment and it is recommended that seedlings must be removed as early as possible. Cutting stumps stimulates re-sprouting instead of eliminating it.

2.1.7 Solanum elaeagnifolium

Brief description

Perennial herbs up to 50 cm tall, vegetative growth usually annual, erect, branched above, usually armed with straight, fine, reddish prickles 2-5 mm long, usually on stems, occasionally on petioles, leaves, and calyx, all parts densely and closely tomentose with stellate hairs, general aspect silvery green, rarely reddish brown, forming colonies from underground root system. Leaves simple, alternate, lower leaves oblong-lanceolate, up to 10 cm long and 4 cm wide, margins sinuate-undulate, apex acute or obtuse, base rounded or cuneate, upper leaves smaller, oblong, entire. Flowers perfect, actinomorphic, few in racemose cymes, peduncle up to 1 cm long, pedicels ca. 1 cm long at anthesis, elongating to 2-3 cm long in fruit; calyx tube up to 5 mm long, 5-ribbed by the principal veins, the lobes subulate; corolla blue, rotate-stellate, 2-3 cm in diameter, the lobes divided ca. 1/2 their length; stamens inserted near base of corolla tube; filaments 3-4 mm long; anthers yellow, slender, tapered upward, conspicuous, erect, not coherent, 5-8 mm long, opening by apical pores; ovary pubescent toward summit; style 10-15 mm long; stigma terminal. Berries at first marbled green, later yellow to finally orangish brown, mucilaginous, globose, 0.8-1.4 cm in diameter, calyx covering base of fruit. Seeds pale brown, discoid, flattened, ca. 3 mm long, smooth.

The species is widely naturalized. It has spread primarily as a seed contaminant in soil and crops. It is *m* is adapted to a wide range of habitats, but appears mostly in areas of relatively low annual rainfall (300-500 mm). The weed thrives on disturbed land areas. It is Pioneer in disturbed areas. Shade tolerant.

It can grow in areas with a hot dry summer and a cool wet winter, and can apparently withstand low temperatures of –23 to –18°C. The species appears to prefer loamy, droughty soils, but is

found on virtually all soil types including nutrient-poor sandy soil, although it cannot tolerate deep sands.

Results of the two-year monitoring in the Nestos Delta, Greece

Most probably, *Solanum elaeagnifolium* was introduced in Europe unintentionally from Texas in the 1930s. The invasion started from the Mediterranean Basin and expanded into other areas of the continent, and *S. elaeagnifolium* is now classified among the most aggressive IAS in Europe. Its range in Greece has increased by 1750 % during the last few decades, which indicates its great invasiveness and rapid spread.

Solanum elaeagnifolium has been recorded in only 5 grid cells along Nestos River, although it is a common species in Greece where it can be found in cultivated, abandoned, managed or disturbed lands, pastures, urbanized areas, and roadsides. This scarcity in the study area can be attributed to the fact that many grassland communities along Nestos River are classified as mesic or temporary wet grasslands, which are not very suitable for the plant. However, the populations in the invaded grid cells are already characterized by the typical large numbers of individuals affecting the physiognomy of the plant communities. Moreover, as a poisonous plant to both humans and cattle, *S. elaeagnifolium* is not affected by grazing. On the contrary, as grazing reduces the competitive capacities of the valuable forage plants, it finds the necessary space for its expansion and thus it can become the dominant species within a few years after being established in an area.

Distribution trend

According to the EUNIS typology, *S. elaeagnifolium* has been found in the following habitats of the study area: E1: Dry grasslands

Estimated damage to the deltaic ecosystems

Competition - monopolizing resources

Possible management

S. elaeagnifolium is perennial, very difficult to control. Benefits from human activities Several control methods have been investigated but none has proved conclusive

Fig. 11. *S. elaeagnifolium* – monitoring observation points in the Nestos Delta, Greece

2.1.8 Ambrosia artemisiifolia

Brief description

Annual herb (therophyte), 20-60 cm tall. Stems erect. Leaves opposite (proximal) and alternate, with blades lanceolate or elliptic, 1-2-pinnately lobed, sparsely pubescent abaxially, glandular-dotted on both faces, petioled [petiole 25-35mm long]. Flowers arranged in capitula, the male

capitula (5-20 flowers per capitulum, the involucre being cup-shaped, glabrous to pubescent) forming a terminal spike-like inflorescence, the female capitula proximal to the male ones. Fruit globose to pyriform, 2-3 mm long, more or less pubescent. It is a fast growing herb which can completes its growth cycle in 115 to 183 days with each plant producing a high number of viable seeds, small in size and low in weight. Pollination is performed by wind.

Results of the two-year monitoring in Adjara, Georgia

A. artemisiifolia is one of the most common alien species in the area of Adjara, the frequency of its appearance in the sampled plots was 100%.

Distribution trend

The distribution of the weed is rapidly increased. Temperature is the main factor limiting the spread of *A. artemisiifolia;* under cooler conditions, plants fail to produce flowers or seeds fail to ripen. Because of climate change, *A. artemisiifolia* may increase its distribution.

Estimated damage to the deltaic ecosystems

A. artemisiifolia is classified among the 100 most invasive alien plant species in Europe whose area in continuously increased in all European countries, where it is mostly found in agricultural field, along roadsides and in riverbanks. *Ambrosia artemisiifolia* is a very competitive species. It

is known for its allelopathic properties, which can prevent the growth and development of all neighboring plants. We found it in the study area growing almost everywhere, in all types of soils. The impact of this species on the biodiversity of the Chorokhi Delta is high, with a particularly large impact on semi-natural ecosystems. It reduces soil fertility and changes its structure.

Possible management

A. artemisiifolia competes with native plants species for space, nutrients, light and water and may result in changes to habitats and a decrease in biodiversity.

It may be controlled by hand weeding and mowing. Mechanical cutting can reduce *A. artemisiifolia* seed production. *A. artemisiifolia* has been the subject of a biocontrol programme with *Zygogramma suturalis, which* has resulted in controlling it.

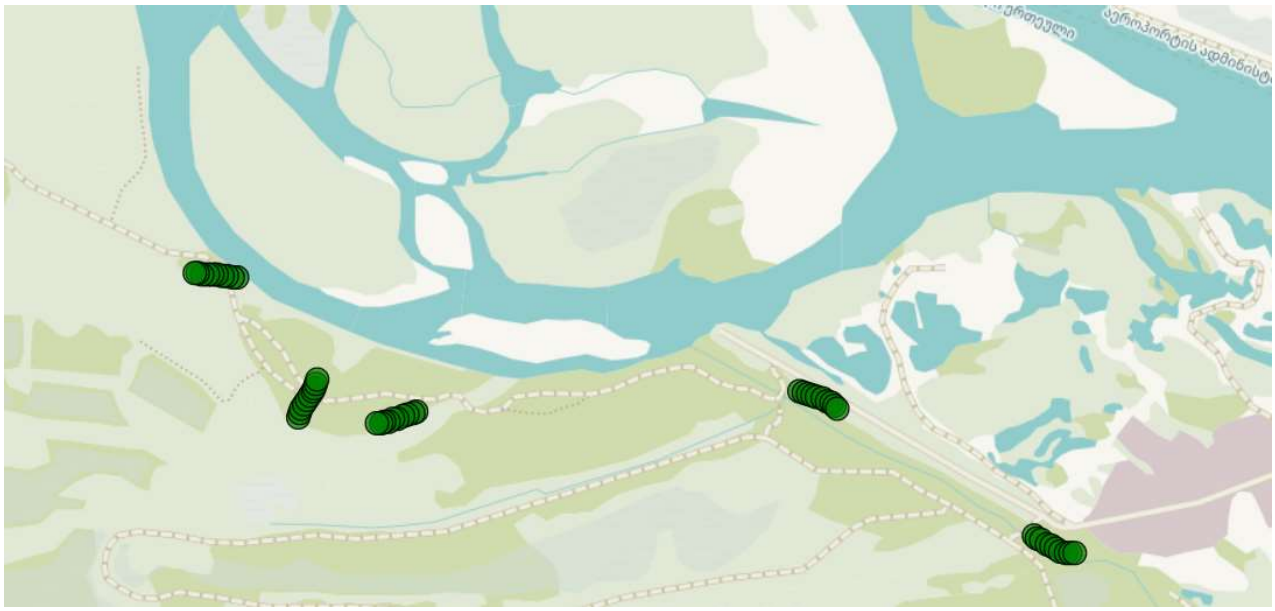

Fig. 12. *Ambrosia artemisiifolia* – monitoring observation points in Adjara, Georgia

2.1.9 Sicyos angulatus

Brief description

The leaves of *S. angulatus* are thin, 5-lobed, up to 25 cm across and pubescent petioles 2.5 to 10 cm long. They are alternate, broadly heart-shaped and finely toothed. Stems are hairy and form a creeping vine up to 6 m long, with numerous branched tendrils. New vines can form by growth from axillary buds. The root system consists of a shallow branched taproot.

S. angulatus is monoecious with 5-petalled, green and white flowers. The male flowers appear in a corymbose raceme on a very long peduncle and the female flowers appear in a capitate cluster on a short peduncle.
The bur-like fruits are small and spiny, 1.0-1.5 cm long, one-seeded, produced in clusters of 3-20, initially green, turning brown, indehiscent, containing a single brown flattened seed. Each fruit contains one seed, and 3 to 15 fruits are borne in a cluster.
Although *S. angulatus* requires adequate soil moisture, it adapts to wide range of environment conditions.

Results of the two-year monitoring in Adjara, Georgia

It was recorded a decade ago in Georgia, and now it is considered among the most aggressive alien species, which is widespread in the western part of the country. As field studies have shown that the new seedlings of *Sicyos angulatus* are very similar to the cucumber seedlings, the difference becomes noticeable in the flowering and fruiting phase, at which time the plant is abundantly branched and completely covers other plants in the distribution area. According to literature sources, the length of the stems ranges from 10-12m.. During our research, we observed stems up to 20 m long, which is caused by the specific climatic conditions of the study area.

Fig. 13. *Sicyos angulatus* – monitoring observation points in Adjara, Georgia

Distribution trend

Grain importation is the most likely pathway of accidental introduction of *S. Angulatus*. However, The rapid local spread of *S. angulatus* may occur via dispersal in flowing water. Its establishment along riversides may present a higher risk for local spread.

Estimated damage to the deltaic ecosystems

The negative ecological impact of *Sicyos angulatus* on the native flora and vegetation of the Chorokhi Delta is very visible. Large-sized populations developing on moist soils engulf all plants found in the distribution area and inhibit their growth and development, resulting in thick and heavy mats covering the existing vegetation. In the future, its uncontrolled distribution can cause great damage in agricultural terraces, especially in corn crops and citrus plantations. It can drastically reduce the yield of agricultural crops, as well as their qualitative and quantitative indicators. In the soil-climatic conditions of Western Georgia, there is a great potential for invasion. Its control is quite difficult, because after the destruction of the above-ground part of the plant, the presence of its seeds in the soil can last for at least three years.

Possible management

It is necessary to carry out fighting measures at the beginning of vegetation.

2.1.10 Solidago Canadensis

Brief description

S. canadensis is an erect rhizomatous perennial plant native to North America which has spread throughout a number of European countries after its introduction as an ornamental. It is among the most successful invasive species in Europe. It continues to be available from mail-order catalogues and websites of commercial nurseries and botanical gardens and as such further introduction of this species are likely.

S. canadensis is a 25-250 cm tall, erect rhizomatous perennial with annual aboveground shoots and persistent belowground rhizomes. One to several rhizomes emerge near the base of the dying shoots in autumn, thus leading to a branched rhizome system rooted mainly at the old and current shoot bases. Each rhizome has the potential to produce a single aerial stem arising from the apex of the rhizome in the following spring. Roots arise from the shoot base and reach a minimum depth of 20 cm.

Stems are branched only in the inflorescence, glabrous at the base, weakly to densely pubescent at least in the upper half and often reddish. Inflorescences form broad pyramidal panicles with recurving branches and a central axis. Bracts of the involucre are linear, obtuse or somewhat acute. Ray florets are lemon yellow, female and fertile, disc florets bisexual and fertile. The corolla is 2.4-2.8 mm long. Achenes are pubescent, 0.9-1.2 mm long, with a pappus of 2.0-2.5 mm. Individual clones are long-lived and can reach an age of 100 years.

It was found that both plant diversity and cover were adversely affected by its invasion in Poland but more disturbingly the abundance, species richness and diversity of wild bees, hoverflies and butterflies were al reduced in the invaded wet meadows.

Results of the two-year monitoring in Adjara, Georgia

The species, although it is not characterized by a massive spread on the Chorokhi Delta, its broad ecological requirements and its clonal growth leave no doubt that it is a highly dangerous invasive species. Through vegetative and generative propagation, it spreads widely, creates stable and resistant colonies and occupies new territories. Thus, *S. canadensis* can become the dominant plant species for a long time after establishing in an area. Despite its negatively effects in semi-natural ecosystems and agricultural landscapes, in natural ecosystems it cannot dominate and become abundant, thus appearing in the form of few isolated individuals.

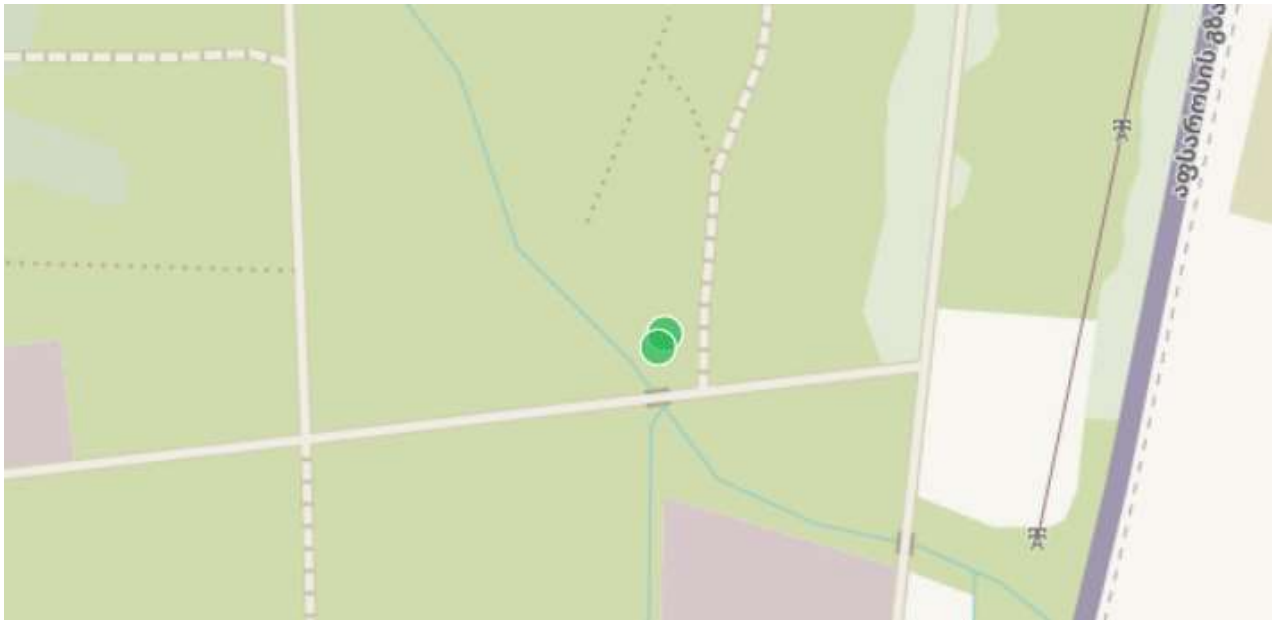

Fig. 14. *Solidago canadensis* – monitoring observation points in Adjara, Georgia

Distribution trend

Solidago canadensis was first described in the flora of Georgia in the first half of the 20th century. Its distribution was mainly limited to a narrow local area. Mass distribution on the Kolkheti lowland began at the beginning of the current century, and the first individuals appeared on the Chorokhi Delta 5-15 years ago. Moreover, it is believed – albeit not yet proven – that the expansion of the distribution area and the conquest of new territories by the two mentioned species is related to the global climatic changes.

Estimated damage to the deltaic ecosystems

Low, till now

Possible management

It is an undesirable invader due to its large rhizomes, vigorous growth and allelopathic effects which lead to gross changes in the native vegetation and fauna. It is easily controlled by cultivation but difficult to control in natural areas due to its long persistence.

2.1.11 Verbena brasiliensis

Brief description

Verbena brasiliensis is an annual or short-lived perennial herb with erect, hispid, quadrangular stems of 1-2.5 metres in height. Upper branches are 4-9cm long, opposite, and ascending. Opposite, elliptic leaves are simple and serrate, 4-10cm long by 0.8-2.5cm wide. Leaves are generally hispid, with veins on undersides bearing large bristles. Bracted flowers are borne on terminal, loosely arranged spikes which are 0.5-4.5cm long by 4-5cm wide and are arranged in triads. Lanceolate bracts subtend the 5-lobed calyx, which is 2-3.5mm long, with lobes united nearly to the apex. The bluish purple corolla is salverform, zygomorphic, and is exserted from the calyx slightly. The tube is 2.75-3.25mm long and lobes are less than 1mm in length. Bracts, calyx, and corolla tube are all pubescent. Anthers are attatched in the upper part of the corolla tube. Fruit is a schizocarp which usually produces 2 brown nutlets, 1.2-1.9mm long.

Verbena brasiliensis is a facultative wetland species that can be found both in wetland/riparian areas as well as in drier, upland habitat. In its native areas it is found in dry fields and arable land

as a weedy species, but in areas in which it is invasive it thrives in riverine areas or roadsides, old fields, and other disturbed areas.

Results of the two-year monitoring in the Nestos Delta, Greece

Verbena brasiliensis is an annual or short-lived perennial plant in its homeland. In the study area, it exhibits a perennial life cycle, being vegetative almost throughout the year, whereas only the top branches wither in the winter. It is being propagated by seeds, and by underground root shoots, features that make it a significant invasive species. According to the Global Invasive Species Database (GISD 2023), it is considered a significant invasive species of the mid-south United States. It was introduced in Georgia some decades ago and since then, it became widely distributed in the lowlands of Adjara, where it is mostly found in ruderal places, agricultural lands and near canals and rivers.

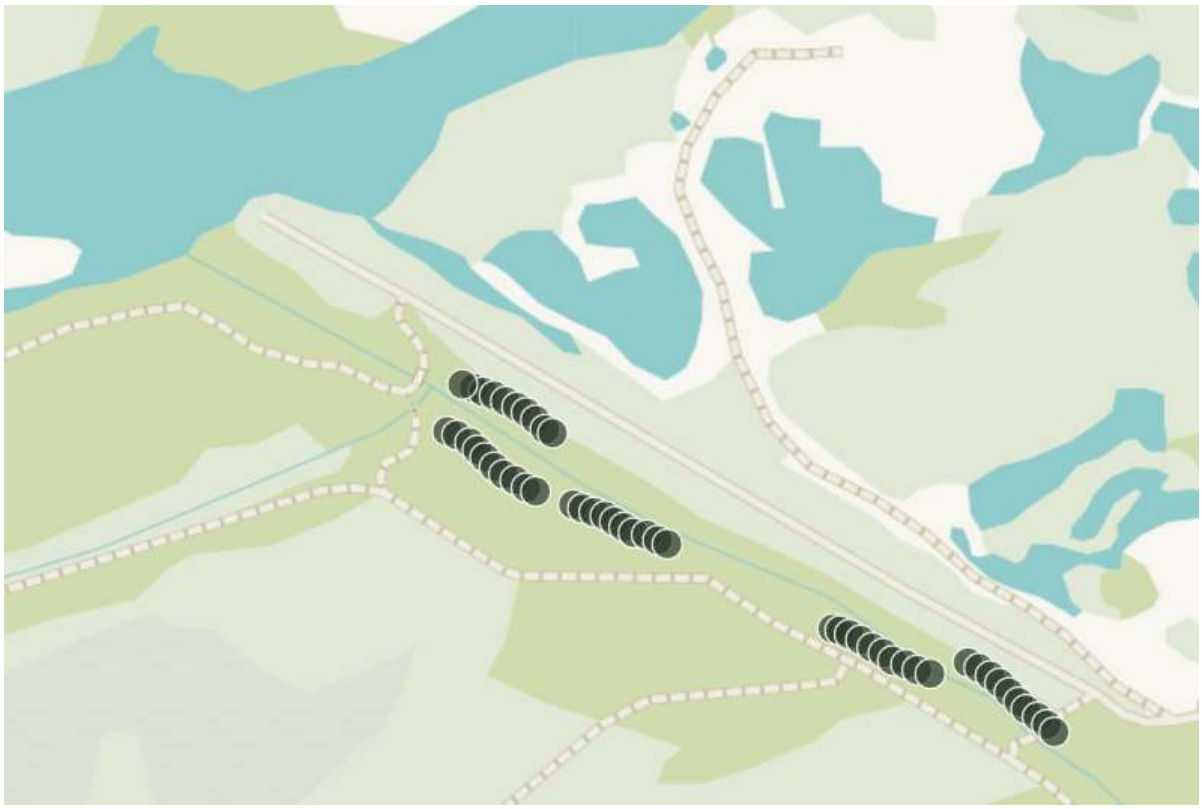

Fig. 15. *Verbena brasiliensis* – monitoring observation points in Adjara, Georgia

In sites, where it is introduced, it has the ability to alter the floristic composition as the result of its highly competitive ability. Moreover, its invasion capability is also shown by the fact that it was recently recorded in the northern part of Turkey. It should be noted that *V. brasiliensis* is much favoured by the local population for its beautiful flowers. However, it is a plant species that has

flower buds, flowers and mature seeds in the same individual at the same time. So, once it is used as an ornamental plant, people are intentionally dispersing large quantities of seeds that can germinate in new environments.

Distribution trend

Verbena brasiliensis were first described in the flora of Georgia in the first half of the 20th century. Their distribution was mainly limited to a narrow local area (Kolakovski 1982). Mass distribution on the Kolkheti lowland began at the beginning of the current century, and the first individuals appeared on the Chorokhi Delta 5-15 years ago (Mikeladze 2017; Mikeladze 2021). Moreover, it is believed – albeit not yet proven – that the expansion of the distribution area and the conquest of new territories by the two mentioned species is related to the global climatic changes.

Estimated damage to the deltaic ecosystems

Verbena brasiliensis is an invasive plant that may threaten native plants species by displacing them

Possible management

As a preventative measure, the species should not be planted or sold as an ornamental. It can be chemically managed with the herbicide Triclopyr 480.

2.1.12 Xanthium strumarium L.

Brief description

Also known as common cocklebur, is an invasive plant species that has been causing significant ecological problems in the Danube Delta Biosphere Reserve. Originally from North America, this plant was introduced to Europe in the 18th century as a garden plant, but has since spread rapidly throughout the continent and beyond, becoming one of the most widespread invasive species in the world.

The plant thrives in disturbed habitats such as roadsides, fields, and riverbanks, where it outcompetes native vegetation and reduces biodiversity. Its large, spiny burrs are also a nuisance to animals and humans, as they can become entangled in fur and clothing, causing injury and irritation.

Xanthium strumarium is an invasive plant species that has successfully adapted to various environmental conditions, allowing it to spread rapidly across different regions. The plant is highly tolerant to drought, salinity, and low nutrient levels, making it able to thrive in disturbed habitats such as roadsides, fields, and riverbanks.

Results of the two-year monitoring

In the Danube Delta Biosphere Reserve, *Xanthium strumarium* poses a significant threat to the unique wetland ecosystem, which is home to numerous rare and endangered species. The plant can grow up to two meters in height, forming dense stands that shade out other plants and alter the microclimate of the area. This can lead to changes in soil moisture, nutrient availability, and the composition of the plant community, ultimately affecting the food web and ecosystem functions.

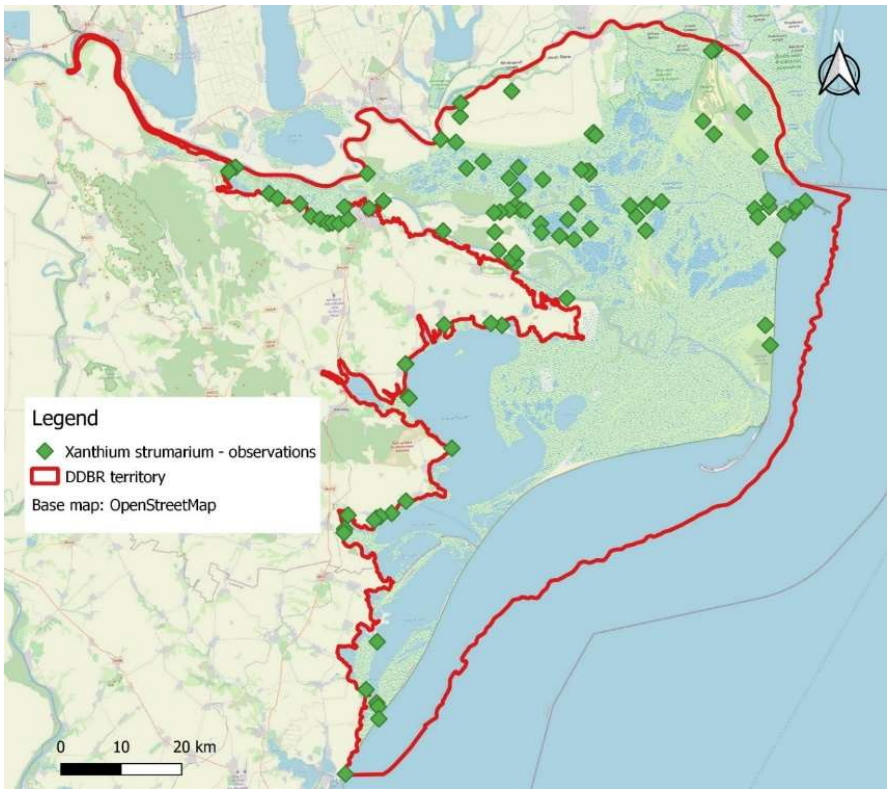

Fig. 16.*Xanthium strumarium*– monitoring observation points in Danube Delta (Romania)

Distribution trend

The species is slowly and steadily expanding its range.

In the Danube Delta, *Xanthium strumarium* can be found growing in disturbed areas such as roadsides, agricultural fields, and waste areas. It is a hardy plant that can tolerate a wide range of soil and moisture conditions, and it is well adapted to the local climate.

It reproduces by producing numerous seeds that can remain viable in the soil for several years, even under adverse conditions. The plant can spread rapidly if left unchecked, as each plant can produce hundreds of seeds that can be easily transported by animals, wind, or human activities. Additionally, *Xanthium strumarium* can also produce vegetative shoots that can develop into new plants.

Estimated damage to the deltaic territory

In the Danube Delta Biosphere Reserve, *Xanthium strumarium* poses a significant threat to the unique wetland ecosystem, which is home to numerous rare and endangered species. The plant can grow up to two meters in height, forming dense stands that shade out other plants and alter the microclimate of the area. This can lead to changes in soil moisture, nutrient availability, and the composition of the plant community, ultimately affecting the food web and ecosystem functions.

Possible management

Efforts to control the spread of *Xanthium strumarium* require a comprehensive approach that includes prevention, early detection, and rapid response. Preventative measures such as monitoring and regulation of the trade of ornamental plants can help to limit the introduction of new invasive species. Early detection of *Xanthium strumarium* is also crucial to prevent its establishment and spread. Rapid response strategies such as mechanical removal, herbicide treatment, and biological control can be effective in controlling the spread of the plant, but in the allowed special regulations of DDBR.

2.1.13 *Elodea nuttalli* (Planch.) H.St. John, 1920

Brief description

Also known as Western Waterweed, is an aquatic plant species that has been introduced to many aquatic ecosystems around the world. It is an invasive aquatic plant species that has been as well introduced to the Danube Delta Biosphere Reserve. Originally native to North America, it was brought to Europe as an ornamental plant in the aquariums, but has since become a nuisance in many aquatic ecosystems. The plant has spread rapidly in the Delta due to its ability to reproduce both sexually and asexually, producing large amounts of vegetative fragments that can quickly establish new populations.

This species has a range of environmental and ecological preferences that contribute to its success as an invasive species.

Results of the two-year monitoring

Overall, the spread of *Elodea nuttalli* in the Danube Delta Biosphere Reserve highlights the importance of preventing the introduction and spread of invasive species in aquatic ecosystems. The most affected are the lakes directly connected to main branches of Danube Rivers, rich in nutrients as water quality. The introduction of *Elodea nuttalli* to the Danube Delta has had significant ecological and environmental impacts. The dense growth of this species can outcompete native vegetation, reducing biodiversity and altering the structure and function of the ecosystem. It can also interfere with water flow and nutrient cycling, leading to changes in water quality and potentially affecting other aquatic species.

Distribution trend (Romanian part)

The species is slowly and steadily expanding its range.

Elodea nuttalli is well adapted to the environmental conditions found in the Danube Delta Biosphere Reserve. It prefers shallow, nutrient-rich waters with moderate to high levels of light, and can tolerate a wide range of water temperatures and salinities. The plant can also survive in low oxygen conditions, allowing it to outcompete other aquatic species that may be less tolerant of these conditions.

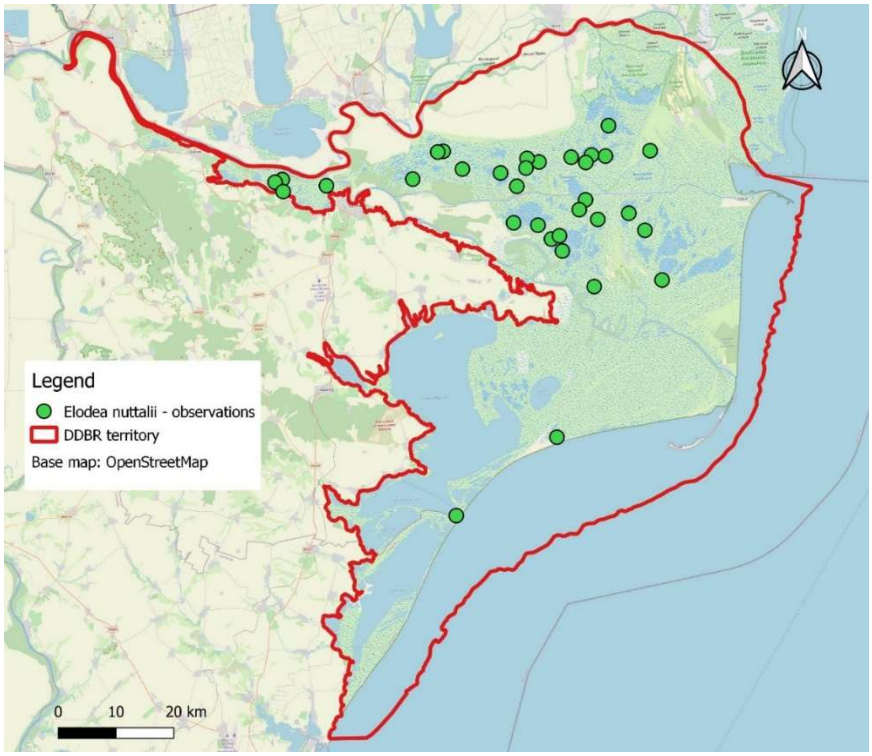

Fig. 17. *Elodea canadensis* – monitoring observation points in Danube Delta (Romania)

Distribution trend (Ukrainian Part)

Elodea canadensis have a high invasive potential, which contributes to their expansion in all types of reservoirs of Ukraine. It is very adaptable and has can spread under a wide range of conditions and nutrient concentrations. This species requires constant monitoring and, under a combination of favorable conditions, can show its high life potential in the Danube Delta.

When comparing the results of field studies in 2021 and 2022, it was found that the population of the model invasive species *Elodea canadensis* Michx. met at different stations. In 2021 in the area of the Danube-Sasyk Canal (st. 13) and Buzunchuk Bay (06.10.2021), in 2022 in the area of the Ochakovsky Mouth (st. 1) and the «Pelican» base (st. 15) (09.11.2022). In 2021, in the area near the Danube-Sasyk Canal (st. 13), the biomass of *E. canadensis* was an order of magnitude higher compared to 2022.The maximum value of biomass for the entire period of the study of *Elodea canadensis* Michx. was recorded at station st.13 in June 2021 and amounted to 0.726 kg m^{-2}. In 2022 for Elodea canadensis Michx. an average decrease in biomass was recorded

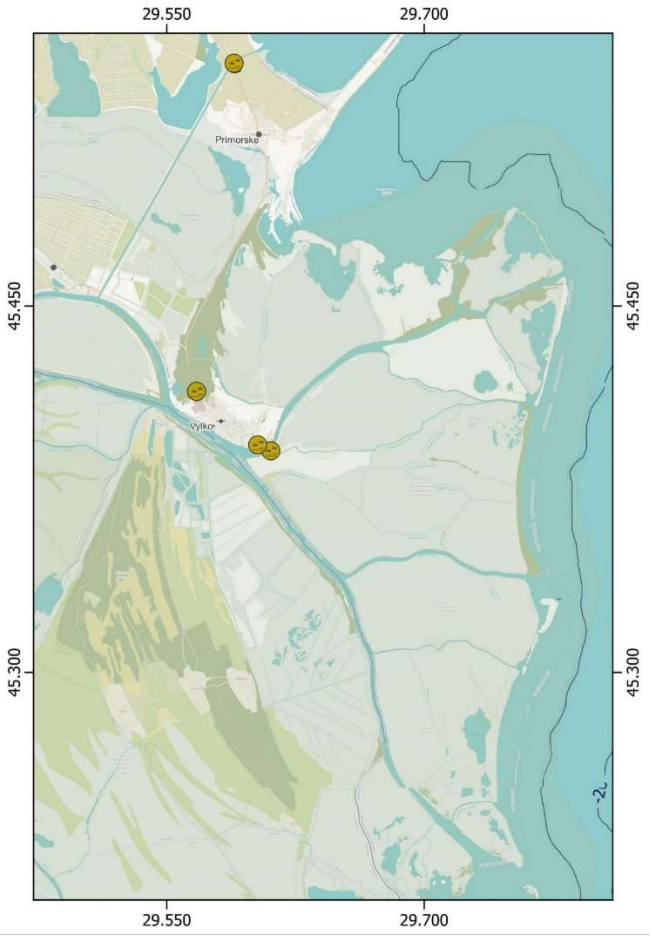

Fig.18 .*Elodea canadensis* – monitoring observation points in Danube Delta (Ukraine)

Estimated damage to the deltaic territory

The introduction of *Elodea nuttalli* to the Danube Delta has had significant ecological and environmental impacts. The dense growth of this species can outcompete native vegetation, reducing biodiversity and altering the structure and function of the ecosystem. It can also interfere with water flow and nutrient cycling, leading to changes in water quality and potentially impacting other aquatic species.

Possible management

Effective management strategies, including early detection and rapid response to new populations, can help to minimize the impacts of invasive species and protect the ecological integrity of these important habitats, therefore monitoring of this specie is crucial.

The penetration of *Elodea canadensis* can lead to significant changes in the aquatic ecosystem, for example, to a decrease in species diversity, accelerated nutrient cycling, eutrophication, so it

is important to monitor the emergence of new habitats in aquatic ecosystems and determine their status. The greatest danger is the increase in the intensity of the autotrophic process, which destroys the trophic relationships of the aquatic ecosystem. Particular attention and control over this species must be carried out in places with low water exchange. The clearing of "eriks" (channels) vegetation and the creation of high flow can be considered as management measures aimed at curbing the spread of the dangerous invader "water plague".

2.2. FAUNA

2.2.1 Canis aureus L., 1758

Brief description

Canis aureus appeared in Ukraine in 1997–1998 in the Dniester and Danube deltas. The reason for the appearance of this species in the Danube Delta is the expansion of its range. The range of the species covers the Balkan and Arabian peninsulas, Turkey and almost all of South-West Asia. In the last 20 years, the species has been actively spreading to the territory of Eastern Europe. The status of the species in Ukraine has not been fully determined, however, the species behaves as an invasive species in places of settlement.

Canis aureus is a social omnivorous predator. The species has a very wide spectrum of nutrition: plant food, fish, amphibians, reptiles, birds and their eggs, rodents, hares, ungulates, etc. During research in the Danube Delta, eating jellyfish thrown ashore was also recorded.

Canis aureus inhabits various ecosystems, but in Ukraine it prefers wetland ecosystems.

After the expansion to the territory of Ukraine, the species created numerous local populations here. Canis aureus has been observed throughout the territory of the Ukrainian part of the Danube Delta, where it exerts a predatory influence, competes with native species for food and

habitat, destroys bird nests, and is involved in the circulation of dangerous pathogens, including rabies.

Results of the two-year monitoring (fig. 6)

The results of research showed a wide distribution of C. aureus in the ecosystems of the Danube. In the Danube Biosphere Reserve, this species significantly outnumbers other species of predatory mammals, which are similar in size: Vulpes vulpes, Melesmeles and the invasive Nyctereutes procyonoides. *Canis aureus* penetrates into all ecosystems of the Danube delta. Facts of predatory influence on aboriginal species, primarily colonial settlements of birds on sand spits, have been revealed. Registered cases of rabies among *C. aureus* in southern Ukraine.

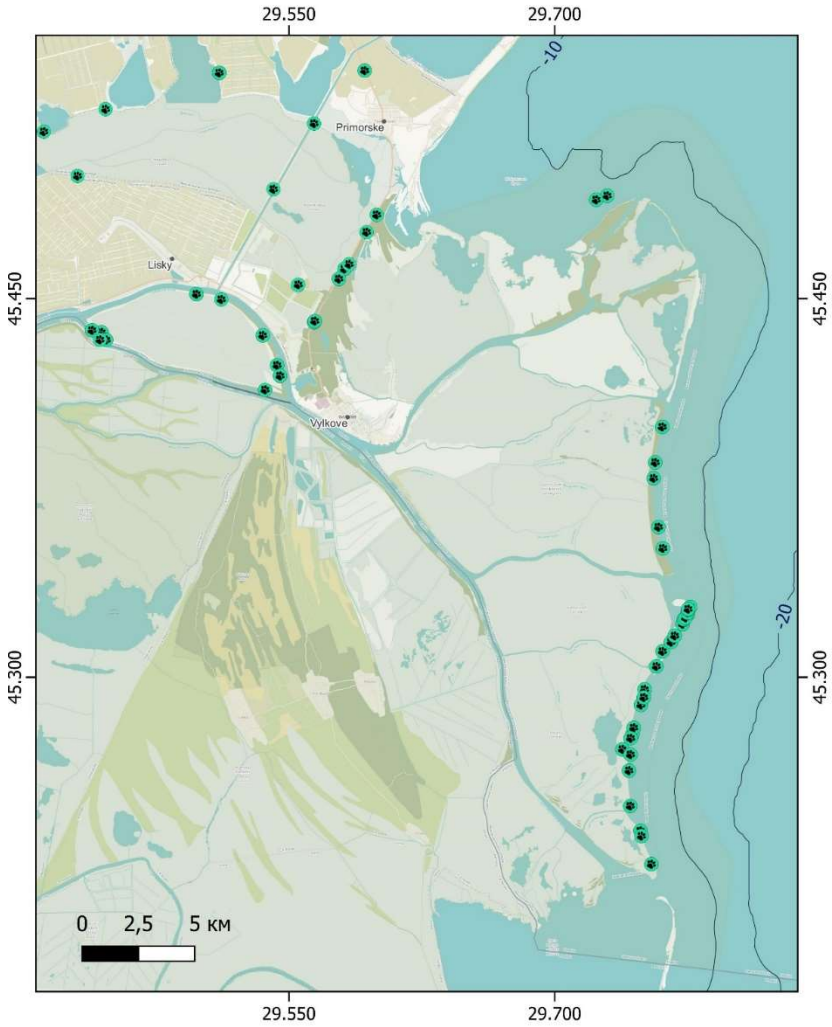

Fig. 19. Canis aureus – monitoring observation points in Danube Delta (Ukraine)

Distribution trend

The species is aggressively expanding its range.

Estimated damage to the deltaic territory

The most important factor influencing C. aureus on the ecosystems of the Danube Delta is predation. First of all, important bird colonies of the wetland complex suffer from such an impact. Another factor is the participation of this species in the circulation of rabies, which can lead to the formation of local foci of infection. C. aureus can attack farm birds and animals and thus cause harm to the local population.

Possible management

Expansion of the range of a species is a natural process. Regulation of the number of species on the territory of the Danube Biosphere Reserve is impossible according to legislation. In the adjacent territories, since 2021, regulation is impossible due to martial law. A mitigation strategy for the species should be to adapt urbanized and natural ecosystems to the presence of C. aureus. This may include isolating important breeding colonies of birds, immunizing C. aureus against rabies, and changing the conditions of farm animals to account for the presence of this species. Further monitoring of the population and distribution of this species is important work.

2.2.2 Leptinotarsa decemlineata Say, 1824

Brief description

Currently, the Colorado potato beetle, is distributed widely throughout North America east of the Rockies as well as some of Europe and Asia. Its distribution covers about 8 million km² in the Nearctic Region and about 6 million km² in the Palearctic and Oriental regions. Originally, Leptinotarsa decemlineata was found in the southwestern United States into Mexico. As potatoes were extensively planted for agriculture, the species spread into agricultural areas throughout North America, Europe, and Asia. It is predicted that *Leptinotarsa decemlineata* could occupy other regions including Korea, Japan, parts of Africa, and most of the temperate Southern Hemisphere

Results of the two-year monitoring

The Colorado potato beetle is found mostly in farm fields that specialize in growing agricultural crops in the family Solanaceae, such as potatoes, tomatoes, tobacco, eggplants and peppers. It can also be found on non-agricultural solanaceous plants in open grassland areas.

Distribution trend

The invasive species with constant presence

Estimated damage to the deltaic territory

Leptinotarsa decemlineata is a species generally associated with agricultural crops. However, there are situations, it is true, rarer, in which the species has been observed colonizing some uncultivated areas. In recent years, farmers have noticed a diversification of the trophic spectrum of the species - if the larval form, in particular, or the adults were observed attacking potato plants, lately attacks have also been observed on other cultivated plants of the Solanaceae family - pepper, tomato or bruise. In the Danube Delta, the presence and distribution of the species Leptinotarsa decemlineata followed this trend, but it was observed exclusively in the cultivated areas inside or in the immediate vicinity of the localities.

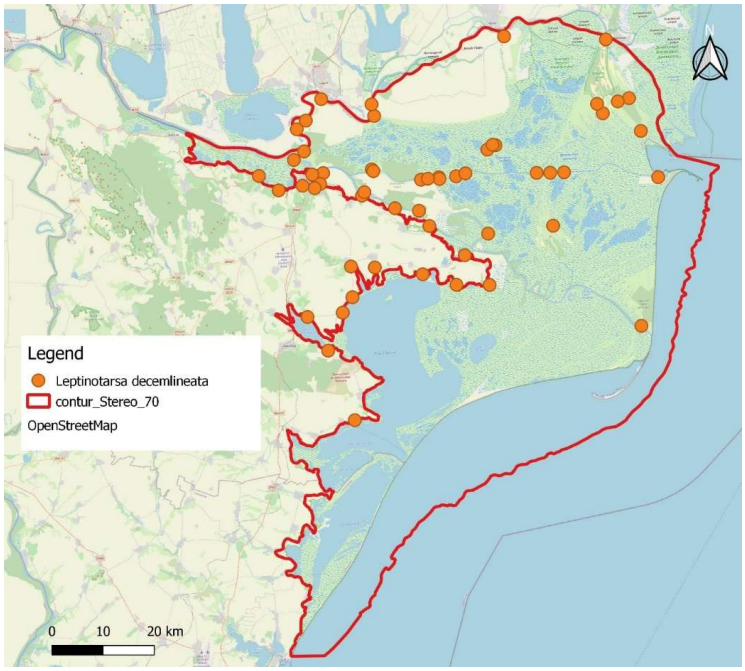

Fig. 20. *Leptinotarsa decemlineata*– monitoring observation points in Danube Delta (Romania)

Possible management

Management measures that can be used to control the Colorado potato beetle:

- Crop rotation: Rotate potato crops with non-solanaceous crops to reduce the beetle population. This will also reduce the buildup of potato pathogens in the soil.
- Biological control: Encourage natural enemies of the Colorado potato beetle such as ladybugs, ground beetles, and parasitic wasps. Introducing predatory nematodes can also be effective in controlling beetle larvae.
- Insecticides: Use insecticides that are specifically labeled for Colorado potato beetle control. The use of insecticides should be done with caution to avoid the development of resistance in the beetle population.
- Cultural control: Handpicking adult beetles and larvae can be an effective way to control the population. Place a cloth or plastic sheet underneath plants and shake them to dislodge the beetles. This can be done in the morning or evening when the beetles are less active.
- Monitoring: Regular monitoring of potato plants for signs of damage and beetle presence can help in early detection of the beetle population and in taking timely management actions.

It is important to note that a combination of these measures should be used for effective management of the Colorado potato beetle.

2.2.3 Perccottus glenii Dybowski, 1877

Brief description

The natural distribution range of P. *glenii* is situated in the Russian Far East (Amur Region, Southern Khabarovsk Territory, Primorski Krai, north-west of Sakhalin Region), in north-eastern China and in the north of Northern. A large part of natural distribution range of rotan includes Amur River basin, where rotan inhabits most flood plain water bodies of this river and its tributaries, among them large tributaries, such as Zeya, Sungari and Ussuri. In the north distribution range of rotan reaches basin of Tugur River. In the south from the Amur drainage, rotan is known from rivers of the Sea of Japan including Suifun, Tumen-ula, Liao River, and from the region of Liushung city (former Port Arthur). In the Sunguri Rive r basin, this “goby” (under that name it was known in Harbin) inhabits everywhere preferring, however, stagnant waters or marshes.

In the upper part of the Sunguri River rotan is apparently absent. In the west this fish probably doesnot occur up the Amur River higher than Dzhalinda (Nikolsky, 1956). Reference of V.N. Elovenko (1981) to the discovery of rotan by B. I. Dybowski (1877) in the rivers Onon and Ingoda is not correct. Taranetz (1937) indicates occurrence of rotan in the north-west of Sakhalin, opposite Amur Liman and makes a supposition that historically it had recently crossed the Tatar Strait (Bogutskaya & Naseka, 2002).

Results of the two-year monitoring

In the Danube Delta, Perccottus glenii has become an invasive species and is considered a major threat to the native fish populations. This species is known to have a high reproductive rate, aggressive behavior, and a flexible diet that allows it to compete with and prey on other fish species. It can also tolerate a wide range of environmental conditions, making it adaptable to various habitats in the delta.

P. glenii is characterized by great endurance and ecological plasticity. It can live in bodies of water that freeze through or completely dry out, can live in water with low oxygen content or even in a swamp. Under adverse conditions, it sinks into the mud. *P. glenii* is a voracious predator. It attacks any prey smaller than itself, including individuals of its own species.You can attack fish even with a full stomach. It also feeds on fish roe and carrion.

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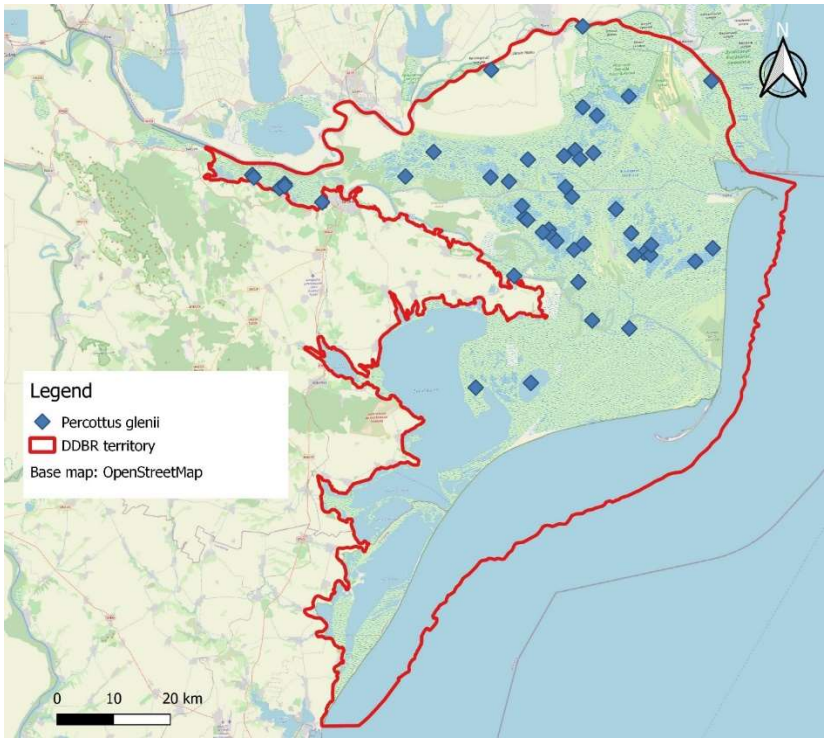

Fig. 21. *Percotus glenii*– monitoring observation points in Danube Delta (Romania)

In the basin of the lower Danube, *P. glenii* occupied a rather narrow specific niche. It lives in shallow, slow-flowing, swampy and overgrown water bodies (channels, backwaters, puddles). At the same time, it often keeps on overgrown silty areas near the very edge of the coast. These biotopes are generally not suitable for the existence of most other fish species, so it has practically no competitors here. *P. glenii* is caught only with specific fine-mesh fishing gear (a dip-net with a mesh of 5 mm and multi-mesh nets, 5-55 mm). P*. glenii* is not caught in commercial fishing gear, and fishermen usually do not even suspect its existence. The length of P. glenii individuals in the Danube Delta usually do not exceed 10 cm. The average weight of fish is 3-5 g. These growth values are significantly lower than the maximum recorded for this species (up to 25 cm), which may indicate the absence of particularly favorable conditions for its existence in the delta.

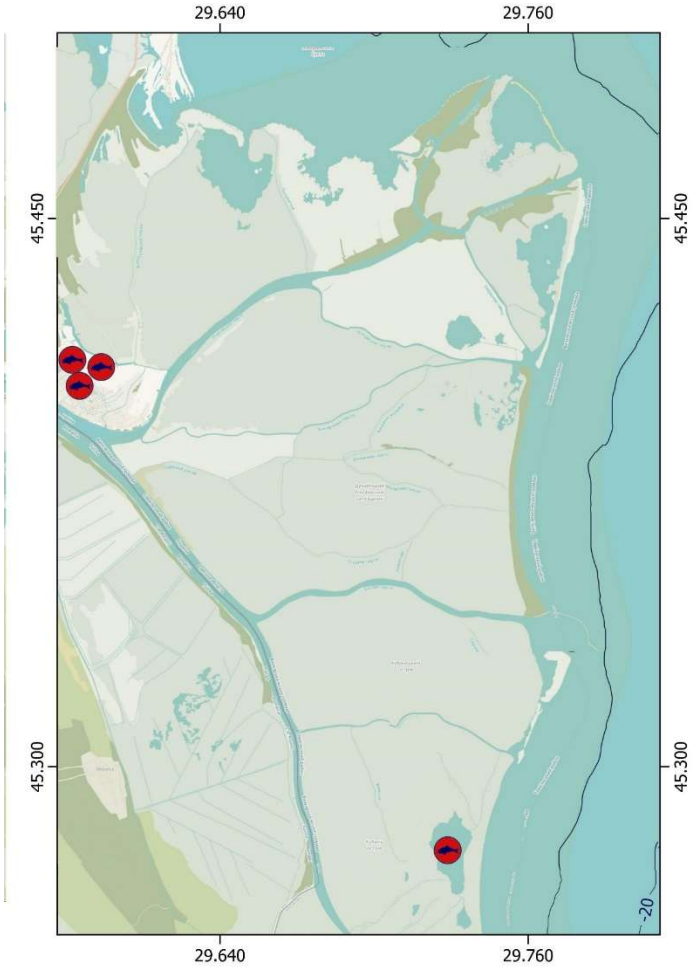

Fig. 22.*Percotus glenii*– monitoring observation points in Danube Delta (Ukraine)

Distribution trend

The species is aggressively expanding its range.

No dangerous trend in the abundance of P. gleniihas been observed in recent years in the Ukrainian section of the Danube. The frequency of occurrence of this species in 2021-2022 remained at the same low level.

Estimated damage to the deltaic territory

The presence of Perccottus glenii in the Danube Delta has caused concerns among conservationists and fisheries managers, who are working to control and eradicate this invasive species. Various methods, such as trapping, electrofishing, and the use of chemical agents, have been employed to reduce their numbers. However, the effectiveness of these measures is limited, and there is a need for continuous monitoring and management to prevent the further spread of this invasive species.

Possible management

The management of Perccottus glenii in the Danube Delta and other areas where it has become invasive, is a challenging task that requires a multi-faceted approach.

some possible management strategies that can be employed:

- Prevention: The best way to manage invasive species is to prevent their introduction in the first place. This can be done through measures such as controlling ballast water discharge from ships and monitoring the import and trade of live fish.
- Early detection and rapid response: Early detection of Perccottus glenii populations is critical to prevent their establishment and spread. This can be achieved through regular monitoring of the water bodies where they are likely to occur, and prompt action can be taken to remove or control them when they are detected.
- Control methods: Various methods can be employed to control or eradicate Perccottus glenii populations, including trapping, electrofishing, and the use of chemical agents. These methods should be used in combination and adapted to the specific conditions and constraints of each site.
- Public awareness and education: Raising public awareness about the negative impacts of invasive species and how to prevent their introduction and spread is essential. Education and outreach programs can also help to engage stakeholders and build support for management efforts.
- Research and monitoring: Research and monitoring are critical to understand the biology and ecology of Perccottus glenii and to evaluate the effectiveness of management strategies. This can inform adaptive management approaches and help to refine management efforts over time.

Overall, the management of *Perccottus glenii* in the Danube Delta and other areas requires a coordinated effort and collaboration among multiple stakeholders, including researchers, managers, policymakers, and local communities.

2.2.4 Carassius gibelio (Bloch, 1782)

Brief description

Prussian carp is one of the most invasive freshwater fish species in the Deltaic aquatic environment. They produce thousands of eggs and can tolerate low dissolved oxygen. Carassius gibelio cause environmental damage by leading quantitative changes in the communities. They became the dominant species and shifted food chain by altering physico-chemical properties of the environment and by altering available food sources. Prussian carp have been also responsible for degradation and alteration of habitat quality by disturbing sediment during foraging, furthering declines in native fish species. Differences in the abundance of native species before

and after Prussian carp invasion demonstrated significant declines in the abundance of native species

Results of the two-year monitoring in the In Kızılırmak Delta, Turkiye

In Kızılırmak Delta case for instance, total landed *C. gibelio* is at least three times more than any other fish species. Moreover, *C. gibelio* is threatening local fish species. Some of the native fish species in the Delta such as the rudd (*Scardinius erythrophthalmus*) is eradicated after *C. gibelio* invasion. Even though C. gibelio is edible, it is not preferred as a food sources in Turkey for being small in size and for being bony which makes it harder to control their invasion.

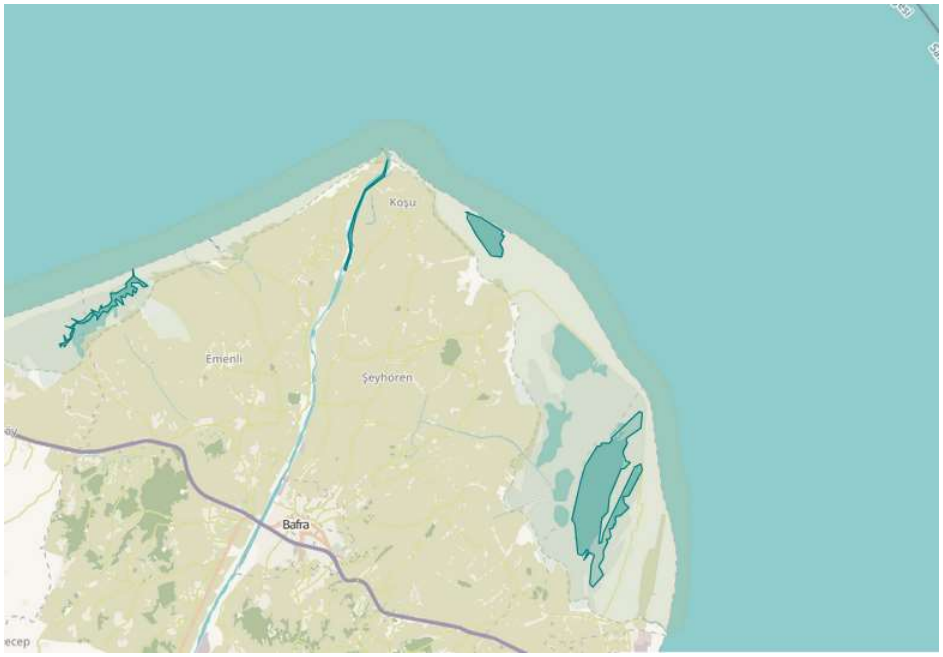

Fig. 23. *Carassius gibelio* – monitoring observation points in Kızılırmak Delta (Turkiye)

Distribution trend

Aggressively expanding

Possible management

At the beginning of the project, there was no management plan to reduce or a new plan to use of this species. Lately, the government and the Authority of the protected area have been a management plan to reduce this species the decrease the pressure on the native species. They have been distributing the net for catching this species and they have been buying from fishermen to motivate catching.

2.2.5 Mosquito fishes (Gambusia holbrooki (Girard, 1859); Gambusia affinis(Baird and Girard, 1853)

Brief description

These species are native to Central and North America. The main diet of these species are pelagic eggs and larvae including insect eggs and larvae. Thus, this species have been introduced worldwide mainly as biocontrol agents against mosquitos and have become an invasive species in many places including Kızılırmak river and Kızılırmak Delta (Ugurlu ve Polat, 2007; Kurtul and Sarı, 2019). These species are mainly aggregated in slow-flowing vegetated shallow waters where most of the insect species choose to lay eggs. Mosquito fish can tolerate temperature, pH, and chemical stressors far beyond most of the other fish species (Pyke, 2005). Invasion of the mosquito fish species dates back almost a hundred years ago and believed to be one of the earliest introduced exotic fish species in Turkey (İnnal and Erk'akan, 2006; Kurtul ve Sarı, 2019).

Results of the two-year monitoring in the In Kızılırmak Delta, Turkiye

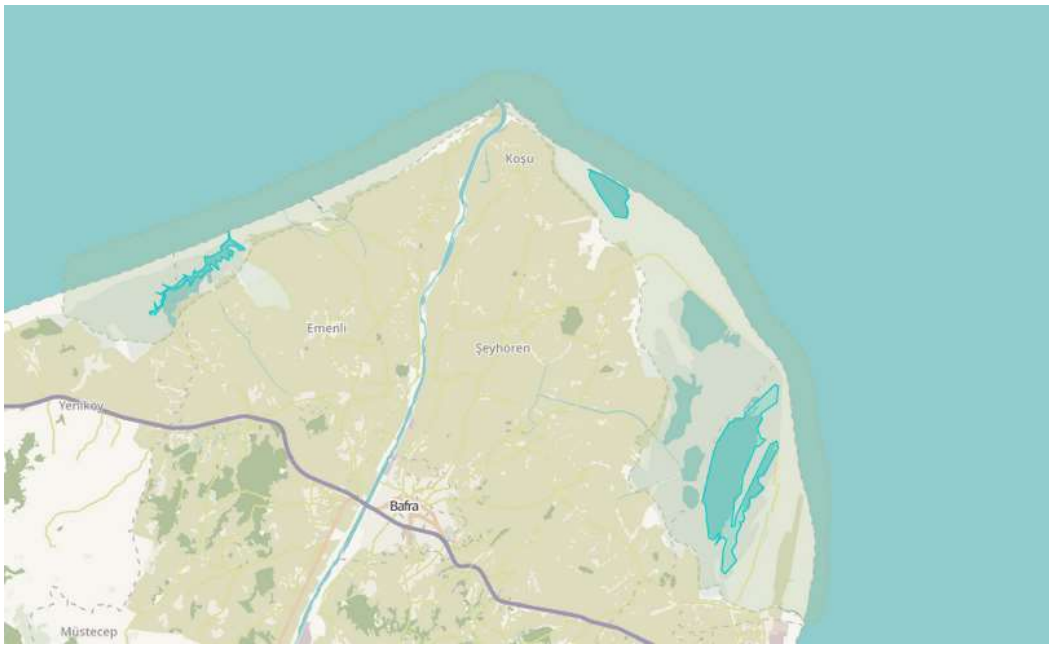

Fig. 24. Mosquito fishes – monitoring observation points in Kızılırmak Delta (Turkiye)

Distribution trend

Aggressively expanding

Estimated damage to the deltaic ecosystems

Mosquito fish have the ability to produce swiftly under different environmental conditions. Despite being only couple cm long, it is listed under 100 worst invasive species. They pose great threat to existence of various aquatic organisms that produce pelagic eggs and larvae.

Possible management (added probable proposal of new research or experimentat

There is no management plan to reduce the mosquito fish population in the delta aquatic environment. This species is still using as a biological control agent in 2022. Because of very small and still useful for mosquito control, there is no management plan to reduce their population.

2.2.5 Pseudorasbora parva

Brief description

Pseudorasbora parva originates from the East Asian subregion. *P. parva* typically is found most abundantly in small, vegetated water bodies, but its ability to tolerate a broad spectrum of

environmental conditions also. The species can survive in wide climate range where temperatures can range from 5 to 22ºC. *P. parva* has early maturity, batch spawning, nest guarding, and broad environmental tolerance limits to establish sustainable populations after being introduced into new environments . *P. parva* life history traits are also highly plastic which facilitates the species' adaptation to new environments and changing conditions.

Pseudorasbora parva is an omnivore whose diet generally includes zooplankton, micro-crustaceans, molluscs, fish eggs and larvae, algae, and plant detritus. Pseudorasbora parva will also feed opportunistically on floating objects such as plant seeds and terrestrial insects. Small age-0 individuals feed predominantly on zooplankton and phytoplankton and can shift their diet to chironomids and other benthic organisms as they get older and larger.

Distribution trend

Due to its high reproductivity, adaptability, and competitive abilities, Pseudorasbora parva is one of the most (or the most) dominant species in fish assemblages where it is established.

Estimated damage to the deltaic ecosystems

P. parva poses a threat to commercial and recreational fisheries. Pseudorasbora parva may outcompete native prey species and carry pathogens/parasites that are known to affect salmonids and Northern pike. P. parva has at least 84 documented parasite species. *Pseudorasbora parva* is considered a major threat to the sea bass aquaculture industry in Europe.

Results of the two-year monitoring in the In Kızılırmak Delta, Turkiye

Fig. 25. *Pseudorasbora parva* – monitoring observation points in Kızılırmak Delta (Turkiye)

Possible management

P. parva was not a chosen species at the beginning of the project. After an investigation into the delta and scientific expert advice, this species entered our IAS list for the delta. And the results demonstrated that these species is a very big threat and the impact will increase in the time being. There is no management plan to reduce P. parva population in the delta.

2.2.6 Rapana venosa (Valenciennes, 1846)

Brief description

Rapana venosa is a successful invader because of high fecundity, early sexual maturity, fast growth rate, and broad tolerance to salinity temperatures and pollution. The Rapa whelk is native to the Sea of Japan, Yellow Sea, East China Sea and the Bohai Sea. It was accidentally introduced into the Black Sea in 1946 with the first record from Novorossiysk Bay. Its distribution range extended to the northwest Black Sea to the coastlines of Romania, Bulgaria, and Turkey from 1959 to 1972.

Project funded by
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Results of the two-year monitoring in the In Kızılırmak Delta, Turkiye

Rapana venosa is a successful invader because of high fecundity, early sexual maturity, fast growth rate, and broad tolerance to salinity temperatures and pollution. The Rapa whelk is native to the Sea of Japan, Yellow Sea, East China Sea and the Bohai Sea. It was accidentally introduced into the Black Sea in 1946 with the first record from Novorossiysk Bay. Its distribution range extended to the northwest Black Sea to the coastlines of Romania, Bulgaria, and Turkey from 1959 to 1972.

Distribution trend

Its establishment in the Black Sea appeared to be facilitated by the general lack of competition from other predatory gastropods and an abundance of potential prey species. Rapa whelk caused significant damage due to no predators in the Black Sea.

Estimated damage to the deltaic ecosystems

*R.venosa i*s a voracious predator with a preference for mussels, oysters and other bivalves. Diet preference of Rapa whelk is bivalve mollusk including Chamelea gallina, Gouldia minima, and Pitar rudis. It affects ecosystem services primarily through its negative impacts on mussel, oyster beds, and native benthos.
Some native bivalve species including Ostrea edulis, Pecten ponticus, and Mytilus galloprovincialis, on the Gudaut were near extinction due to predation by Rapa whelk.
Rapa whelk is a commercially important invasive species in the Black Sea. Rapana fishery has developed and the revenue is €15 million. The indirect ecologic impact of Rapana on benthic ecosystem is rapana fishery. Rapa whelk is harvested by dredge and beam trawls in Turkey. Dredges are harmful to the bottom habitat and the biodiversity due to high by-catch rates

(Saglam and Duzgunes, 2014). This species has a positive impact on the socio-economical life of the fishermen's communities. The species support artisanal fisheries as an important income source since 1980s.

Fig. 26. *Rapana venosa* – monitoring observation points in Kızılırmak Delta (Turkiye)

Possible management

R. venosa became a commercial species in the deltaic area since 1980. The population of this species is under fishing pressure. There are eight whelk processing plants and most of them are located in Samsun and Sinop. Due to no domestic consumption in Turkey, all the production is exported as frozen meat to Asian countries. It provided foreign currency of about 15 million euros in 2013. Not only exported meat of rapa whelk but also its shell and operculum are exported to foreign countries especially Japan, Kore, China, Thailand, US, France, etc.

2.2.7 Corbicula leana Prime, 1867

Brief description

The bivalve fresh water mollusc is native to Southeast Asia. Due to its high ecological plasticity and the ability to quickly colonize new water areas, it has become a widespread invasive species in the world, including the Danube Delta.

Corbicula colonizes various types of substrate, but the most suitable bottom sediments for its settlement ares and mixed with silt and clay. This species is characterized by early maturity, high fecundity, hermaphrodite type of reproduction, high growth rates, and the ability to spread rapidly, which makes it highly invasive and adapted to life in unstable, disturbed habitats. High reproductive potential and high growth rate contribute to the rapid growth of density in the new environment. Due to the peculiarities of its life cycle, the species is able to recover from a catastrophic drop in population density, even if it has been reduced to one individual. It is widely distributed in drainage systems subject to anthropogenic pressure such as, dredging, organic or chemical pollution.

At the same time, it is sensitive to changes in environmental factors such as water temperature oxygen content, pH, and nutrient concentration. Under conditions of low pH values, the mortality rate of the mollusk increases, the low content of dissolved oxygen inhibits its growth, hightemperaturescausemassdeathandweightloss, and low temperatures limitits colonization in the invasive area.

Corbicula is an active seston feeder, characterized by high filtration capacity, filters out phytoplankton and other particles in the water, which are an important food source of other organisms, but can also feed on organicm at sandy or muddy bottom.

Results of the two-year monitoring

Features of biology and ecology contributed to the wide distribution of the species in the Danube Biosphere Reserve. Monitoring should be constantly carried out, assessment of the risks of

spread, in forming the society about the risks of introduction and possible consequences and changes in the functioning of ecosystems. Given the characteristics of the life cycle and ecology of Corbicula, efforts should be directed to contain and preventits spread.

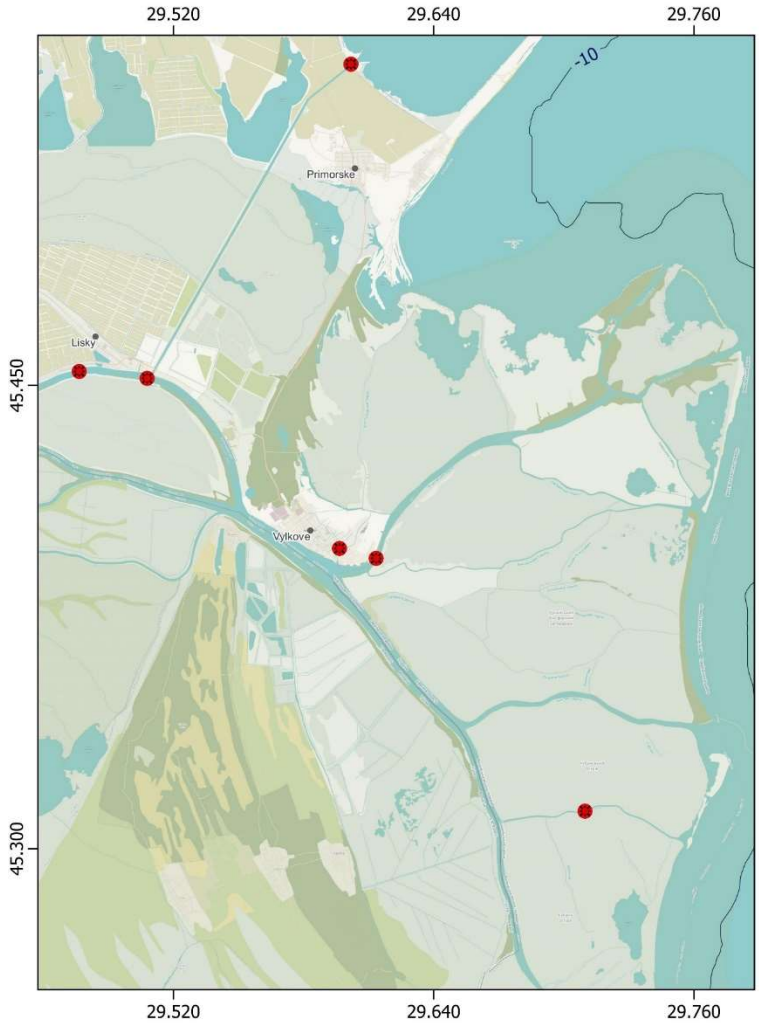


Fig. 27. *Corbicula leana*– monitoring observation points in Danube Delta (Ukraine)

Estimated damage to the deltaic territory

A negative consequence of the introduction of t6he species can be a decrease in the indices of the abundance of plankton, the productivityof the reservoir, the transformation of the biotope, and a change in the structure and diversity of the ecosystem.

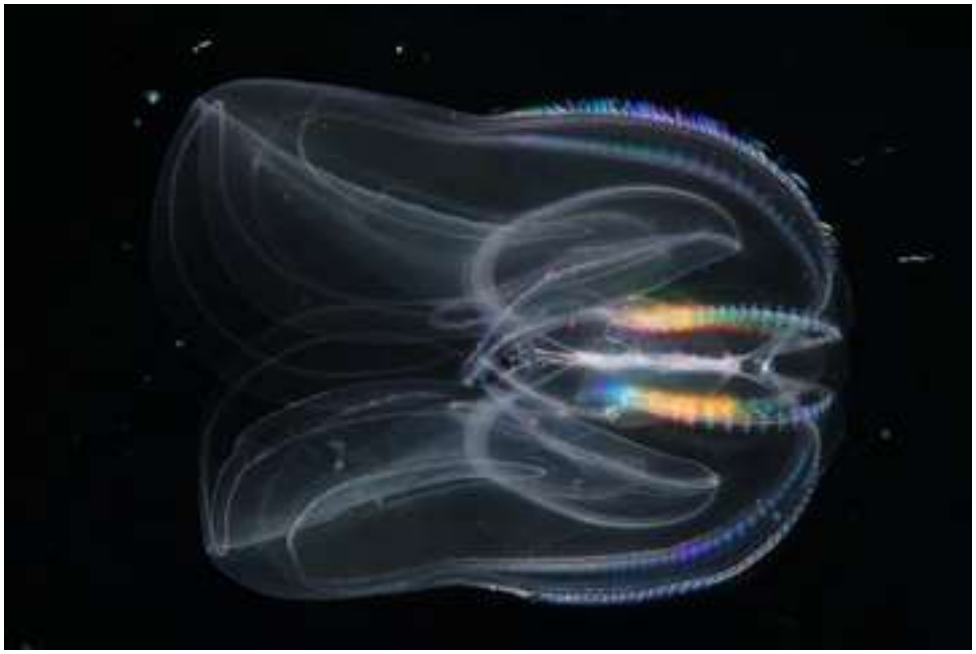
Possible management

As a preventive measure, it is necessary to monitor and assess the risks of further introductions. Given the characteristics of the life cycle and ecology of it, efforts should be directed to contain and prevent its spread.

2.2.8 Mnemiopsis leidyi (Agassiz, 1865)

Brief description

M. leidyi is characterized by the presence of two large mobile lobes referred to as lateral or oral lobes). The oral lobes are derivatives of the ctenophore body (spherosome). Four smaller lobes are situated under the two principal oral lobes. Closing over one another by their distal edges, they completely envelop the mouth area of the animal
Under the oral lobes, four smaller lobes are located called auricles. When oral lobes are closed, they completely cover the auricles. At the oral edge of the body, on either flattened side, there is a tentacular apparatus. The central part of the tentacular apparatus is located above the lip of the slit-like mouth. Right and left of the tentacular bulb, fascicles of thin tentacles extend over the sides of the body following special deep grooves. Both sides of the long slit-like mouth are bordered with a row of short simple tentacles, which are continuous with those of the deep lateral furrows.



Results of the two-year monitoring in Kızılırmak Delta (Turkiye)

First seen in the Black Sea ecosystem in 1982, M. leidyi has spread to the whole ecosystem as of 1988

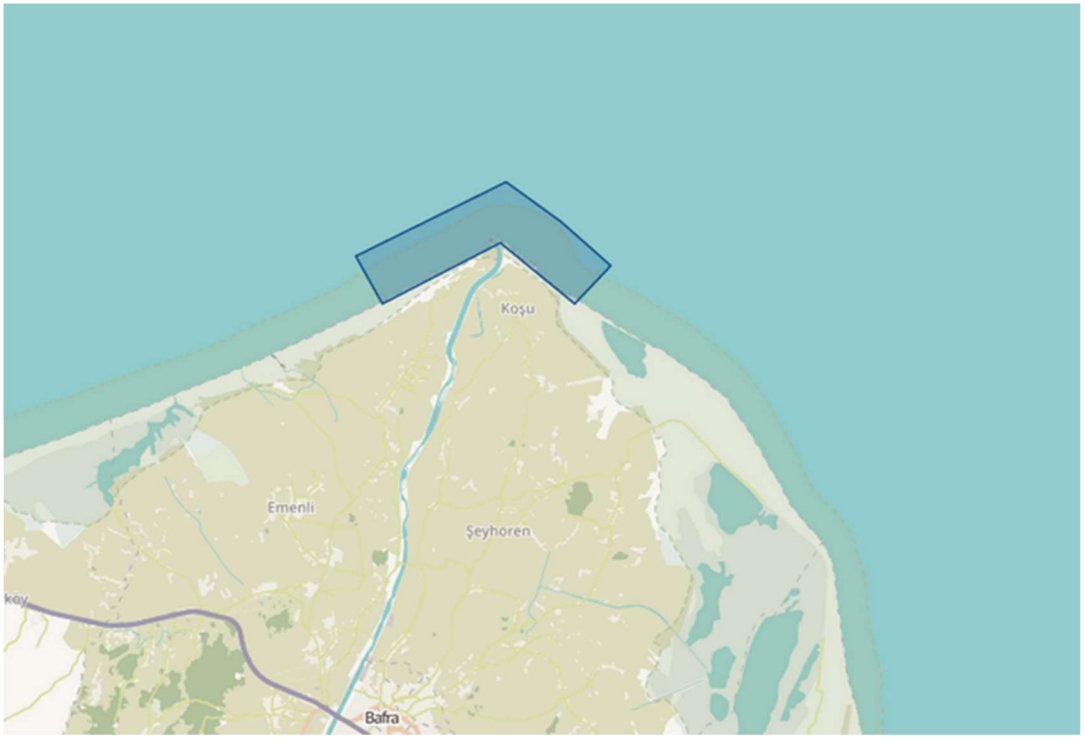


Fig. 28. *Mnemiopsis leidyi* – monitoring observation points in Kızılırmak Delta (Turkiye)

Distribution trend

The entry of the invasive comb jellyfish species from the East coast of the North America into the Black Sea ecosystem is considered one of the most disastrous invasions ever known.

Estimated damage to the deltaic ecosystems

Mnemiopsis leidyi was accidentally introduced to the Black Sea in the early 1980s; within 10 years, it had destroyed the fishing industry in the entire region, outcompeting native planktonic fishes and disrupting the food chain. This species has caused dramatic changes on copepoda group and plankton biodiversity. The feeding ecology and the lack of predator combined with the special oceanographic conditions of the Black Sea have become this species quickly dominant species in pelagic zone. Between the effects of its penetration and adaptation in the Black Sea can be said the extreme reduction of pelagic fish populations. Also *M. leidyi* heavily affect the main components of the pelagic community; mesozooplankton, ichthyoplankton, and fish resources.

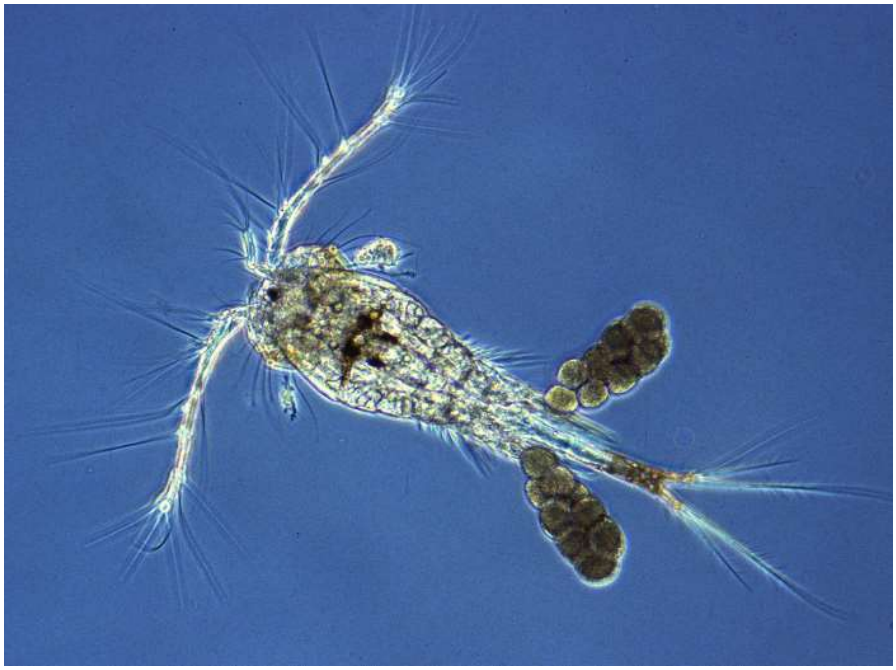
Possible management

There is no specific management plan for reducing *M. leidy* population. But after 15-20 years of this species (ends of the 1980s) being introduced to the Black Sea basin, another species was introduced into the Black Sea Boreo ovata (1997s) that was the only predator of M. leidy. Nowadays the M. leidy population is steady state all around the Black Sea basin.

2.2.9 Oithona davisae Ferrari & Orsi, 1984

Brief description

Oithona davisae became established in the Black Sea ecosystem since the 2000. It was first recorded in Sevastopol Bay in 2000, next it was found only in 2005 and after that it is expanding along the Black Sea coast since 2009. The genetic analyses supported identification of *O. davisae* The small flagellate development in the Black Sea during last years may be a significant driving force contributing to the proliferation of the O. davisae population, especially in the eutrophic inlets.



Oithona davisae reproduce and established self-sustaining populations in their new Black Sea environment with regular occurrence in coastal, shelf, slope and open sea. *Oithona davisae* is the most abundant in the coastal waters up to 30-50 m depth but it was recorded also in the deep waters of the open sea. It occupies own niche in the Black Sea forage zooplankton useful for planktophagous commercial fish species.

Results of the two-year monitoring

Oithona davisae was found during both monitoring years on the stations with high impact of the marine waters. This species can not survive in the fresh water. In transitional and marine waters of the monitoring area it formed the significant part of the forage zooplankton in 2021 and 2022.

It is recommended to continue monitoring observation in order to clarify its role in the forage zooplankton formation in the Danube Delta Biosphere Reserve.

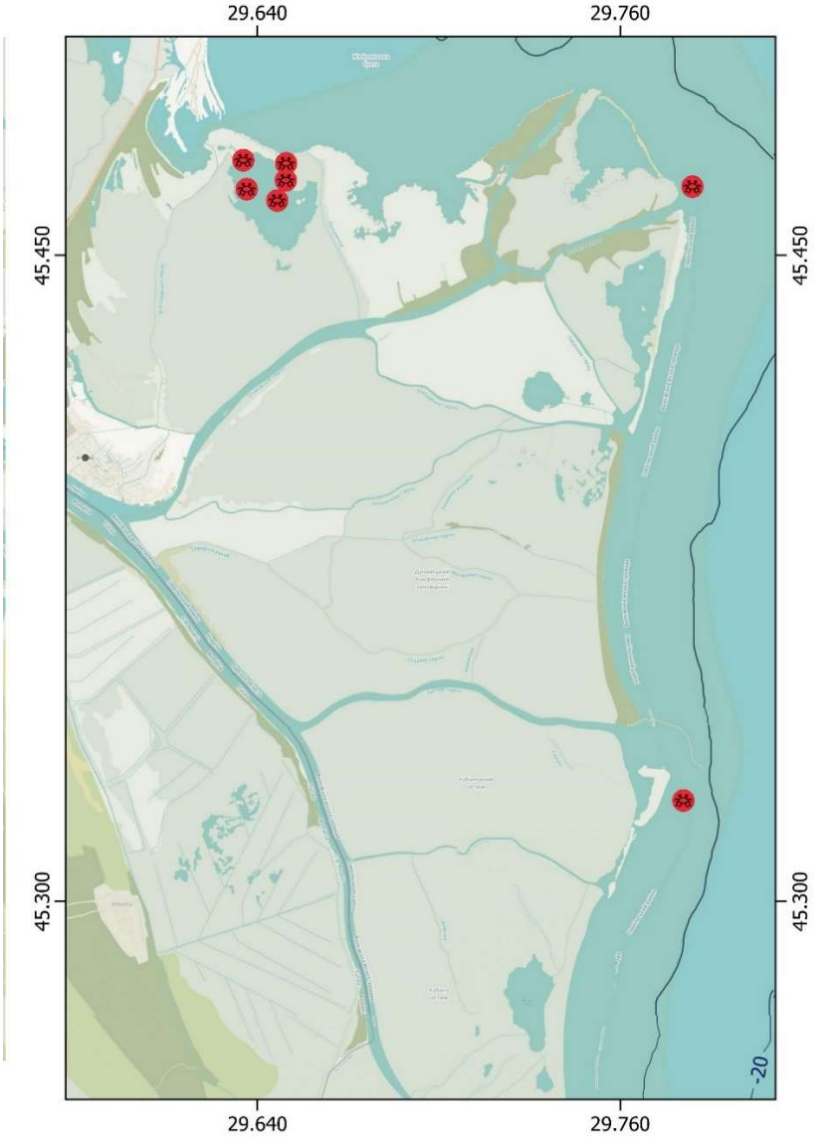


Fig. 29.*Oithona davisae*– monitoring observation points in Danube Delta (Ukraine)

Distribution trend

The species does not change its range in the North-Western part of the Black Sea nowadays.

Estimated damage to the deltaic territory

At present time for *Oithona davisae* have not been reported any negative impact on the ecosystems. This species is a part of forage zooplankton for commercial fishes so plays at least some positive role.

Possible management

It is recommended to continue monitoring observation in order to clarify its role in the forage zooplankton formation in the Danube Delta Biosphere Reserve.