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LITTER POLLUTION IN EVROS DELTA NATIONAL PARK

Litter types and quantities

CURRENT STATE ANALYSIS

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Black Sea CROSS BORDER COOPERATION

Eco-Conscious Minds to Stop Pollution in the Valuable Wetlands of Black Sea Basin

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All photos were provided by the Management Body of Evros Delta and Samothraki Protected Areas and iSea

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Contents

1. Evros Delta wetland

At the southeastern edge of Evros Prefecture, on the border with Turkey, Evros River after flowing through Bulgaria and Turkey, and dividing in two branches, forms an extensive Delta of international ecological importance, covering an area of 188 km^2. The river's mean water supply is estimated at about 100 m^3/sec, which accounts for an extended deposition of sediments in the Evros Delta.

The wetland is an extensive area of fresh and salt water marches, riparian forests, lakes (Nymphon), lagoons (Drana, Paloukia, Laki), irrigation and drainage canals (Sarantametros, Dekametros), wet meadows and sandy islets. It is one of the most important wetlands in Greece and Europe. It maintains a variety of habitats over a relatively small area, several of which are of great importance to the Mediterranean region. It hosts, preserves and protects a big variety of birdlife. It is an important habitat for the wintering, migration and breeding of many rare and endangered species.

1.1. Habitats and vegetation

All the typical formations and vegetation units of a Mediterranean delta are found in Evros. More than 350 species of plants have been recorded both in the delta and in the zone along the river, playing an important role both in the regulation of water resources and in the improvement of the quality of surface and groundwater. A dense forest of poplars, willows, alders, elms and climbing plants is formed along the river. A "flooding zone", located in the northeastern part of the Delta, is covered by dense clusters of tamarisk bushes, while to the south the area is covered by dense reedbeds in freshwater lakes.

In the canals, water lilies are observed and water chestnuts floating, in the meadows, irises and orchids, while on the shores and in the sand dunes plants grow with few requirements of natural resources.

In the Evros Delta, there are 7 characteristic categories of habitats:

- Riverine vegetation
- Tamarisks
- Wet meadows with Juncus
- Submerged vegetation of saline and brackish waters

- Lagoon and fresh water vegetation
- Halophytic vegetation
- Vegetation of sandy islets

The soil, the microclimate, and the prevalence of fresh or salt water are the factors that determine the predominant vegetation that grows in each area.

1.2. Fauna in Evros Delta

The favorable geographical position of the Delta in relation to the migration routes of birds, the rich habitats and the relatively mild climate of the area, as well as the fact that the area is relatively isolated, are decisive factors that create the ideal conditions for the existence of many species of fauna. The Evros Delta is home to 40 species of mammals, 21 species of reptiles, 7 species of amphibians and 46 species of fish. Many of these recorded species are rare and protected by international, European and national conventions and legislations.

More important, however, is the rich bird fauna found in the area. At least 324 species of birds have been recorded in the wetland, out of the 456 found in Greece. Evros Delta is proved to be an important link in the wetlands chain that exists in the wider area and is crucial for the survival of birds. It functions as a nesting and feeding area for many species and a refuge for large populations of waterfowl from northern parts of Central and Eastern Europe during the winter. Large populations of birds, moving from Africa to Europe and vice versa, cross the Delta where they stop to feed and rest in its rich and safe habitats, until they reach their destination.

Migration

Due to its location, Evros Delta is of particular interest in the spring where a large movement of birds is evident. During their journey, migratory birds, which move from Africa to Northern Europe, find a safe and rich in food and water habitat to rest, feed and continue to their breeding sites. This season is usually wet and the temporary fresh water wetlands and shallow lagoons host thousands of waders, such as Black-winged Stilts, plovers, stints, snipes, terns, swallows and many passerines. Other species observed during spring migration are the White Stork, the Black Stork, the White and Dalmatian Pelican, the Garganey, the Ferruginous Duck, the Lesser Spotted Eagle, and the Blackwed Godwit.

Wintering

In winter, Evros Delta shelters thousands of birds that arrive from the north to spend the cold season in milder climate. Areas like the lagoons, the wet meadows and the flooded areas are flooded for several months by water birds. Thousands of ducks are observed that time, the most common of which are the Mallard, the Teal, the Wigeon, the Coot, the Pintail, and the Shoveler. In the same areas, swans are observed (Mute Swan, Whooper Swan and Bewick's Swan). In the meadows, geese are feeding during the whole day; thousands of White-fronted Geese, almost all the natural breeding population of Lesser White-Fronted-Goose, Red-

breasted goose, and Greylag Goose. At the same time of the year, thousands of Flamingos are observed in saltwater areas, Great White Egrets and Grey Herons in all watery areas, along with Avocets, Oystercatchers, Pygmy Cormorants, grebes, pelicans, and sandpipers. Winter is the season with the most species of raptors in the Delta. Tens of eagles such as Spotted Eagles, Imperial Eagles and White-tailed Eagles and smaller raptors, such as Marsh Harriers, Hen Harriers and Buzzards are observed in the wetland.

Breeding

Due to the shrink, drainage and conversion of habitats into agricultural land, there is a significant reduction of breeding species that occur in the wetland. Already by the 1970's, many important species of birds had stopped breeding and, since then, they are only observed during the migration or the summer. Nevertheless, several species of birds continue to find a safe and rich habitat, so that they can breed, such species are: the Cormorant, the Grey Heron, the Purple Heron, the Ruddy Shelduck, the Shelduck, the Mallard, the Short-toed Eagle, the White-tailed Eagle, the Marsh Harrier, the Oystercatcher, the Black-winged Stilt, the Avocet, the Spur-winged Plover, the Kingfisher, the Bee Eater, the Collared Pratincole, and the Little Tern.

1.3. Protection scheme

The importance of Evros Delta has been acknowledged in a series of international and national Conventions, Directives and Laws. Evros Delta:

- is designated as a National Park with the name "National Wetland Park of Evros Delta" by the Joint Ministerial Decision (K.Y.A. 4110/2007, Government Gazette 102 / D / 16.03.2007), which includes measures for the protection of wetlands and natural formations at the mouth of the Evros River and their wider area.

- part of the wetland with a total area of 69,000 acres is a Wildlife Refuge (Government Gazette 674 / B / 1991, as amended by Government Gazette 841 / ΄B / 2001).

- part of the Delta belongs to the European Network of Protected Areas Natura 2000 and has been designated as both a Special Protection Zone for Birds (GR1110006 "Evros Delta", 125,000 acres) and a Special Conservation Zone (GR1110007 "Evros Delta and west arm 99") according to JM 50743/2017 (Government Gazette 4432 / ΄B / 15-12-2017): "Revision of national list of areas of the European Ecological Network Natura 2000", in compliance with Directives 2009/147 / EC ("On wild bird conservation") and 92/43 / EEC ("On the conservation of natural habitats and of wild fauna and flora").
- is included 1 of the 10 Greek wetlands included in the International Ramsar Convention (Ratified by Law 191/1974).
- is protected by Bern Convention on the Conservation of European Wildlife and Natural Habitats.
- is protected by Bonn Convention on the Conservation of Migratory Species of Wild Animals.
- is protected by Barcelona Convention on the Protection of the Mediterranean Sea against Pollution.

1.4. Human activities

Apart from its international ecological importance, the wetland is further supporting the local communities providing a variety of resources and thus, an array of human activities are taking place in the area. Agriculture, animal breeding, and fishing are the main economic activities of the productive sector carried out in the Delta.

Agriculture

Almost half of the Delta is given to agriculture. From that, about 5,000-6,000 Ha are cultivated, mainly with wheat, clover, rice, and cotton. The construction of various flood defense barriers and other drainage works has resulted in soil salinization, due to the infiltration of salt water into large areas of the Evros Delta.

Animal breeding

Wetlands, as a place for grazing farm animals, are particularly valuable and attractive. Evros Delta is also an important grazing ground. The high quality and quantity of available grazing material as well as the possibility of water disposal and easy access to it, compared to other pastures, makes Evros Delta a place where thousands of sheep and cattle graze freely during most of the year.

Fishing

Fishing is carried out in the marine part of the Evros Delta and in rivers and canals, divided into marine and inland waters fishing, respectively. Professional fishers with boats mainly use nets, longlines and reeds, while also recreational fishers are fishing from both land and sea using rods, reins etc. Fishers' catches mainly consist of eels, sea bream, seabass, and mackerel.

Hunting

Another activity that takes place in the wetland is hunting, which due to the relatively large number of aquatic species attracts a large number of hunters from all over Greece. Hunting is allowed in specific part of the wetland and is regulated with temporal restriction, restriction in the hunted species and number of prey.

Ecotourism and recreation

The beaches near Evros Delta estuary are a recreation place among locals. In addition, the great variety of bird species, as well as the natural beauty of this wetland, attract a large number of

visitors. The Management Body of the Evros Delta and Samothraki Protected Areas promotes the place among local and foreign tourists and conducts organized tours throughout the year in the protected area of the Evros Delta.

In addition to ecotourism, its activities include:

- the operation of 2 Visitor Centers
- scientific monitoring
- supervision of the area
- implementation of Environmental Education Projects
- organization of events
- implementation of public awareness projects on wetland protection issues
- coordination of the services and authorities for the protection of the area
- the overall management of the wetland

2. Wetland pollution

Globally, wetlands are among the most productive ecosystems but they are also quite fragile and threatened. According to Xu et al. (2019) the most important threat for wetlands is pollution, followed by the exploitation of their biological resources, the modification of the natural system, agriculture, and aquaculture. Among all types of wetlands, marine and coastal wetlands are the most susceptible to pollution. They are usually located in lower reaches of water courses with all water streams of a basin ending up in them; therefore, this makes them susceptible to contamination from several different pollution sources that may be even distributed in outer areas. The incoming pollution has the potential to accumulate and affect their health in a negative way. The primary sources of wetland pollution are agricultural and industrial/municipal wastes that increase the level of nutrients, pesticides, and/or heavy metals within these water bodies (Owen, 2007) threatening wildlife and lowering the ecosystem quality. Additionally, wetlands are facing the rapidly increasing and severe threat of plastic pollution (UNEP, 2016).

2.1. Pollution in Greek wetlands

In Greece, wetlands face a number of threats including loss of area due to land-use changes (e.g. housing developments, land clearing), illegal hunting, unsustainable irrigation, diversion of water courses, and last but not least pollution (Zalidis et al., 1997; Goutner et al., 2001; Valavanidis, 2018). The primary sources of pollution in the Greek wetlands are:

Agricultural activities

Fertilizers and pesticides runoffs as well as manure are among the greatest threats posed to the Greek wetlands by agricultural activities. Stock farming liquid waste, pesticides, and fertilizers contain chemical nutrients, especially phosphorus and nitrogen, that can lead to nutrient pollution. They may also contain heavy metals that accumulate in the soils and eventually end up in waterways; irrigation can also lead to heavy metal contamination. Additionally, soil erosion and sedimentation, that occur due to intensive farming, can also contaminate water bodies adjacent to agricultural land with agrochemical residues (Gerakis & Kalburtji, 1998; Casentini et al., 2011).

Municipal solid waste (MSW)

Currently, municipal solid waste, e.g. product packaging, clothing, bottles and cans, etc., is responsible for the widespread pollution of soil and aquatic ecosystems. In Greece, in 1997, 4

million tons were produced, a number that increased to 6 million tons in 2011 and continues to augment. The high numbers of generated waste coupled with inadequate MSW management and illegal dumping of waste, lead to the contamination of water, soil and wetlands (Valavanidis & Vlachogianni, 2015). According to Andrea et al. (2020), stakeholders consider the insufficiency of the MSW management and recycling system as the most important environmental factors affecting the coastal area of a Greek protected wetland.

Plastic waste

Plastic waste pollution is one of the greatest threats to the environment. Intensive plastic production, everyday use of plastics in all aspects of life, and thoughtless disposal of large quantities of plastic items lead to their leakage into rivers, wetlands, and oceans, with devastating effects to marine organisms, ecosystems as well as economic activities (Boucher & Friot, 2017). Additionally, both primary and secondary microplastics, i.e. particles smaller than 5 mm, have been found in every marine ecosystem. Microplastics are not biodegradable thus, they accumulate in ever increasing rates and are almost impossible to remove (Barboza et al., 2019). They pose severe effects to the marine ecosystems due to their filtration and ingestion by marine species (Boerger et al., 2010) and the chemicals they release (Cole et al., 2011; Koelmans et al., 2016).

3. Pollution in Evros Delta

An example of wetlands' high exposure to several polluting sources can be found in the case of Evros Delta in Greece. The pollution mechanisms of this wetland were examined in an early study by Angelidis et al. (1995) and it was found that the eastern part of the delta was impacted by transported pollution originating from its greater catchment basin in Bulgaria, Turkey, and Greece, while the western part was mainly affected by local activities (i.e. agriculture and animal breeding) and had lower pollutant concentrations. According to this research, it is evident that transported pollution from a number of sources is a major contributor to a wetland's overall pollution levels.

For monitoring the current situation of Evros Delta National Park, different sources of information were used together with in situ observations. Litter type and quantity in selected survey areas were collected, water and sediment samples were analysed and local ecological knowledge of stakeholders was examined through the means of a questionnaire. Data regarding seafloor litter gathered in the context of "Fishing for Litter" project are also reported. While regarding heavy metal pollution, data collected in the context of the project "Elasmobranch fisheries and trade in North Aegean" are included.

3.1 Survey areas selection and protocol

Twenty-two (22) different survey areas were chosen based primarily on the human activities taking place, but also their spatial distribution and their geomorphological characteristics in order to achieve the most accurate information about the current situation of litter pollution within the Delta. For the collection of data regarding stranded litter in Evros Delta the following survey sites (Figure 1) were selected:

- 2 survey areas along riverbanks (1,6)
- 2 shores of the 2 main irrigation canals (3,9)
- 2 beaches near Delta (12,13)
- 1 farm (2)
- 3 small fishing ports (2 for recreational (15, 16) and 1 for professional fishers (4))
- 1 recreation place by the beach (10)
- 1 army outpost (14)
- 1 area designated for the disposal of fertilizers' containers (21)
- 5 survey areas along different road types (1 in the special protection zone with low traffic (5), 3 in the permitted area (17,19,20) and 1 road close to marches (22))
- 1 survey area in the marches (11)
- 3 survey areas in the shores of Drana and Paloukia lagoons (2 of them were located in Drana (7,8) and 1 of them in Paloukia (18), Nymphon Lake was inaccessible during the period of time that surveys were conducted due to the highly vegetated flood area around it)

The Marine Strategy Framework Directive 2008/56/EC protocol was applied and the litter were reported according to the Master List of Categories of Litter Items proposed by the MSFD Technical Subgroup on Marine Litter. A total surface area of 7760 m^2 was monitored (Figure 1).

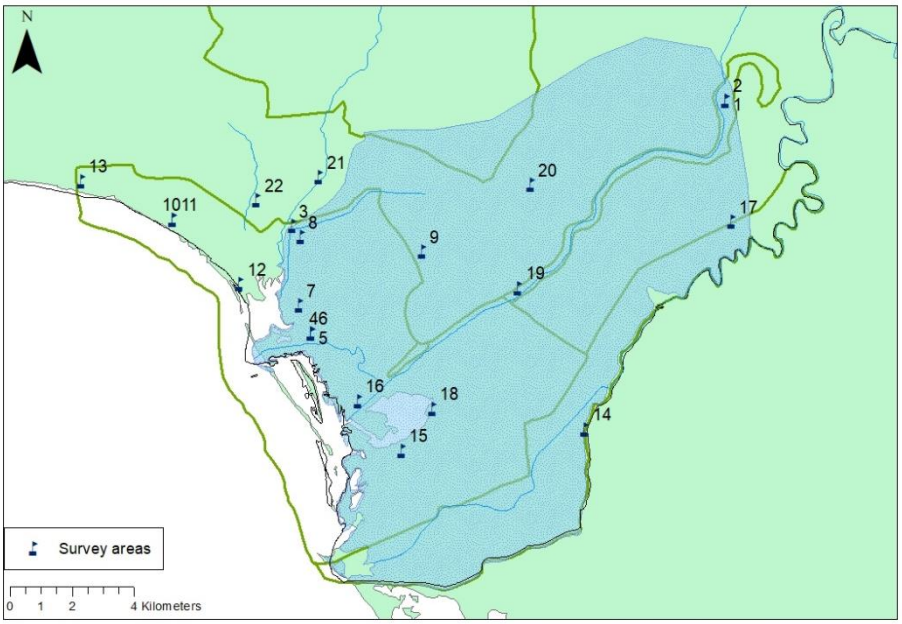


Figure 1: Visual observation of sampling sites

3.2 Types and quantities of litter in Evros Delta

The number of items reported according to their material is presented below (Table 1). A total number of 2979 items were observed, with 85% of them being plastics (2537 pcs), followed by paper (165 pcs) with a much lower percentage (5.5%). The percentage of glass/ceramic and rubber items was low. These materials represented only 0.8% (23 pcs) and 0.4% (12 pcs) of the total items observed respectively. It is important to highlight that plastic items were observed in all surveyed areas. On the other hand, fabric and paper items only appeared in 50% of the surveyed areas.

Table 1: Litter types reported by number of items (pcs) and percentages (%) of the total items

Materials	pcs	%
Artificial Polymer Materials	2537	85.16%
Paper/Cardboard	165	5.54%
Processed wood	114	3.83%
Metal	79	2.65%
Fabric/Textile	49	1.65%
Rubber	23	0.77%
Glass/Ceramics	12	0.40%
Total	**2979**	**100%**

The 10 most abundant items are presented in Table 2. Those items are cumulatively contributing to the 60% of the total amount of litter observed and they are all plastic. The most abundant and commonly found item was plastic bags which accounted 10.94% of the total amount of litter observed in the area. Drinking bottles (9.13%) and cords (8.15%) follow. The average of litter items observed in the selected survey areas of Evros Delta was 1.35 items/m^2 with a standard deviation 1.74 indicating a wide range of items/m^2 over the surveyed areas (Figure 2).

Table 2: The most abundant items reported in Evros Delta National Park

Items	pcs	%
Plastic bags	326	10,94%
Drinking bottles <0,5 l	272	9,13%
String and cord	243	8,16%
Cups and cup lids	167	5,61%
Drinking bottles >0,5 l	161	5,40%
Plastic pieces <2,5 cm	161	5,40%
Plastic caps/lids from drinks	134	4,50%
Wet wipes	115	3,86%
Plastic caps/lids from chemicals	106	3,56%
Polysterene pieces <2,5 cm	106	3,56%
Total	**1791**	**60,12%**

According to the results summarized in Figure 2, fishing ports (4, 16), fertilizers disposal place (21), and the beach closest to the urban area (13) could be characterized as very dirty, since most of these areas were covered with litter. On the other hand, only 23% (8, 17,19, 20) of the surveyed areas could be described as very clean, since only a few litter (<10 pcs) were found on their surface.

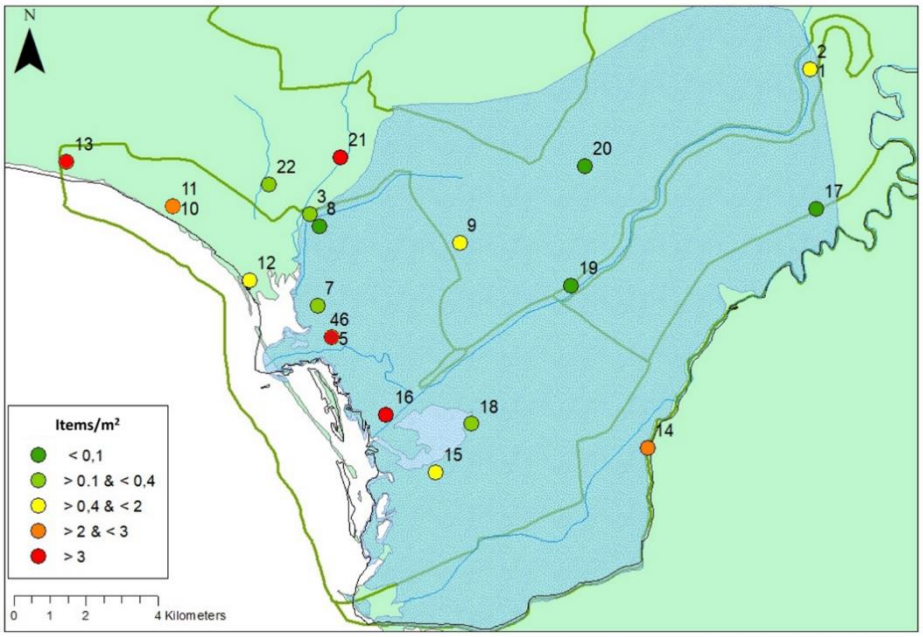


Figure 2: Surveyed sites and litter density

Table 3: Most abundant items based on the surveyed areas

Survey areas	Most abundant items	%
Fishing ports	Plastic Bags	18.63
Beaches	Plastic Bags	29.96
Army post	Wet wipes	30.30
Farm	String and Cords	58.86
Fertilizers' bins	Plastic caps/lids from chemicals	25.84
Roads	Drink bottles	19.08
Riverbanks	Plastic pieces >2,5 and <50 cm	10.12
Lagoons	Plastic pieces	28
Marsh	Polystyrene pieces	46.03

Whereas, lightweight plastic bags appeared in most of the surveyed areas, heavyweight plastic bags for ice packaging, sold in the Central Markets and Fisheries Organisation SA (CMFO SA) outnumbered them in the fishing ports. In fishing ports, the highest number of plastic bottles was also observed. Big numbers of plastic bags and plastic bottles also appeared in locations that are used for recreation e.g. beaches etc. In both cases, near the fishing ports and the recreation place, lack of bins intensifies their direct disposal to the environment. Furthermore, about 14% of the items reported from a surveyed fishing port were pallets of processed wood, related to the installed deck and the abandoned fishing boats.

The biggest amount of shotgun cartridges was also observed in the fishing ports even though hunting is prohibited there. It is highly probable, that shotgun cartridges existed in bigger amounts in areas where hunting is allowed however, hunters are hiding in locations with limited access and therefore it was impossible to observe shotgun cartridges. Additionally, it is further possible that shotgun cartridges observed in big amounts at the ports, which are in the estuary area of Evros Delta, because of drifting from other upper locations, within the Delta.

Apart from the fishing port, the beaches surveyed near Evros Delta also exhibited high numbers of litter along with other hot spots of litter identified in the area. Due to the Evros Delta geographical position, army presence is one of the main human activities taking place in the wetland. The area of an army outpost located near the Evros main river was surveyed in order to clarify the litter caused by the intensive army presence there. A surface area of 200 m^2 was

surveyed, where wet wipes proved to be the most significant disposed item along with plastic drinking bottles, cigarette butts and filters, single use plastic cups and their lids, single use plastic straws, and food packaging. The litter gathered in the area come from the direct disposal from soldiers and are linked to their needs and activities during their shift. The isolation of the area, the lack of bins and the presence of a high number of people in a daily basis leads to a very dirty area with more than 95% of plastic litter.

Due to the geographical position of Evros Delta National Park and as a result of the general geopolitical situation, an amount of litter related to the current human crisis was also observed mainly across the riverbanks. Plastic boats, life vests, clothes, like shoes and bags, and plastic food containers were observed. Such items were gathered and abandoned across the riverbanks where people crossing the boarders to Greece through Evros River reach. Clothing and single use plastic containers were also observed in roadsides, but in lower frequency. It can also be assumed that many of these items are also gathered in inaccessible places of dense vegetation and flooding areas where it is impossible to be detected or observed.

Two of the most polluted areas were linked to agriculture and farming. A farm area was monitored where almost 60% of the items observed were cords less than 1 cm diameter thick that are used as packaging for the collected crops and the animal feeds in huge quantities, as stated by the local farmers interviewed. They were observed trapped in the farms' fences. Animal tags were exclusively observed in this area, used by the stock breeders. Another surveyed hotspot was the location with bins and water supplies serving the farmers' needs for fertilizers' preparation and disposal. More than 95% of the reported items were plastics, plastic cups, lids and bottle rings from fertilizers, and single use plastic cups in particular, all of them linked to the farmers' activities. It should be also noted that, according to locals, inadequate bin emptying leads to their overflow. Since the place is located near a torrent flowing out in Evros Delta, the torrent is their potential pathway to the sea during and after rains and/or floods.

Another detected hotspot, between Evros Delta National Park and the closest villages and areas of agricultural activities, were some illegal dumps. Most of the litter from illegal dumping were observed in two places near torrents ending in Evros Delta. The most common items observed in both cases were bulky cement and plastic building materials. In one case most of the items also included big tires from agricultural machineries, like tractors, whereas in the other case big furniture were mainly observed like sofas and tables. In both cases, the items were illegally

dumped there after reconstructions of houses or agricultural facilities. The specific areas were not monitored, since they were located in inaccessible fields and dried torrents.

All of the roads were clean, apart from the one near the professional fishers' port which is located in the highly protected zone of the National Park where authorized access is only permitted. More than 44% of the items observed in this road were plastic bottles. About 75% of the items in this surveyed area were also observed in the professional fishers nearby port indicating that the port is the source of litter for the broader area. Metal drums for example, were only observed in the professional fishers' port area and this particular roadside. Plastic caps from drinks appeared in 4 of the surveyed roadsides. Apart from the plastic bottles the biggest number of items observed in the roadsides were plastic strings with < 1cm diameter that were also observed in 4 of the surveyed roadsides.

Surveyed riverbanks were clean, covered with less items than the average number found in Evros Delta. This is also the general picture for most riverbanks in Evros Delta, even if not surveyed. The only exception was a location with an installed deck that was used for fishing boat mooring. In all the surveyed riverbanks, plastic cups and lids consisted most disposed items. While in the irrigation canal unidentified pieces of plastic > 2.5 and < 50 cm were the most common. In all these surveyed areas, buried items were observed. This is the result of the fluctuating flow of the river and the consequent vast amount of sedimentation. It is safe to suspect that in the river bottom in several locations throughout the Evros Delta, especially in the flooding areas, buried litter exist, potentially in large numbers. It is also important to mention that in locations with medium height vegetation along riverbanks and roads, several lightweight litter items were found trapped, as the first are working as natural obstacles preventing them to enter the rivers, tributaries and irrigation canals while transported through winds.

All of the surveyed lagoon shores were clean and the low number of litter observed exclusively consisted of plastic items, mainly including plastic bags and unidentifiable plastic pieces < 2.5 and > 2.5 cm. These items were found trapped among vegetation and buried in the muddy space around the lagoons' shores. A march located in the area of the National Park was also monitored where more than 98% of the litter were plastic items mainly trapped among the vegetation. An amount of 0.62 items/m^2 was reported in the area that consisted of polystyrene pieces > 2.5 and < 50 cm to an extent of 46%, possibly due to their light weight which contributes to their transportation through wind.

3.3 Microplastic pollution

Rivers proved to play a significant role for microplastics' input in the oceans. In addition, microplastics accumulate in wetlands due to their vegetation, which along with the hydrodynamics, affect the spatial distribution of microplastics (Helcoski et al., 2020). Spatial distribution of microplastics is also affected by land and marine based human activities and by the coastal land use of an area (Zhou, 2020).

3.4 Sampling stations and sample examination

In order to detect the existence of microplastic pollution, 16 sampling stations were chosen from where water and sediment samples were collected. Two (2) liters (L) of surface water (Barrows et al., 2016) and 500 mL sediment of strandline samples of 3 cm depth layer collected in containers (Browne et al., 2010) from every station. The surface water was filtered through a 300 μm laboratory filter and the remains were examined via stereoscope (SLX-3; OPTIKA). The sediment samples were both examined via stereoscope for precipitated microplastics and floating microplastics were also separated through salinisation and filtering.

The sampling stations were (Figure 3):

- 2 in Drana lagoon (13,15)).
- 3 in beaches of the Protected Area (1 from the beach in the estuary of Evros Delta (2), 1 from Anthia Beach (4) and 1 from Apalos Beach (9)).
- 3 sites from the irrigation canals (1 from each main irrigation canal (3,8,14))
- 5 sites from pollution hot spot areas (1 from the professional fishers' port (16), 2 from the recreational fishers' port (5,11), 1 from the army post (6) and 1 from a farm (10))
- 3 sites from the river and riverbanks (1 sample from Evros main river (7) and 2 from its west branch (1,12))

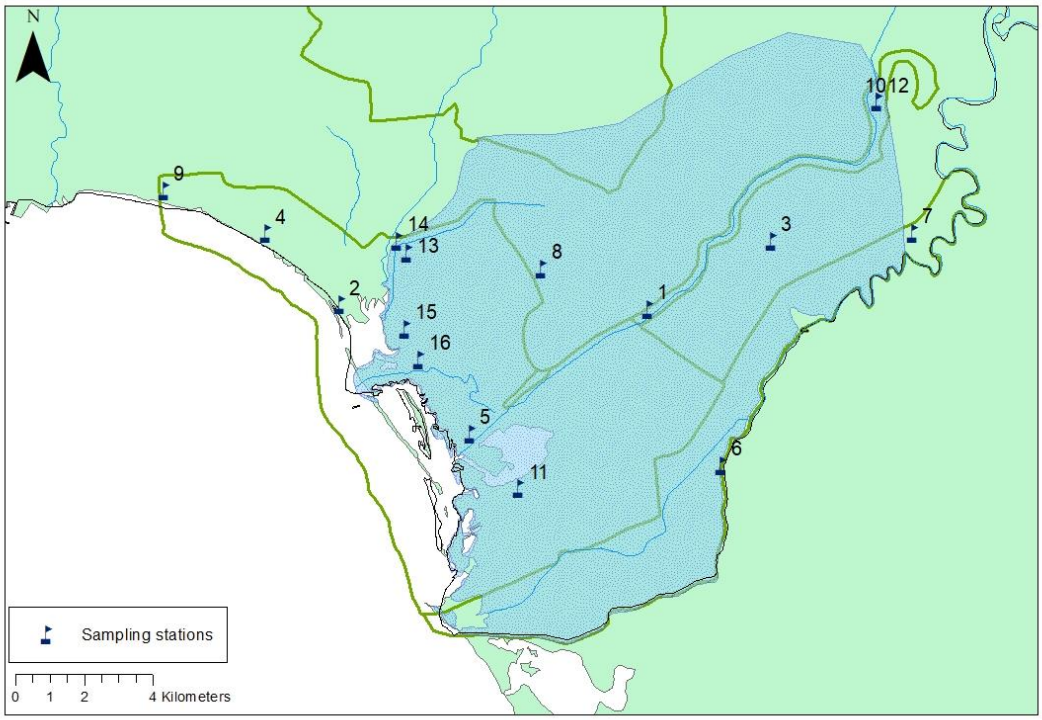


Figure 3: Water and sediment sampling stations for microplastic monitoring

3.5 Microplastic occurrence in Evros Delta

In all the above areas, microplastics were detected. Particularly, in 47% of the water samples and in 80% of sediment samples, microplastics were found. About 63% of the microplastics detected were plastic fragments in a variety of colors (green, blue, black, pink, white and transparent). An average amount of 1 microplastic particle/L (±2) was detected in all water samples of the area of Evros Delta and an average amount of 95 microplastic particles/L (±171) were detected in all sediment samples of Evros Delta. 63% of the microplastics detected were floating, whereas 37% of them were precipitated in the sediment samples.

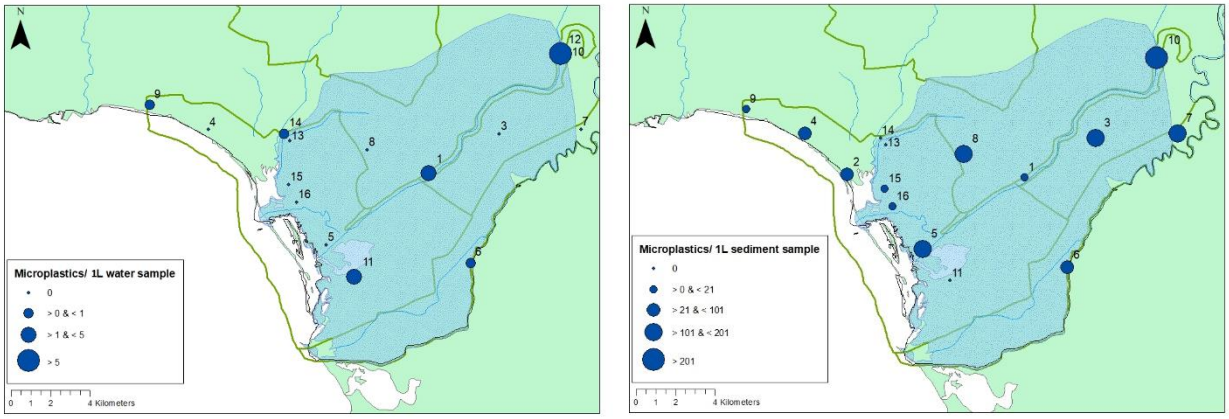
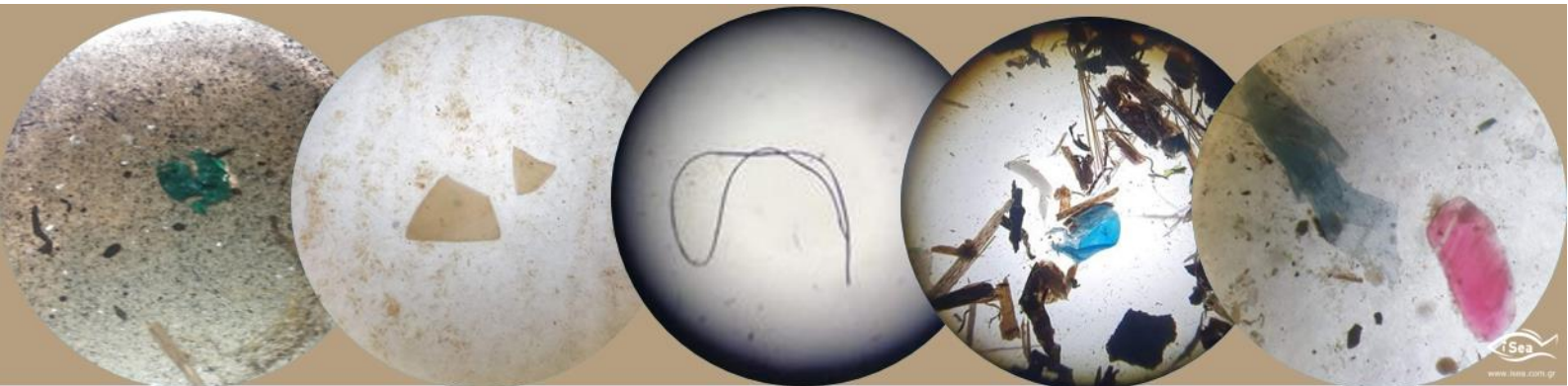


Figure 4. Abundance of microplastics in water (left) and sediment (right) samples

The highest number of microplastics in the water samples was detected in the West Branch of Evros River, numbering 9 plastic particles/L, but no microplastics were found in the sediment sample of the particular area, probably due to the high sediment deposition rate of the river. As a result, by far, most of the microplastics were found in the sampling station of Apalos Beach, where 1 plastic fragment was detected in the 2 L water sample, but more than 700 plastic particles/L in the sediment sample (Figure 4). Evros main river is the second highest, regarding the number of microplastics detected. More than 150 plastic particles/L were detected in the sediment samples, in this case, even though the water samples examined, did not contain microplastics, probably due to the high vegetation and stem density filtering the water in this sampling station.

Sarantametros irrigation canal and Drana lagoon were the sites where the lowest number of microplastic particles detected. Only 0.5 and 2 microplastic particles/L were detected in Sarantametros and Drana, respectively. Drana lagoon was also the cleanest area according

to the results of visual observations regarding macro and meso litter. The low abundance of microplastics in these sampling stations could be attributed to their isolation and no connection to any other lagoon, river or cannel, at the particular period of time when saplings took place, since transportation of plastic particles from tributaries, rivers, and canals is confirmed. In addition, the high abundance of microplastics, from more than 40 to more than 100 microplastic particles in the estuarine areas supports the fact that rivers are transport vectors of microplastics into the ocean.



3.6 Seafloor litter in Evros Delta estuary area

Rivers, especially large ones like Evros, are the route of waste into the sea contributing to marine pollution. All kinds of litter are transported through river flow and subjected to the sea currents and tides which determine their further deposition in the seafloor, as soon as they reach the coastal zone. Since rivers are considered a significant input factor of litter in the marine environment and a transport mechanism across different areas, data collected in the context of "Fishing for Litter" were taken into consideration. "Fishing for Litter" is a project implemented in the North Aegean as a proposed action by the MSFD for the reduction and the monitoring of seafloor litter.

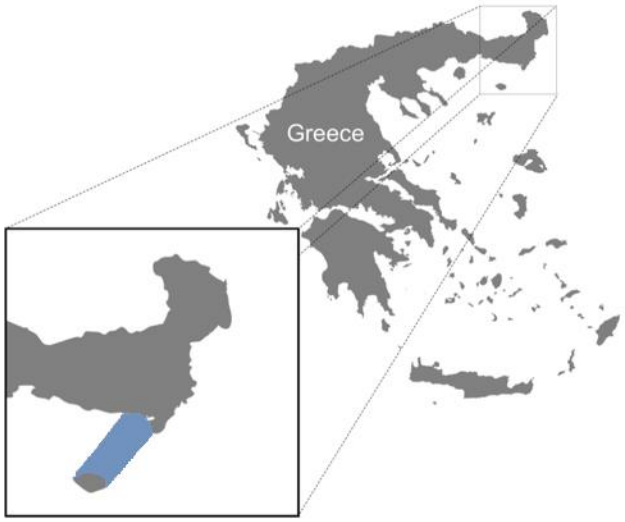


Figure 5: Trawling areas where the particular fishing trips took place

The protocol applied is based on the OSPAR Agreement 2017-18 with the aim to provide important information regarding the seafloor litter in deep depths. The data presented below were collected in 18 fishing trips in the area between Evros River and Samothraki Island, during the Spring of 2020 where part of the items were possibly transferred via Evros River flow. More specifically, in 17 fishing trips, 150.4 kg of litter were accumulated in the nets of fishers while in only 1 fishing trip no litter were retrieved. Litter composition can be found in Table 4 presented by category along with the number of items and their percentage to the total number.

Table 4: The retrieved litter by type along with the number of items (pcs) and percentage (%) to the total number of items collected during 18 fishing trips in Spring 2020.

Material	pcs	%
Plastic	3435	81.2
Metal	443	10.5
Glass– Ceramic –Cement	150	3.6
Fabric	88	2.1
Wood	64	1.5
Paper	26	0.6
Rubber	23	0.5
Other waste	2	0
Total	**4231**	**100**

In accordance to the existing data from European coastal surveys, plastic items are the most abundant, exceeding 81% (Addamo, 2017). In Table 5 the most abundant items collected in the 18 fishing trips are presented.

Table 5: Most abundant items "fished" during 18 fishing trips through spring of 2020.

Items	pcs
Plastic bags	1116
Hard plastic (e.g. containers, buckets, barrels)	588
Ropes	547
Plastic bottles	473
Aluminum cans of soft drinks/ beer	277
Food packaging	207
Fishing nets	168
Fishing lines	168
Large items (cement)	112
Other items related to fisheries	70

From the above list, all items, except the aluminum cans of soft drinks/beers and large items, are made from plastic. A big percentage of the retrieved litter are also related to fisheries.

3.7 Heavy Metal pollution in Evros Delta

Evros River and Delta have a long story of heavy metal pollution as a result of domestic and industrial effluents, primarily industrial activity in all countries sharing the basin (namely Bulgaria, Greece, and Turkey), including metal works, chemicals, wood processing, textiles and tanneries, and others. Since 1996, when the first studies published (Angelidis and Albanis, 1996), traces of heavy metals in quite high levels were evident. In the most recent study of Karaouzas et al. (2020), Evros River was found among the most polluted water bodies from heavy metals in Greece among 46 rivers and 22 lakes that were examined. The surface water samples of the river exceeded the environmental quality standards (EQS) for Pb and Zn, as defined by the Directive 2013/39/EC (Directive EU, 2013). In the same study of Karaouzas et al., (2020), a Heavy Metal Evaluation Index applied, and the Degree of Contamination assessed for 46 rivers and 22 lakes across Greece, in both cases Evros River was in the "High" category (see Figure 6).

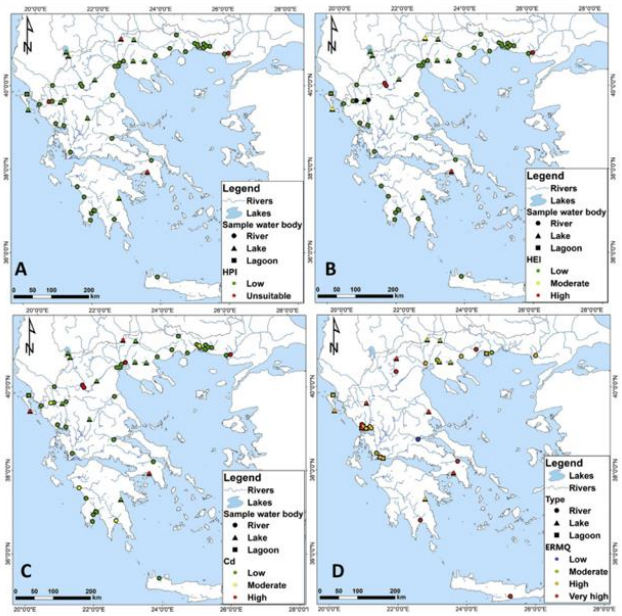


Figure 6: From (Karaouzas et al., 2020): Heavy Metal Pollution Index (A), Heavy Metal Evaluation Index (B) and Degree of Contamination (C) for Surface Waters of rivers and lakes; ERM quotient (ERMQ) for Greek sediments for rivers and lakes (D).

High concentration of heavy metals has been also detected in organisms of the Evros wetlands. For example, Malea et al. (1995) and Malea et al. (2008) detected high concentration of heavy metals in *Halophila stipulacea* and *Ruppia maritima*, respectively. More recently Aloupi et al. (2017), detected high levels of Cu, Zn, Mn, Cr, Cd, and Pb in the brain and the liver of waterfowl from the Evros Delta.

As part of the iSea project "Elasmobranch fisheries and trade in North Aegean" specimens of elasmobranchs collected from different areas of the North Aegean region. Among 59 samples, 31 samples were captured in areas with high proximity to the Evros Delta (Figure 7). Results showed in several cases high levels of primarily Pb (11 out of 31) and then Hg (4 out of 31) in the flesh of marketed elasmobranch species like Dasyatis sp. and Raja sp. In all the above cases,

the concentration levels exceeded the limits for safe consumption as set by the Commission Regulation (EC) No 1881/2006.

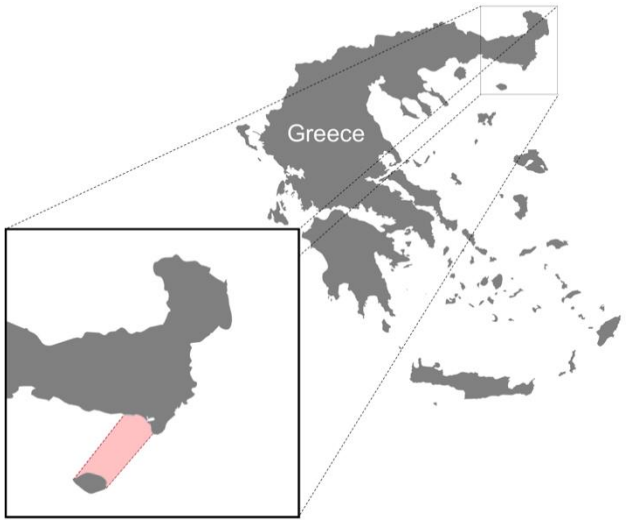


Figure 7: Sampling location of the elasmobranch specimens presented in the current work.

As apex predators, elasmobranchs are exposed to environmental contamination through bioaccumulation and biomagnification processes, accumulating high levels of heavy metals in their tissues, while recent toxicological studies showed greater sensitivity to dissolved metal levels in seawater compared to marine teleosts (De Boeck et al., 2001). However, some of these species are highly migratory and cannot act as good indicators for the contamination of a particular area. In this case, the species analysed, are species that exhibit site fidelity like *Dasyatis pastinaca* (11 out of the 31 cases) and therefore the results can be used for drawing a brief picture of the heavy metal pollution in the broader marine area of the Evros Delta.

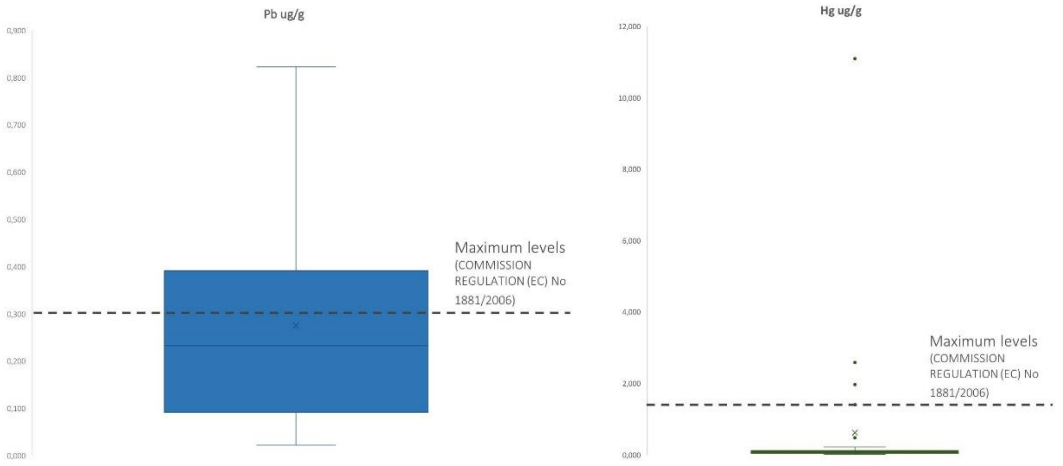


Figure 8: Levels of Pb and Hg in samples from Evros Delta marine area

3.8 Sources of pollution

Beaches located in the context of Evros Delta National Park and in the adjacent areas are proved a sink of land-based activities known to take place across the wetland. Most of the items observed through the surveyed beaches were stranded as a result of tides and strong winds drifting items mismanaged on land. More than 92% of the stranded litter in these beaches were plastic, possibly due to the combination of the material's lightweight and durability that enables them to follow the river and sea flow and maintain the weather and water conditions. Evros River, its tributaries and nearby torrents seems to be the pathway for pollution in the marine ecosystem. Characteristic findings are the bottles of fertilizers and ice bags that were observed in big amounts in the Evros Delta area. Thus, is evident that the Delta and the activities taking place within it influence pollution in the adjacent areas.

Organisms attached on the litter (e.g. balanoids) observed on the beaches, in combination with the fact that 58% of the plastic items (persistent buoyant) observed in the riverbanks were also observed in the adjacent to the estuary beaches, proves that Evros River is an important input of pollution for the marine environment. In fact, it is so important that non-buoyant or non-persistent litter items, like glass, were not observed in these beaches confirming that litter pollution of the area mainly comes from other activities other than beach users. Of course, land-based litter entering the ocean through Evros River is a cross border issue affected by all activities taking place in the Black Sea Basin. Litter reaching its estuary is probably sourced closed to it and thus, Evros Delta wetland. As a result, improper disposal and mismanagement, like illegal dumping or inadequate management taking place near the riverbanks, leads to their drifting due to weather conditions, winds, and rains that create their pathway to river water, and finally, to the marine environment.

Crossing through both urban and densely populated, as well as intensively industrial areas of Turkey and Bulgaria, municipal solid wastes and industrial wastes are significant contributors to the high abundance of microplastics in Evros River. The number of plastic fragments and fibers detected indicate the amount of secondary microplastics coming from bigger items' fragmentation and through wastewater treatments that end in Evros River. During Autumn, microplastics are more abundant in sediment layers than water, since shallow river waters and dried flooding areas are suspended to microplastics carried through the water column during the seasons of the river's highest flow. As a result, resuspension of sediment layers during

Winter and Spring could contribute to substantial amounts of microplastics to the sea through the water column.

By far most of the microplastics detected in the water column appeared in the closest part of the river to a Greek residential area. All of them being fibers, we can assume that they come from the area's wastewaters. Particularly for the case of Evros Delta, sediment acts as a sink for microplastics flowing through the river, since the highest abundance of microplastics was detected in sediment layers where levels of water flow seem to alternate more often. Their burial due to this alternation also contributes to their fragmentation and thus, microplastic pollution. Most of the microplastic fragments were detected in Apalos Beach possibly due to the combination of its adjacent to an urban and the most densely populated place near Evros Delta with different mainland uses taking place, other torrents flowing out near this beach and its type of sediment, including Posidonia Oceanica deposits.

Sediment samples of the main river follow regarding microplastic abundance. In addition to the water level alternations and the quantities of buried litter also observed, microplastic abundance is possibly increased in the particular sampling stations due to the meandering flow with high vegetation. As a result, the structural complexity of the river flow seems to increase the retention degree of microplastics. Sarantametros canal and Drana lagoon were the sampling stations with the lowest number of microplastics detected. The apparent lack of high density of microplastics could be explained by the fact that they are both disconnected from the sea, Evros River, and tributaries at the period of time when samples were taken. As a result, microplastic from water pathways do not reach them. Taking into account that the lowest numbers of litter items were also observed in the particular areas it can be stated that relatively stagnant environment contributes to low litter pollution density.

Heavy metal pollution in Evros River investigated during the last decades is attributed to human activities, like industry and agriculture, taking place not only in Greece, but all countries Evros River crosses. Agriculture in Greece, Bulgaria, and Turkey, untreated sewage from heavy industrial activity including metal works, textiles, tanneries, chemical, paints and batteries production, mainly in Bulgaria and the effluents of urban centers, mainly in Turkey, contribute to the high concentrations of heavy metals in Evros River waters. The high levels of Pb detected in species exhibiting site fidelity from the marine area of Evros Estuary is an issue of transboundary pollution mainly attributed to the intensive industrial and mining activities

taking place in the countries the river crosses, but is also associated with the abandoned Lead-Zinc mine in the Kirki region, a mountain area located in Evros Prefecture.

4. Evros Delta litter pollution based on local users' perception and activities

In order to investigate the issue of litter pollution in Evros Delta area the local ecological knowledge of local users was additionally used. A total number of 60 questionnaires were collected among 50 individual locals and 10 associations and entities active in the area. The participant associations included environmental organisations, fisher associations, hunting associations, Evros Delta municipalities and agricultural associations. The majority of the individuals participated were farmers and fishers followed by livestock breeders, more than 50 years old (43.3 %).

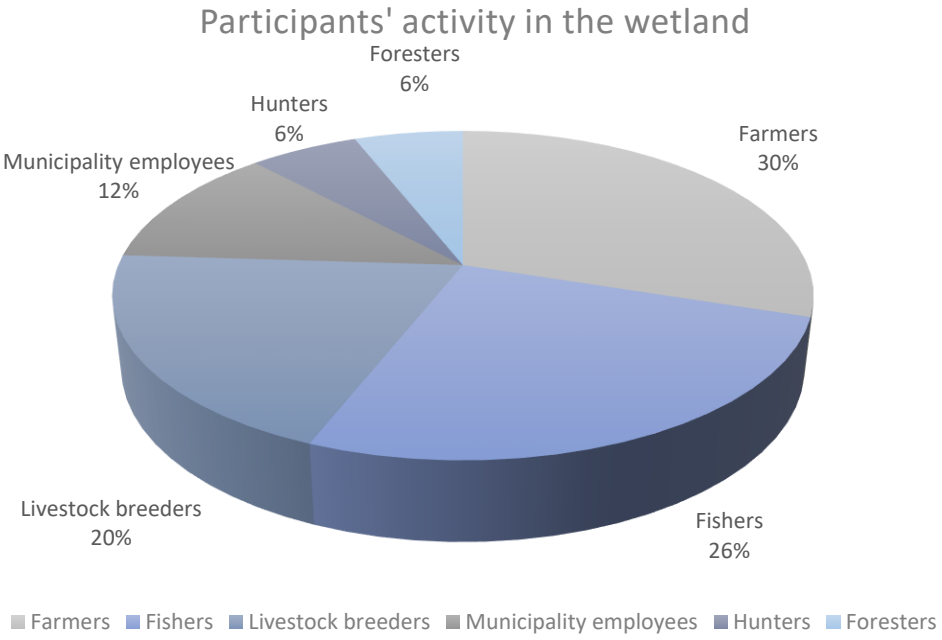


Figure 9: Participants' activity within Evros Delta by %

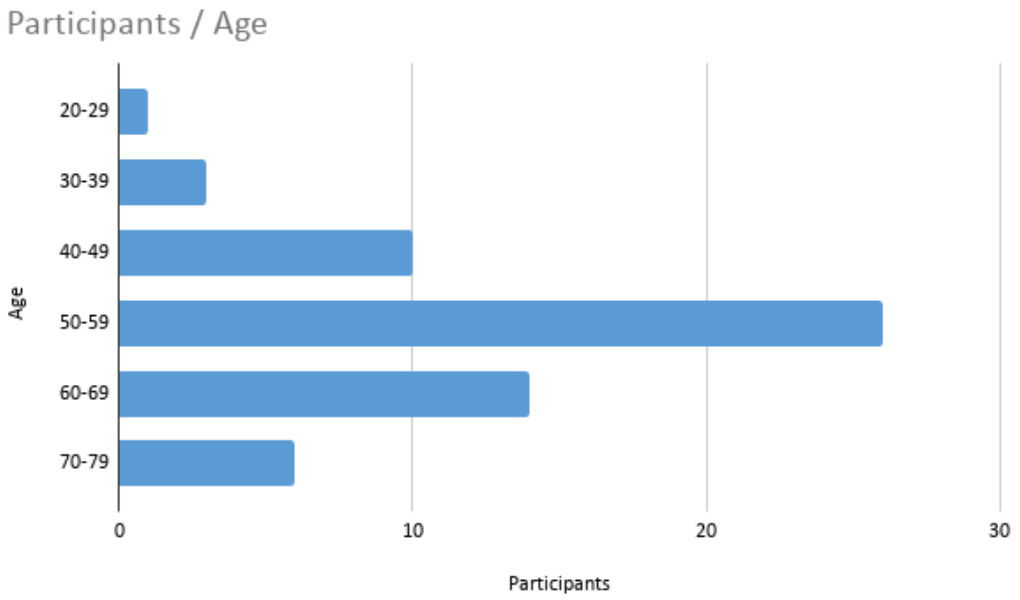


Figure 10: Participants' age by %

The structured questionnaire was developed specifically for this study in Greek. Participants were questioned in person by a representative of the Management Body of Evros Delta and Samothraki or iSea. It needed approximately 15 minutes to be completed and the answers were recorded anonymously. The questionnaires consisted of four sets of questions (Appendix A). The first set included general questions about demographic characteristics like age, participant's activity in the context of the wetland and their opinion about the main environmental threats for the area. The second set of questions targeted the participants' opinion about litter pollution of the area. Six questions about their opinion on litter pollution and the main litter types observed in the area were provided. The third set of questions included four questions addressing the types and quantities of litter they produce while in the wetland. Finally, the last set of questions included an open question regarding the participants' suggestions for the prevention and mitigation of litter pollution in Evros Delta.

Litter pollution was among the main environmental threats for the area (13%) resulting by the open-ended question "Which is the main environmental threat for Evros Delta". The majority of the participants (14%) claimed that human intervention is the main threat, without specifying particular human activities leading to environmental threats for the area. From those specifying the main threats for Evros Delta, the majority (15%) indicated fertilizers as the major threat, followed by litter.

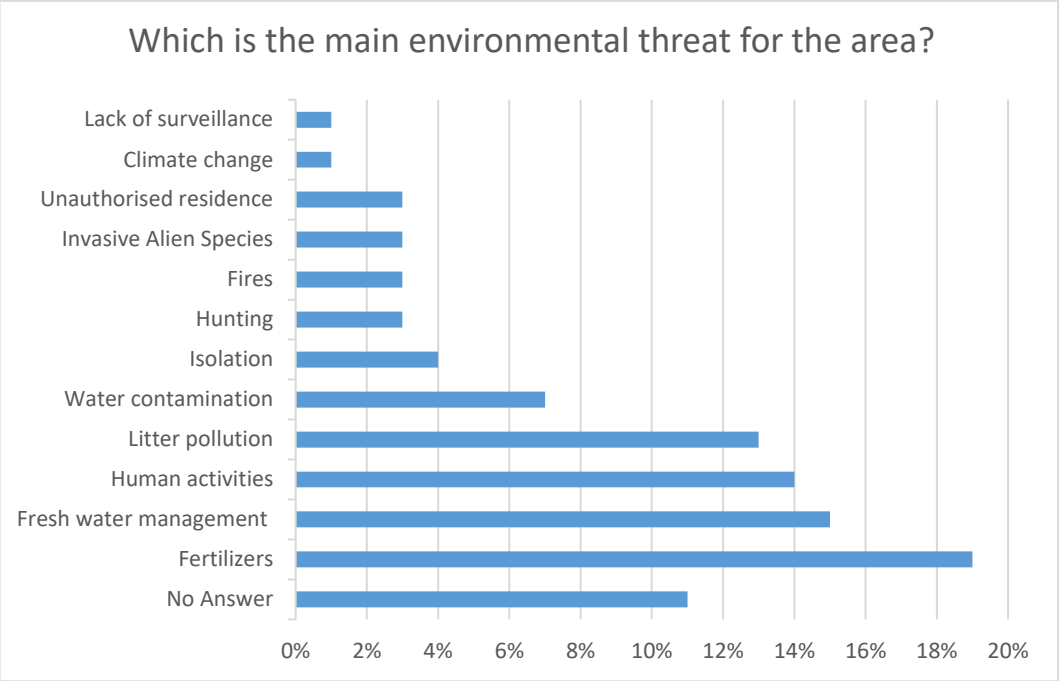


Figure 11: Participants' opinion about the main environmental threat of Evros Delta ecosystem by %

Participants' opinion about the environmental impact of litter pollution in Evros Delta was also supported by their percentage of agreement to "Litter pollution is a severe environmental threat for the area". According to their answers, 80% of them definitely agree or agree with the statement. On the other hand, only 5% of the participants did not agree that litter pollution is a severe environmental threat for Evros Delta.

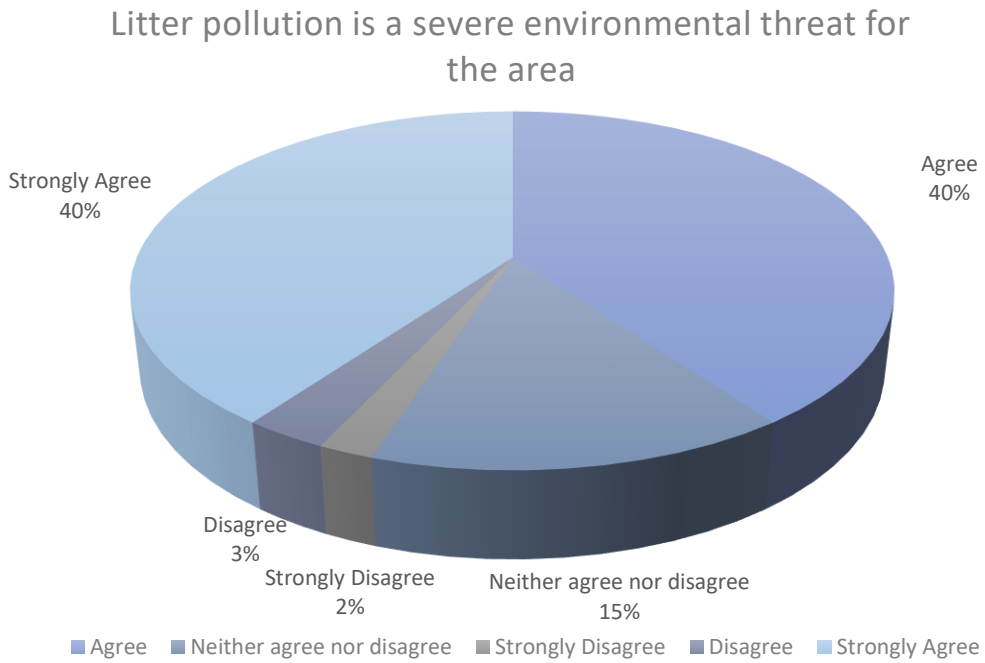


Figure 12: Participants' level of agreement towards litter pollution as a severe environmental threat for Evros Delta by %

Participants were also asked to describe the area from very clean to very dirty according to the density of litter they observe during their interaction with Evros Delta (a Likert scale was used from 1 to 5; 1 was very clean and 5 was very dirty). The majority of responders describe the wetland as moderate (value 3) concerning the density of litter followed by those who describe it as dirty (value 4).

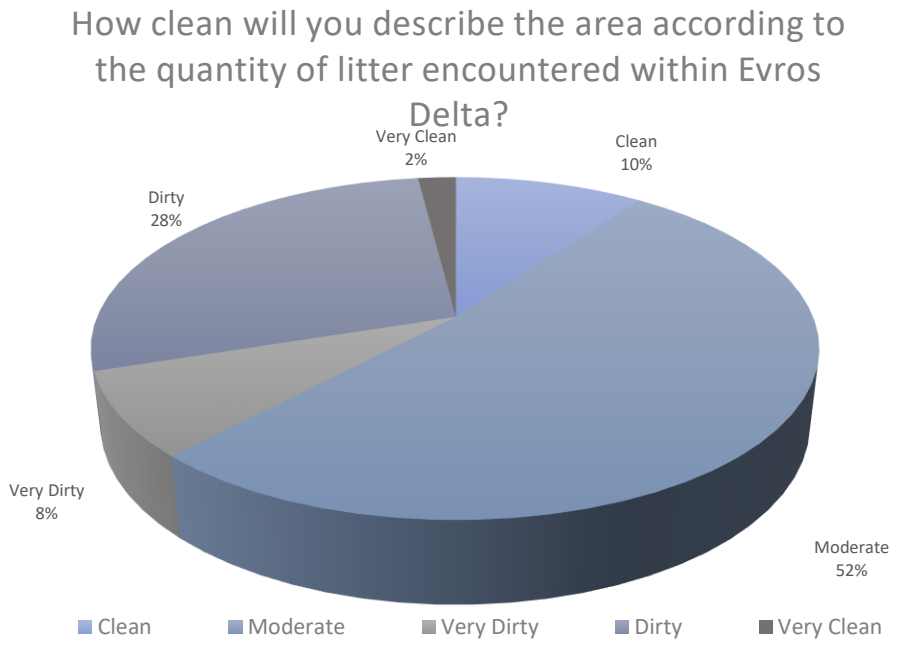


Figure 13: Participants' opinion on how clean is the area of Evros Delta by %

Regarding the most littered area, the majority of the participants stated that the highest amount of litter is gathered in the estuaries of Delta. According to the results of the data obtained from visual observations, is confirmed that fishing ports, located near the estuaries, were the most polluted areas, followed by other hotspot points.

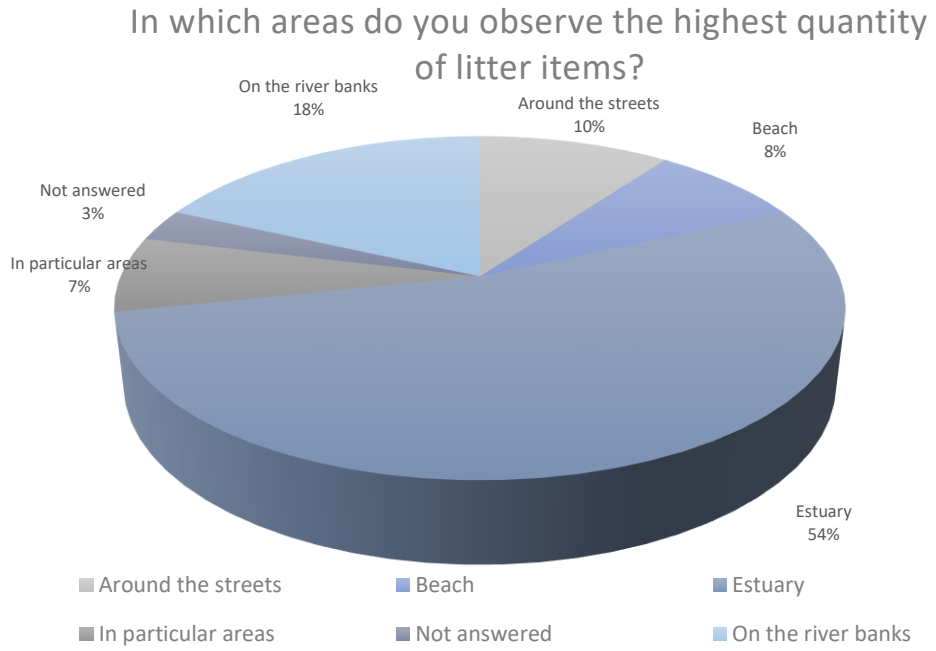


Figure 14: Participants' opinion on how the places where more litter pollution is observed

About 95% of the participants stated that litter items observed in the area are plastics, which is in accordance with the collected data. In addition, the highest majority stated that plastic litter exist in very large amounts in the area, followed by disposed items from textile, which a significant lower percentage of participants stated that also exists in such large amounts. The quantity of textile disposed items presented by the participants does not reflect the picture obtained from the data, since only 1.7% of the reported litter were made from textile, mainly clothing, backpacks and bags. On the other hand, clothing and shoes gathered in particular areas across the riverbanks. On the other hand, no one of the participants stated that building materials are disposed in very large quantities, whereas building materials were the main litter items dumped illegally in at least two areas around the National Park of Evros Delta.

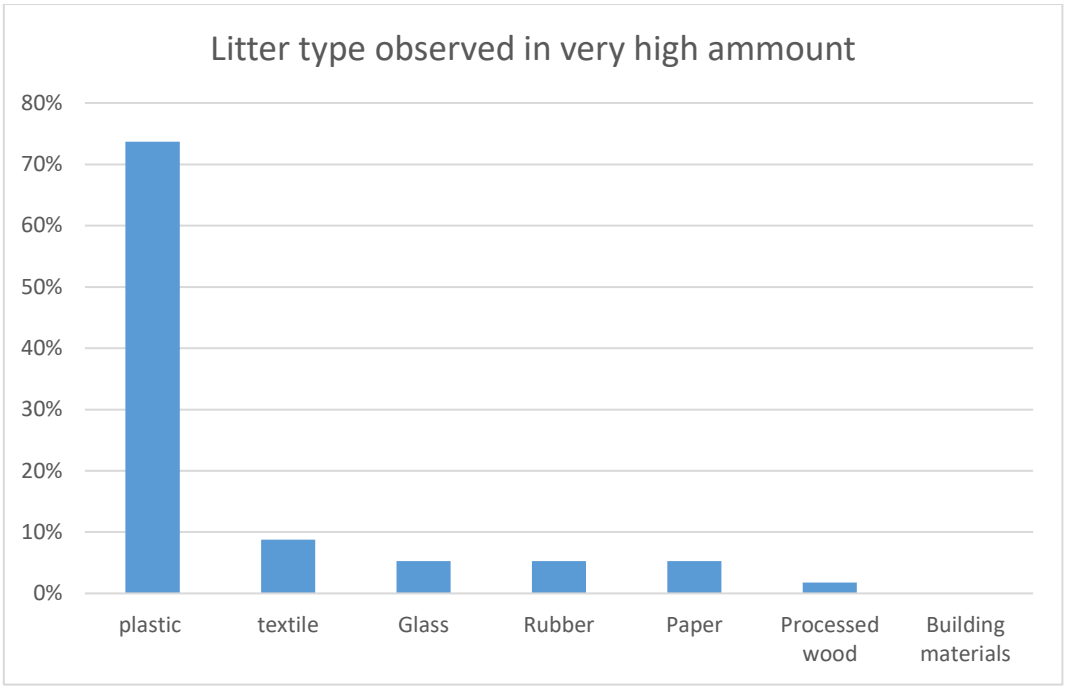


Figure 15: Participants' opinion on the litter type observed in the biggest amount by %

87% of the participants mainly use Single Use Plastic items during their activities in Evros Delta wetland. In particular, 57% of them mainly use plastic bags and plastic drinking bottles. The vast majority of the participants also stated that, due to the lack of bins and proper waste management in the National Parks, they prefer to dispose their litter in their residence.

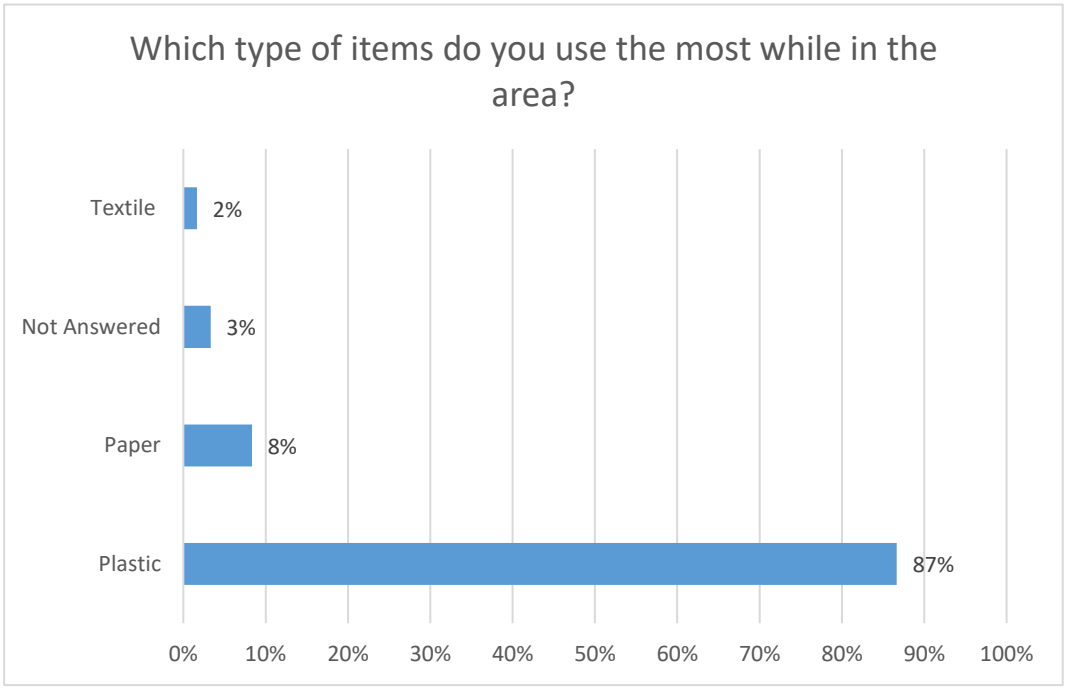


Figure 16: Most abundant type of litter resulting from the participants' activity within Evros Delta

Participants provided their suggestions for the prevention and mitigation of litter pollution in Evros Delta through an open-ended question. According to the majority of the answers provided (35%), bin installation will prevent litter coming from people visiting or working in the area. About 22% of the participants claimed that raising awareness about the issue is of high importance in order to mitigate pollution in the area. Two of the participants specifically stated the importance of raising awareness among students, highlighting the important role of future generation towards environmental protection. Regarding the enforcement of stricter measures, 14.46% stated that would contribute to the prevention of Evros Delta litter pollution, specifying that unauthorized access should be forbidden in the Protected Area and fines should be imposed to people littering the area.

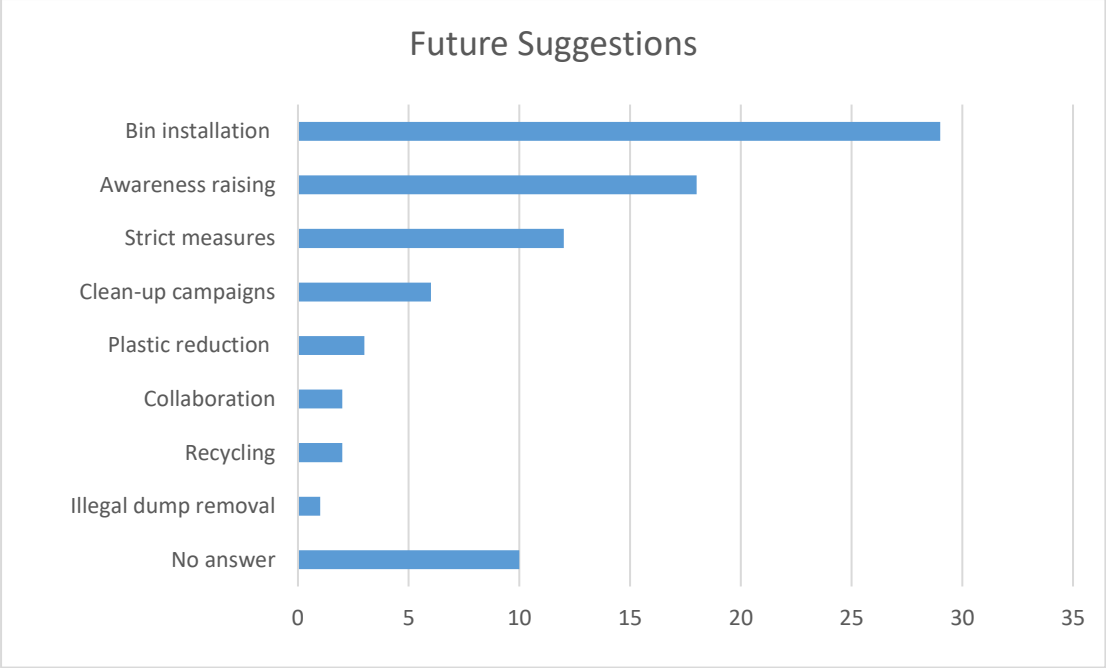


Figure 17: Participants' opinion about solutions against litter pollution in Evros Delta

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Glossary

Microplastics: Plastic litter, smaller than 5 mm in diameter (in all dimensions), categorised in two different types depending on their origin, primary and secondary. Primary are those intentionally manufactured which are smaller than 5 mm in size, and secondary sourced microplastics, which result from fragmentation and weathering of larger plastic objects.

Elasmobranchs: Sharks and ray species

Appendix A: Questionnaire for the investigation of Evros Delta litter pollution based on local users' perception and activities.

General Questions

1.Age:

2. How many years have you been interacting within the area?

3. Activity in the area:

- Farmer
- Fisher
- Livestock breeder
- Hunter
- Municipality employee
- Forester
- Representative of a local association
  Entity:

- Which is the main environmental threat for Evros Delta wetland?

5.How significant environmental threats do you consider the following for the area:

	Not at all	Slightly	Moderate	Very	Extremely
Urban waste					
Litter pollution					
Industrial waste					
Overflows					
Irrigation systems					
Hunting					
Logging					
Fisheries					
Other					

6. Litter pollution is a severe threat for Evros Delta area.

- Strongly disagree
- Disagree
- Neither agree or disagree
- Agree
- Strongly agree

Litter Pollution in Evros Delta

1. How clean will you describe the area according to the ammount of litter observed in the wetland?

- Very dirty
- Dirty
- Moderate clean
- Clean
- Very clean

2. Which is the most abundant type of litter observed in the area

- Plastic
- Metal
- Textile
- Paper
- Processed Wood
- Glass/Ceramics
- Other

3. In which amount do you observe the following types of litter in the area?

	Not at all	Small	Moderate	High	Very high
Plastic					
Metal					
Textile					
Rubber					
Paper					
Processed wood					
Glass					
Other					

4. Which three litter types are observed in the area the most (prioritize them beginning from the most to the least)?
   1.
   2.
   3.

5. Which is the source of the litter pollution in Evros Delta according to you?

6. In which particular areas do you observe the most of the litter items?

- Estuary
- River flow

- River Banks
- Beach
- Across the roads
- In particular areas
  Specify areas:

7. Have you ever encountered with an entangled, wounded or dead animal due to litter?

   Entangled….. Number……
   Wounded …. Number ……..
   Dead …… Number ……..

   Participants' litter production while in Evros Delta

   1. Which type of litter do you consume the most?

- Plastic
- Metal
- Textile
- Paper
- Processed Wood
- Glass/Ceramics
- Other

   2. Which three litter items do you dispose the most while in Evros Delta (prioritize them beginning from the most to the least)?

   1.
   2.
   3.

   3. Define the exact quantity of each item you dispose on a monthly base?

   1.
   2.
   3.

   4. Where do you dispose them?

   Future solutions and proposals

   1.What solutions would you suggest for the prevention and mitigation of litter pollution in the area?

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