

ECOPOTENTIAL4Schools

An international game experience with students

ECOPOTENTIAL PROJECT



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<http://www.ecopotential-project.eu>

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1. Intro

1.1 The game

¹Citizen science and information communication technology are key in connecting science and education, by expanding ecological research frontiers and public engagement. Science games, included in educational programs, are a direct and effective way of communicating. The [ECOPOTENTIAL4Schools](#) game is developed in the context of ECO POTENTIAL, a large European-funded H2020 project that focuses its activities on a targeted set of internationally recognised Protected Areas, blending Earth Observations from remote sensing and field measurements, data analysis and modelling of current and future ecosystem conditions and services. The [ECOPOTENTIAL4Schools](#) game is finalized to enhance participation, knowledge and skills of all players, from scientists, stakeholders to citizens. Playing [ECOPOTENTIAL4Schools](#), students will deepen their ecological knowledge and awareness, engaging the foundations of the 'deductive thinking' and 'logical reasoning' necessary not only for science, but also for their future life of young students.

1.2 Wetlands

Wetlands are a diverse array of dynamic ecosystems formed in the contact of land and water. They have long been considered unproductive and unhealthy places, and only recently it has been realized their importance for the conservation of biodiversity and for the ecosystem services they provide. Public awareness is fundamental to conserve properly and gain the maximal benefit from these environments. The [ECOPOTENTIAL4Schools](#) game promotes this concept by referring to some of the most important Protected European Transitional Water Ecosystems: The Camargue Biosphere Reserve, the Curonian Lagoon, the Doñana National Park, the Danube Delta Biosphere Reserve and the Wadden Sea.

¹Chapter image: Fish nets in Vaccares lagoon. By J.Jalbert, Tour du Valat





2. Camargue

The Camargue¹ is a delta formed by the Rhône River in southern France. This UNESCO Man and the Biosphere Reserve covers 1,450 km² inland and 480 km² in the Mediterranean Sea. It is comprised of two National Natural Reserves, three Regional Natural Reserves, one Natural Regional Park and several public estates, each with differing protection status. Hydrological management is a prime factor influencing ecosystem functions and services. Different groups based in the Camargue (e.g. conservation organisations, professional fishermen and hunters) have ongoing deliberations on how to best manage water inputs and outputs. The natural habitats of lagoons, brackish and freshwater marshes, temporary pools, halophilous scrubs and steppes are intermingled with human land-use systems adapted for various economic activities such as crop growing, grazing pasture, wildfowl hunting and reed harvesting. The Camargue provides important habitats for charismatic Mediterranean fauna, such as the greater flamingo and the semi-feral Camargue horses and bulls, which attract tourists to the area.

2.1 Climate

The Camargue has a temperate Mediterranean climate. Temperatures in the coldest months (January and February) average between 2 °C and 8 °C, and in the warmest months (July and August) between 19 °C and 29 °C. Nocturnal frost is common in winter. Rain occurs year round, with October being the wettest month (mean participation of 85 mm) and July the driest (mean participation of 21 mm). The region frequently experiences strong, cold winds due to the tramontane (west-blowing) and mistral (north-blowing), these winds are often stronger in winter and spring.

2.2 Habitats

The Camargue contains many emblematic wetlands, including freshwater ponds, wet grasslands, reed beds (Figure 2.1a), semi-permanent brackish marshes (Figure 2.1b), temporary pools (Figure 2.1c), salt marshes and lagoons. In places, the natural habitats have been altered and these wetlands are interspersed with agro-ecosystems dominated by rice paddy fields and saltworks. The natural cycle of Mediterranean marshes is to dry up in summer and re-fill with water over autumn and winter. This cycle allows for the existence of native marsh vegetation and provides suitable habitats for water birds and other fauna. However, over time, human interference has led to a complex network of irrigation and drainage channels being created. Some of these pump freshwater from the Rhône river into the Camargue, primarily to aid rice production. In the south, seawater is pumped into lagoons for salt production. An area of former saltworks under restoration now

¹Chapter image by JAXA, ESA

functions as a natural lagoon complex, with connections to the sea and to irrigation canals. This has enabled native flora and fauna to be re-established. Halophilous scrub, steppes and meadows support native salt-requiring and salt-tolerant flora and cover vast stretches of the flat land. The complicated system of marshes, drainage canals, dry land and ponds results in a highly complex network of habitats in which salinity, temperature, water height and species found can differ significantly throughout time.

2.3 Fauna

The Camargue is well-known for the large variety of bird species found and has been designated an Important Bird Area by Bird Life International[1]. It is one of the most important sites for birds in France and regularly holds more than 20,000 waterbirds. Waterbirds and waders inhabit the marshes, lagoons and ponds, taking advantage of the fish and crustacean prey. Species found all year round include the greater flamingo (Figure 2.2a), white stork, glossy ibis, bittern, great egret, kingfisher, Mediterranean gull, spoonbill and avocet. Many migratory waterbird species visit during the summer months, including little tern, slender-billed gull, redshank and oystercatcher. There are many species of passerines residing both all year round, and over summer during their migration. Over winter, there is an increased richness of birds of prey and duck species. The marshes provide a suitable habitat for many fish and invertebrate species (Figure 2.2b), which are often the prey of birds, and so, support their survival. Common fish species found in the wetlands are mullet (*Liza* spp.), gobies, European eel and *Atherina*. Insects include mosquitos, dragonflies, midges, beetles and *Corixidae*, among many others. Crustaceans inhabiting the wetland include crabs, shrimp, prawns, *Artemia* and *Gammarus*. The Camargue horses (Figure 2.2c) and cattle (Figure 2.2d) are semi-wild and roam the extensive marshland to graze. The Camargue horse is an ancient breed of horse indigenous to the Camargue area. Its origins remain relatively unknown, although it is generally considered one of the oldest breeds of horses in the world. Coypu, beavers and rats can be found along the many canals, while wild boar, foxes and rabbits occupy the steppes. The parsley frog, Mediterranean tree frog, European pond turtle and the Montpellier snake are some of the amphibians and reptilians inhabiting the reserve.





(a) Canal
Tour du Valat



(b) Etang de Vaccares
CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=86826>



(c) Temporary pool in summer
By Tour de Valat

Figure 2.1: Habitats of the Camargue



(a) Flamingos breeding
By Tour de Valat



(b) Dragonfly
By Philippe Lambret



(c) Camargue horses
By Tour de Valat



(d) Camargue bull in saltwort
By Tour du Valat

Figure 2.2: Fauna of the Camargue

2.4 Flora

Aside from agricultural crops, the aquatic, semi-aquatic and terrestrial vegetation in the Camargue comprises of salt-tolerant plants as the tamarisks (Figure 2.3a). The lagoons and ponds contain beds of submerged macrophytes, such as eelgrass, and vegetation growing on the water's surface, such as water-crowfoot. Perennial, flowering plants grow in the marshes and in the saline scrub, steppes and meadows; species found include yellow iris, sea-lavender (Figure 2.3b), *Salicornia* sp. and saltwort. The grazing by livestock of bulls and horses permits the development of a carpet of sea lavenders while several species of saltwort cover the salted and monotonous ground called "sansouire". Along the banks of the Rhône and some canals, you can find narrow borders of trees ('ripisylve') consisting of white poplars, ashes and elms.



(a) French tamarisk

By Christian Ferrer, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=33390045>



(b) Sea lavender

By Tour de Valat

Figure 2.3: Flora of the Camargue

2.5 Human interactions

Humans have lived in the Camargue for millennia, greatly affecting it with drainage schemes, dykes, rice paddies and salt pans. Exploitation of natural resources is the catalyst for human-induced changes in the Camargue, the most prominent of which relate to marsh hydrology. As the prime factor affecting functioning of the wetland, control of water greatly influences what species will live, what plants will grow and, in turn, how much profit can be attained. When water management respects natural cycles, the likelihood of the growth of this native flora is increased. Some areas covered with reeds are harvested in winter; the Charnier-Scamandre ponds are the largest reeded area with 37 marshes (embanked hydrological units) and are mostly covered with common reed or *Phragmites australis*. Reeds are highly useful plants; they can be harvested and used to build roofs, insulate buildings and make paper; they are excellent at filtering out water impurities and capturing excess nutrients; and they provide food, shelter and habitat for wildlife. The Camargue horse is

the traditional mount of the gardians (Figure 2.4a), the Camargue "cowboys" who herd the black Camargue bulls used in bullfighting in southern France.

The use of irrigation and drainage canals is abundant. Each year, 730 million m³ of freshwater are pumped from the Rhône into the Camargue. The majority of this water is used for irrigation of rice fields (Figure 2.4b), but it is also utilised for the production of other crops and pasture fields by avoiding soil salination and enhancing primary production. Fertilisers and pesticides used on farms contribute to water pollution in the Camargue and pesticides used for rice farming have been shown to affect biodiversity. Irrigation also provides important provisioning and cultural services such as reed production, fishing, wildfowl hunting, bird watching and conservation efforts. Controlling the water can create suitable habitats for the flora and fauna involved in the above, e.g. breeding habitats for birds and salinity levels for fish survival. Further, 100 million cubic metres of seawater are pumped into lagoons each year for salt production. This is used to keep the water level stable over summer, leading to increased evaporation in the sunny weather and a higher concentration of salt in the water. Lastly, the creation of canals, agricultural fields, salt pans and roads has resulted in habitat fragmentation which may affect the distribution and abundance of species.



(a) Gardians
By Tour de Valat



(b) Rice field
By Rolf Süßbrich, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=923003>

Figure 2.4: Human presence in Camargue

2.6 ECO POTENTIAL

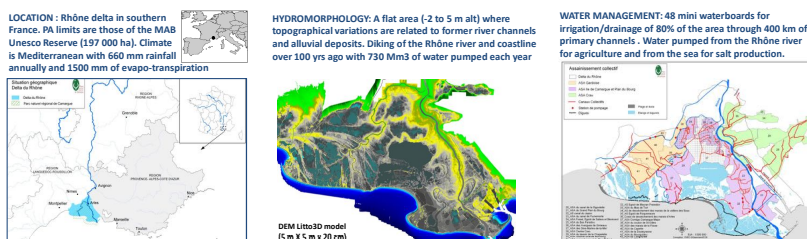


this project is funded by the EU under the grant agreement 641762

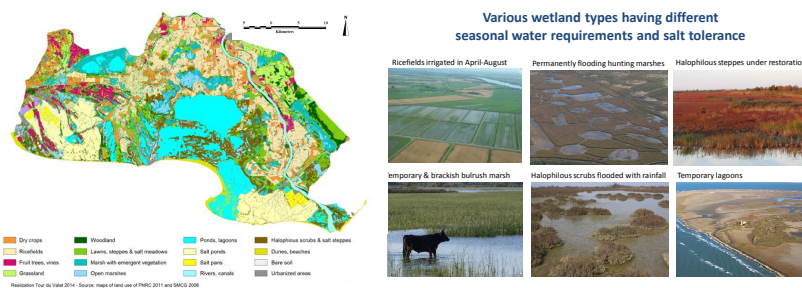
PA : Camargue, France
Contact: Brigitte Poulin (poulin@tourduvalat.org)



A formerly dynamic delta, currently diked and managed through hydraulic structures



A combination of public and privately owned lands under different protection status and anthropogenic influences



Goal: to maintain wetland services while preserving the Mediterranean flora and fauna under global change pressures



Scientific expectations from Ecopotential:

Interdisciplinarity: Synergy between ecosystem knowledge, field and remotely-sensed data to develop relevant, robust and accurate monitoring tools to quantify changes affecting wetland functions and services

Priority needs in terms of management/conservation:

Wetland monthly hydrology: to document gain/loss in Mediterranean biodiversity, habitat shift and extent, changes in management practices (need to detect water below emergent vegetation cover)

A synoptic vision of water and wetland quality: Indirectly estimated through water turbidity, colour, development of submerged macrophytes

Turnover in crop types (due to salinisation): spatial assessment of crops cultivated annually (based on their phenology) to improve collective management of agricultural land and to estimate water allocation to croplands vs wetlands



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Figure 2.5: The Camargue is an ECO POTENTIAL study site.

2.7 Web links

- <http://ecopotential-project.eu/2016-05-24-14-52-12/protected-areas/29-camargue>
- <http://www.tourduvalat.org>
- <https://www.mab-france.org/en/biosphere/reserve-de-biosphere-de-camargue-delta-du-rhone>
- <http://datazone.birdlife.org/site/factsheet/camargue-iba-france>
- <http://www.holiday-weather.com/camargue/averages/>
- <https://en.wikipedia.org/wiki/Camargue>

A satellite image showing the Curonian Lagoon, a large body of water with a complex, irregular shape, surrounded by green and brown land. A thin, curved spit of land separates the lagoon from the Baltic Sea. A blue rounded rectangle with a white border is overlaid on the image, containing the section title.

3. Curonian Lagoon

The Curonian Lagoon¹ is separated from the Baltic Sea by the Curonian Spit. Its surface area is 1,619 km². The Neman River supplies about 90% of its inflows; its watershed consists of about 100,450 km² in Lithuania and Russia's Kaliningrad Oblast. The Lagoon, formed about 7,000 years BCE, is classified as brackish. Water depths average 3.8 meters. A very high biomass production and large biodiversity of communities was recorded in this territory. The whole Lithuanian part of the Curonian lagoon has been designated as NATURA 2000 area (both habitat and bird directive protected territories). The northern part of the Curonian Lagoon is designated as a Baltic Sea Protected territory by HELCOM. The Curonian spit along with the adjusting portions of the lagoon is designated as a National park both in Lithuania and Russian federation. In 2000, the Curonian Spit cultural landscape was as well inscribed on the UNESCO World Heritage List.

3.1 Climate

The climate of the Curonian Lagoon can be described as typical European continental influenced climate with warm, dry summers and fairly severe winters. January is the coldest month with daytime temperatures usually around -5 °CC, but in some cases winter months can be quite colder with temperatures far below zero, about -20 °CC or lower and strong, cold northeasterly winds. Heavy snowfall or even snowstorms are also possible on some days. The weather is often breezy and humid, and the lagoon may ice during winter.

3.2 Habitats

The Curonian Spit (Figure 3.1a) is a 98 km long, thin, curved sand-dune spit that separates the Curonian Lagoon from the Baltic Sea coast. Many rare in Europe types of habitats, listed in the EU Habitats Directive are characteristic of the site. They are of crucial importance for maintenance of biodiversity in the region. Particularly valuable habitat types of the site are estuaries, coastal lagoons, sandy dunes (Figure 3.1b), vast seasonally flooded meadows dunes, active raised bogs, deciduous swamp woods, bog woodland and alluvial forests.

3.3 Fauna

The lagoon and especially the Nemunas delta and its wetlands are considered globally important sites for waterfowl conservation. They serve as one of the most significant staging area for

¹Chapter image by Landsat (NASA)



(a) The Curonian Spit

By A.Savin, FAL, <https://commons.wikimedia.org/w/index.php?curid=59187119>



(b) Sand dunes on the Curonian Spit

By JonasS, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=8164665>

Figure 3.1: Habitats of the Curonian Lagoon

thousands of thousands geese (Figure 3.2a), ducks, swans, and waders on their migration route from Western Europe towards the Arctic. Flooded meadows are important breeding habitats for critically endangered bird species such as the aquatic warbler (Figure 3.2b), great snipe, and several species of terns and waders. The lagoon provides habitats for 50 fish species. Roach, bream, perch are most common species. Deers, roe deers and moose (Figure 3.2c) visit the forests and meadows in the region. Other common mammals are wild boar, fox, marten, raccoon dog, badger, hare, red squirrel, and beaver.

3.4 Flora

Rare and protected plant communities, characteristic exclusively of coastal habitats, distinguish the site. About 500 vascular plant species were recently recorded in the site. The reed beds and dune vegetation (Figure 3.3a) are extremely important both for the coastal protection against erosion along the Curonian spit coast, as a bird breeding habitat and as coastal filter both in the Nemunas delta area and along the continental coast of the lagoon. The vegetation on the Curonian Spit is varied and unique due to the specific climate conditions of the sea coast. Outside the dunes grow birches, solitary pine and fir trees, as well as black alders (Figure 3.3b).



(a) Geese
By Julius Morkunas



(b) Aquatic warbler
CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=663802>



(c) Eurasian Moose
By Gediminas Grazulevicius

Figure 3.2: Fauna of the Curonian Lagoon

3.5 Human interactions

In the 13th century, the area around the lagoon was part of the ancestral lands of the Curonians and Old Prussians. Later it bordered the historical region of Lithuania Minor. After intensive logging in the 17th and 18th centuries, the dunes began moving towards the Curonian Lagoon, burying the oldest settlements. At the turn of the 19th century, it became evident that human habitation would no longer be possible in the area without immediate action. Dune stabilisation work began, and has continued ever since. By the end of the 19th century, a protective dune ridge was formed along the seashore to prevent inland sand migration, and the Great Dune Ridge was reinforced using trees and brushwood hedges. Currently, forests and sands dominate the Curonian Spit. Urbanised areas (eight small settlements) cover just about 6% of the land. After World War II, the southern end of the Spit and the German area south of the river — the part of East Prussia with the city Königsberg located in Sambia — became part an exclave of Russia called Kaliningrad Oblast. At the present time, the port of Klaipėda is in expansion (Figure 3.4).



(a) Sandsvingel

By Kristian Peters, CCBY-SA3.0, <https://commons.wikimedia.org/w/index.php?curid=2825739>



(b) Black alder

By AnRo0002 - Own work, CC0, <https://commons.wikimedia.org/w/index.php?curid=21103166>

Figure 3.3: Flora of the Curonian Lagoon



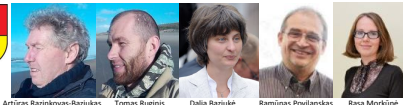
Figure 3.4: Klaipėda's harbour

By Hans Weingartz, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=18274345>

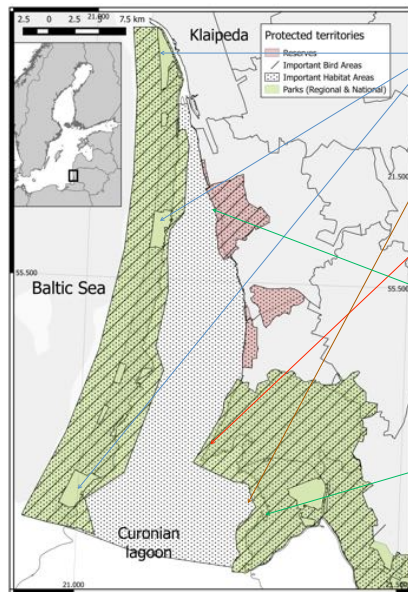
3.6 ECO POTENTIAL



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Protected Area Curonian lagoon



Major Ecosystem Services in Focus

1. Tourism

Recreation
Recreation is popular in the area... (text describing recreation activities)

Birdwatching
Birdwatching is a popular activity in the area... (text describing birdwatching activities)

Amateur Fishery (include ice fishing)
Amateur fishery is popular in the area... (text describing amateur fishing activities)

2. Commercial fishery

Annual catch (in tonnes)

3. Reed exploitation

Reed exploitation is a traditional activity in the area... (text describing reed harvesting)

Conceptual framework

Ecosystem services	Related ecosystem variable groups	Ecosystem variable groups	In situ observations	Earth observations	Statistical Model	Process-based model
Commercial fishing	Fish stocks Water quality Secondary production	Fish populations Census & in situ monitoring data	-	-	ECOSIM* linked to SHYFEM-AQUABC**	
Amateur fishing	Fish stocks Water quality Secondary production	Secondary production In situ monitoring data	-	-	ECOSIM* linked to SHYFEM-AQUABC**	
Recreation	Water quality Bird habitats	Habitat spatial development In situ monitoring data	Land cover (LANDSAT, high or very high resolution images)	TSA ?	SHYFEM-AQUABC** ?	
Reed as provisional service	Reed bed habitats and production	-	-	-	-	

*ECOSIM is a free dynamic ecosystem based fishery and food web model
 **SHYFEM-AQUABC is hydraulic transport 3D FEM model linked to the NPZD and eutrophication model

Measurement	Measurement type	Measurement location	Measurement frequency	Measurement method	Measurement unit
Recreation	Recreation	Recreation	Recreation	Recreation	Recreation
Birdwatching	Birdwatching	Birdwatching	Birdwatching	Birdwatching	Birdwatching
Amateur fishing	Amateur fishing	Amateur fishing	Amateur fishing	Amateur fishing	Amateur fishing
Commercial fishing	Commercial fishing	Commercial fishing	Commercial fishing	Commercial fishing	Commercial fishing
Reed exploitation	Reed exploitation	Reed exploitation	Reed exploitation	Reed exploitation	Reed exploitation

Figure 3.5: The Curonian Lagoon is an ECO POTENTIAL study site.

3.7 Web links

- <http://ecopotential-project.eu/2016-05-24-14-52-12/protected-areas/16-curonian-lagoon>
- <http://www.nemunodelta.lt>
- <https://www.ku.lt>
- <http://www.nerija.lt>
- https://en.wikipedia.org/wiki/Curonian_Lagoon





4. Danube Delta

The Danube Delta Biosphere Reserve¹, Romania, covering about 5100 km², consists of a complex alluvial systems, dominated by wetland ecosystems, of a great socio-ecological and economic importance. From september 1990, the DDBR was listed as a wetland of international importance especially as waterfowl habitat under the Ramsar Convention, and is among the largest of the 600 or so wetlands so recognised. The universal natural heritage value of the reserve was recognised in December 1990 by the inclusion of the strictly protected areas in the World Heritage List under the World Heritage Convention.

4.1 Climate

The climate of the Danube Delta is continental, with strong influences from the vicinity of the Black Sea and its prevalent amphibian environment. It is the driest and sunniest region of Romania. The mean annual temperature is 11 °C (-1 °C in January and 22 °C in July), with mean precipitation between 400 mm/year and 300 mm/year, decreasing from west to east. Evaporation is around 1,000 mm/year, amplified by strong and frequent winds, resulting in long periods of drought in the summer. The northwest winds cause frequent storms in spring and autumn. In the interior of the delta, the continental character of the climate is very pronounced.

4.2 Habitats

The Danube River catchment spreads across nineteen European countries before reaching the West coast of the Black Sea. The Danube Delta falls within the Pannonian steppe ecosystem of eastern Europe. It hosts 23 natural ecosystems, but due to the extent of wetlands an aquatic environment is prevalent; a terrestrial environment is also present on the higher grounds of the continental levees, where xerophile ecosystems have developed. Between the aquatic and terrestrial environments is interposed a swampy, easily flooded strip of original flora and fauna, with means of adaptation to water or land, depending on the season or hydrological regime (Figure 4.1). At the contact between freshwater and sea water, some special physical, chemical and biological processes take place, which have led biologists to consider this area as a very different ecosystem called beforedelta.

¹Chapter image from ESA, CC BY-SA 3.0 IGO



Figure 4.1: Danube Delta in Romania

By Diego Delso, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=50208527>

4.3 Fauna

Situated on major migratory routes, and providing adequate conditions for nesting and hatching, the Danube Delta is a magnet for birds from six major ecoregions of the world, including the Mongolian, Arctic and Siberian. There are over 320 species of birds found in the delta during summer, of which 166 are hatching species and 159 are migratory. The most important are the tufted duck, red-crested pochard, mallard, greylag goose, pygmy cormorant, purple heron, Eurasian spoonbill, great white pelican, Dalmatian pelican (Figure 4.2a). Over one million individual birds (swans, wild ducks, coots, etc.) winter here. The delta hosts numerous species of fish, such as the carp, pike, perch, sheat-fish, and freshwater sturgeon (Figure 4.2b). Among the mammals, there is the European otter (Figure 4.2c), mink, little ermine, and wild cat. On the brink of disappearing from the delta, the wolf and the fox.



(a) Pelicans

By Goliath, CC BY 1.0, <https://commons.wikimedia.org/w/index.php?curid=5150611>



(b) European Sturgeon

By User:Cacophony, CC BY 2.5, <https://commons.wikimedia.org/w/index.php?curid=1027971>



(c) European Otter

By Drew Avery, CC BY 2.0, <https://commons.wikimedia.org/w/index.php?curid=32972272>

Figure 4.2: Fauna of the Danube Delta

4.4 Flora

Reed plants and floating reed islands (called plaur in Romania) are the most common and well known components of the Danube Delta. Vegetation of this ecosystem consists of the common reed and, on near river banks, mace reed/cattail, sedge, Dutch rush and brook mint. The plaur are a mixture of reed roots, grass and soil, usually floating or anchored to the riverbed. As a rule, the reed surrounds the lakes and ponds (Figure 4.3a), and slowly invades the water surface together with floating vegetation as the European white water lily (Figure 4.3b). The firm land of the delta used to be covered with large groves of willow trees, which have been cut down almost entirely and replaced with Canadian poplars. On the river banks kept in their natural state (Figure 4.3c), small groves of willow trees can still be found, mixed with White Poplar. Occasionally, the willow trees form corridors along the arms and bigger channels of the Danube. On the levees of Letea and Caraorman, mixed forests of oak with various trees, shrubs and vines grow on sand dune areas.



(a) Reeds

By TriviaKing, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=38237564>



(b) European white water lily

By la Nicu Farcaș, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=62454738>



(c) Riparian forest

By Von Danutz, Gemeinfrei, Public domain, <https://commons.wikimedia.org/w/index.php?curid=528684>

Figure 4.3: Flora of the Danube Delta

4.5 Human interactions

The Danube Delta is perhaps the least inhabited region of temperate Europe. On the Romanian side live about 20,000 people, of whom 4,600 live in the port of Sulina, which gives an average density of approx. two inhabitants per km². The rest of the population is scattered among 27 villages, of which only three, all situated marginally, have more than 500 people (in 2002). The city of Tulcea (Figure 4.4), at the western edge of the delta, represents the node of the region and the gate to the delta. Its acute isolation and harsh conditions of living, based mainly on subsistence, made the Danube Delta a place of emigration, or transit at least. Very few of those born in the region stay there through adulthood; at the same time, the origins of its inhabitants vary widely, as people from many parts of Romania can be found in the delta. Due to the fact that areas are difficult to be reached on the ground, people inhabiting here preserves their traditions, and in particular case of Danube Delta, the large number of ethnic communities (i.e. Russians, Greeks, Ukrainians, Turks, Italians and Romanians) gives to the area a rich cultural heritage. Despite the small human population living in the area, the Danube deltas is strongly influenced by human activity that usually occurs at catchment level. As consequence of increasing pollution and eutrophication of the waters



4.5 Human interactions



of the Danube, and decades of exploitation and poor fishing regulations, the fish population has been visibly reduced.



Figure 4.4: Tulcea's lighthouse

By Pyretus, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=3257827>



4.6 ECO-POTENTIAL

ECO-POTENTIAL: IMPROVING FUTURE ECOSYSTEM BENEFITS THROUGH EARTH OBSERVATIONS



DANUBE DELTA - Romania

Location and Size

Located where the Danube River flows into the North-Western Black Sea, Western point 28° 10' 50" E (Cotul Pisicilor), Eastern point 29° 42' 45" E (Sulina), Northern point 45° 27' N (Chilia arm, km 43) and Southern point 44° 20' 40" N (Midia cape) (Figure 1).

Total surface of 5,165 km² is shared between Romania (86%) and Ukraine (14%). The Danube Delta is the second largest in Europe, after that of the Volga River.

Biodiversity and Protection

Due to its diversity, both biological and cultural, the area has multiple conservation status (Figure 2):

Globally

- UNESCO World Heritage Sites,
- Biosphere Reserve (since 1990) and
- Ramsar site due to its importance for migratory birds.

European Union (part of Natura 2000 network)

- ROSPA0031 Danube Delta and Razelm – Sinoie Lagoon System,
- ROSPA0076 Black Sea,
- ROSCI0065 Danube Delta,
- ROSCI0066 Danube Delta – marine area, and
- ROSCI0237 – Methanogen submarine structures St. George.

National Level (IUCN category I)

- 20 strictly protected areas covering 509 km²

1. ROSCA - BUHAIOVA (9 625 ha)
2. RĂDUREA LETEA (2 825 ha)
3. RĂDUCIU (2 580 ha)
4. NEBURJU (125 ha)
5. VĂTAFU - LUNGULET (1 625 ha)
6. RĂDUREA CARAORMAN (2250ha)
7. SĂRĂTURU MURGHIOȘ (87 ha)
8. ARINȘUL ERENCIUC (50 ha)
9. ÎNSULĂ POPINA (98 ha)
10. SĂCALIJA JERĂCANI (21 410 ha)
11. PERTEAȘCA - LEAHOVA (4125ha)
12. CAPUL DOLOȘMAN (125 ha)
13. GRINDUL LUPDLR (2 075 ha)
14. ISTRIA - SINOIE (400 ha)
15. GRINDUL CHTUC (2 300 ha)
16. ROTUNDU (1228 ha)
17. POTCOAVA (625 ha)
18. BELCIUG (120 ha)
19. ÎNSULĂ CĂPRAȘ (117 ha)
20. PRINDU CU PĂȘĂRI (187 ha)

Reed forms one of the largest compact areas in the world covering 2400 km².

Letea and Caraorman forests represent the northern limit for two rare species of oak (frequently found in the south of the Italian and Balkan peninsulas).

About half of the world's white pelicans and over 60 % of the world's pygmy cormorants breed within the Danube Delta.

Nearly all of the world's red-breasted geese are wintering here.

Fauna comprises terrestrial and aquatic species:

3272 species of invertebrates (from them 2219 insects), 84 species of fish, 10 amphibian species, 11 species of reptiles, 315 birds species and 41 species of mammals.

Flora from the Danube Delta it is formed by 955 species and 64 subspecies.

34 habitat types listed on the Habitat directive annex can be found here from which seven are EU priority ones (Table 1).

Ecosystem services

Ecosystem types distribution is presented in the Figure 3, it can be noticed that wetland and aquatic ecosystems are the most dominant ones.

Provisioning: fish captures, water (for drinking), reed harvesting as fodder, raw materials (reed, wood, sand), honey, hunting (as wild food), forestry (especially willow and poplar), agriculture (mainly eco and bio certified production)

Regulation and maintenance: mechanical filtration done by plants, filtration done by mussels, biogeochemical cycles occurring in aquatic ecosystems, dilution in lakes, rivers, sea and sediments, transport and storage of sediment by Danube river and delta's lakes and wetlands, pollination by insects; seed dispersal by insects, birds and other animals, important reproduction area for fish and bird populations, gas emissions as result of decomposition processes, carbon sequestration.

Cultural services: leisure and ecotourism, spiritual value (different religious beliefs), human ethno-cultural diversity, bird watching, boating, sport fishing/hunting, research and monitoring activities.



Figure 1. Location of Danube Delta Biosphere Reserve in Europe

Figure 2. Protected areas within the Danube Delta

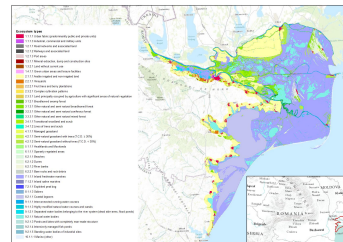


Figure 3. Distribution of land cover types into Danube Delta (www.land.copernicus.eu)



Table 1. Habitat types within the Natura 2000 sites of community importance in the Danube Delta

Site of community importance	Main habitat types (EU habitat code)	Natural Priority 2000 sites (EU habitat type code)	Priority 2000 sites (EU habitat type code)
ROSC0065	1110, 1210, 1310, 1410, 2110, 2160, 2190, 3130, 3140, 3150, 3160, 3260, 3270, 40C0, 6410, 6420, 6430, 6440, 6510, 91F0, 92A0, 92D0	1150, 1530, 2130, 6120, 62C0, 7210, 91AA	
ROSC0066	1110, 1130, 1140, 1160		
ROSC0237	1180		

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Danube Delta Biosphere Reserve <http://www.ddbra.ro/en>
Danube Delta National Institute <http://www.ddni.ro>

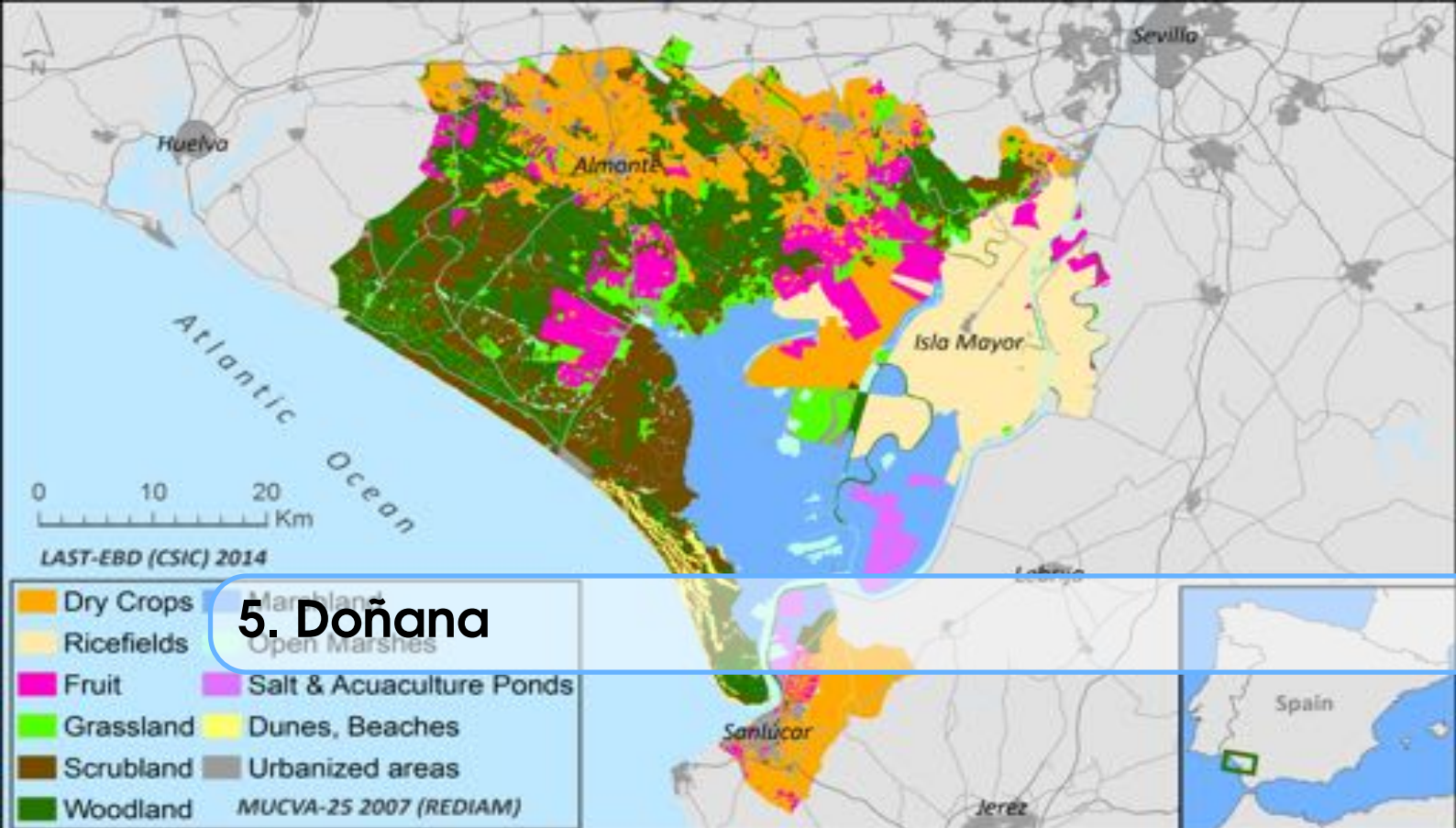
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641762

Figure 4.5: The Danube Delta is an ECO-POTENTIAL study site.

4.7 Web links

- <http://ecopotential-project.eu/2016-05-24-14-52-12/protected-areas/33-danube-delta>
- www.unibuc.ro
- <http://www.ddbra.ro/en/index.php>
- https://en.wikipedia.org/wiki/Danube_Delta





Doñana National Park is a natural reserve in Andalusia, southern Spain, in the provinces of Huelva (most of its territory) and Seville. The Doñana National Park (537 km²) is a protected area since 1969. Currently it is a UNESCO Biosphere Reserve (since 1980), a Ramsar Site (1982), a Natural World Heritage Site (1984) and it is integrated in the Natura 2000 network, which also includes the surrounding Natural Park with a similar extent. The park is twinned with the Camargue Biosphere Reserve. The two parks share a number of characteristics including significance for bird-life and semi-feral horses, and proximity to a pilgrimage site (Saintes-Maries-de-la-Mer and the Hermitage of El Rocío).

5.1 Climate

Doñana marshes have a typical Mediterranean climate. Average rainfall is 549 mm (range: 169.8–1027.8, 35 years). Average minimum temperature during the coldest month (January) is 4.6 °C, and average maximum temperature in the warmest month (July) is 32.6 °C. The hydrological cycle starts in September and usually reaches maximum flood levels during February, driven by the rainfall regime. In late spring, evaporation becomes the most important factor in the water balance, and the marshes dry up slowly by the end of July. At this time, the aquifer plays a central role in maintaining water levels and permanent lagoons. As is the case for most continental wetlands, interannual variability is driven by meteorological patterns.

5.2 Habitats

The park is an area of marshes, shallow streams, and sand dunes in Las Marismas, the delta where the Guadalquivir River flows into the Atlantic Ocean. It contains one of the the largest wetland in Western Europe, an intricate matrix of marshes (Figure 5.1a), phreatic lagoons, and a 25 km-long coastal dune ecosystem with its shoreline and representative Mediterranean terrestrial plant communities (Figure 5.1b). The ecosystem of the mobile dunes (Figure 5.1c), also known as transdunes, which are formed by the prevailing south-west wind, is almost nonexistent elsewhere in the Iberian Peninsula.

5.3 Fauna

There are 20 species of freshwater fish cataloged in the Park, 10 of amphibians, 13 of reptiles, 37 of mammals and 360 non-marine birds, of which 127 have nesting seasons in the park. The protection of the population of Spanish imperial eagle (Figure 5.2a) and the marbled teal are among the main





(a) Wetland

CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=551069>



(b) Riparian vegetation

By Technische Fred, CC BY 2.5 nl, <https://commons.wikimedia.org/w/index.php?curid=3260151>



(c) Dunes

By Tyros.andi, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=48751091>

Figure 5.1: Habitats of Doñana

goal of the park. Reptiles found in Doñana Park include Montpellier snake, ocellated lizard, Iberian newt, European pond Turtle, and the common chameleon (Figure 5.2b). Among mammals, the Iberian lynx (Figure 5.2c) and the European otter are particularly valuable and endangered. The Spanish red deer and the Egyptian mongoose are also present. In Doñana there are two indigenous breeds of horse: the marsh horse and the Retuertas horse; the latter is one of the oldest European breeds, dating to perhaps 1000 BC, and the only one living in the wild and isolated from other populations.

Di Antonio Lucio Carrasco Gómez - Donada por el autor a Usuario:Digallos, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=457640>

5.4 Flora

There are many species of flora in the park: trees, including pines, flowers such as roses, and shrubs. Of special interest are the species *Vulpia fontqueran*, *Tursica Linaria*, *Juniperus macrocarpa* (maritime juniper), *Micropyropsis tuberosa*, *Hydrocharis morsus ranae* or *Thorella verticillatinundata*, many of them endangered. Other notable species in the park, of the more than 875 indigenous to the Doñana ecosystems are: oleander, oak, the sea wallflower, sweet saltwort, the prickly tumbleweed, marram grass, heather, camarina, lavender, sea holly, reed, carnation, bulrush, common fern, sage-leaved rock rose, rushes, labiérnago (Figure 5.3a), sea spurge, mastic, sedge, palm, pine, Scotch broom, rosemary, juniper, sage-leaved rock rose (Figure 5.3b), gorse, thyme, spurge and blackberries.

5.5 Human interactions

The park visitors centre is located in the Acebrón Palace (Figure 5.4a), built in the 1960s as a residence and hunting lodge. Various impact studies and environmental groups have warned repeatedly of problems that threaten the region's flora, fauna, water and soil. While the pressure





5.5 Human interactions

of urbanization and its various demands on local ecosystems has been a concern throughout the years, this is not the only associated risk factor. The park is used by pilgrims on their way to the Romería de El Rocío (Figure 5.4b). As this event attracts a million pilgrims annually, it has a significant negative impact on the park's eco-system. UNESCO has reviewed the nomination of the park for inclusion in its "List of World Heritage in Danger" several times, but has yet to add it. The ecosystem has been under constant threat by the draining of the marshes, the use of river water to boost agricultural production by irrigating land along the coast, water pollution by upriver mining, and the expansion of tourist facilities. Non-native species such as eucalyptus, *Acacia longifolia*, *Gomphocarpus fruticosus*, *Nicotiana glauca* or *Carpobrotus edulis* (cat's claw) are removed by the park service.





(a) Spanish imperial eagle

By Antonio Lucio Carrasco Gómez, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=457640>



(b) Common chameleon

By Benny Trapp, CC BY 3.0, <https://commons.wikimedia.org/w/index.php?curid=12631288>



(c) Iberian Lynx

By Programa de Conservación Ex-situ del Lince Ibérico, CC BY 3.0 es, <https://commons.wikimedia.org/w/index.php?curid=2419253>

Figure 5.2: Fauna of Doñana



(a) Labiérnago
CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=462824>



(b) Sage-leaved rock rose
By ghislain118, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=15946756>

Figure 5.3: Flora of Doñana



(a) Palacio del Acebrón
By José Luis Filpo Cabana, CC BY-SA 4.0-3.0-2.5-2.0-1.0, <https://commons.wikimedia.org/w/index.php?curid=15136636>



(b) Pilgrimage of El Rocío
By Avicentegil, GFDL, <https://commons.wikimedia.org/w/index.php?curid=6934243>

Figure 5.4: Human presence in the Doñana wetland

5.6 ECOPOTENTIAL



Figure 5.5: Doñana is an ECO POTENTIAL study site.

5.7 Web links

- <http://www.ecopotential-project.eu/protected-areas/34-donana-park>
- <http://www.ebd.csic.es/en/inicio>
- <http://donana-nature.com>
- https://en.wikipedia.org/wiki/Doñana_National_Park



6. Wadden Sea

The Wadden Sea¹ is an international, highly productive estuarine area, and one of the largest coastal wetlands in the world. Situated abreast mainland Europe in the south-eastern portion of the North Sea, it borders Germany, the northern portion of the Netherlands, and western Denmark, thereby requiring tri-lateral cooperation in the management and protection of the system. The area has both UNESCO World Heritage and Natura 2000 status. It is approximately 500 km long with a surface area of around 9000 km², a quarter of which is located within the Netherlands.

6.1 Climate

The predominant wind direction is southwest, which causes a moderate maritime climate, with warm summers and cool winters, and typically high humidity. This is especially true close to the Wadden Sea coastline, where the difference in temperature between summer and winter, as well as between day and night is noticeably smaller than it is in the southeast of the country. Ice days—maximum temperature below 0 °C—usually occur from December until February, with the occasional rare ice day prior to or after that period. Freezing days—minimum temperature below 0 °C—occur much more often, usually ranging from mid-November to late March, but not rarely measured as early as mid-October and as late as mid-May.

6.2 Habitats

The Wadden Sea stretches from Den Helder, in the northwest of the Netherlands, past the great river estuaries of Germany to its northern boundary at Skallingen north of Esbjerg in Denmark along a total length of some 500 km and a total area of about 10,000 km². Within the Netherlands it is bounded from the IJsselmeer by the Afsluitdijk. For all its extension, it is characterized by extensive tidal mud flats (Figure 6.1a), saltmarshes, and deeper tidal creeks between the mainland and chain of islands which denote the outer boundary between the Wadden and North Sea. This mosaic of systems interacts dynamically due to wind, wave, tidal and riverine/runoff forcing functions, resulting in the creation of different types of coastlines. The common composition of such a coastline includes one or all of the following : i) a barrier coast with lido, barrier islands, mudflat systems and coastal lagoons, ii) deltaic systems and iii) bar-built and funnel-shaped estuaries. In the case of the Wadden Sea, all aspects are included to varying degrees. Almost the entire region is submerged at high tide (Figure 6.1b), and half the area (the mud flats where many birds feed) is exposed during low tide. As with many lagoonal and estuarine systems, the variety of habitats and

¹Chapter image from ESA, CC BY-SA 3.0 IGO

high productivity lends itself to having a large biodiversity of invertebrates, fish, birds and marine mammals.



(a) Mudflat

By Bermicourt, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=10863704>



(b) A semi-flooded environment

By Ralf Roletschek, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=2884214>

Figure 6.1: Habitats of the Wadden Sea

6.3 Fauna

The Wadden Sea is famous for its rich flora and fauna, especially birds. Hundreds of thousands of waders (shorebirds), ducks, and geese use the area as a migration stopover or wintering site, and it is also a rich habitat for gulls and terns. The Eurasian spoonbill (Figure 6.2a) has a sizeable population living here. Harbour porpoises (Figure 6.2b) and Atlantic white-beaked dolphins (seasonally) which once were locally extinct but have re-colonized into the area, and these two are the only resident cetaceans in present days. Wadden Sea is an important habitat for two species of seals, harbor and grey seals (Figure 6.2c). Larger fish including sturgeons, rays, Atlantic salmon, brown trout, and others like lacuna snails and oyster beds that were once found elsewhere in the region have disappeared as well, as the actual size of the Wadden Sea was reduced to about 50% of the original sea, and nutrients from the Rhine river no longer flow into the sea, resulting in about 90% of all the species which historically inhabited the Wadden Sea being at risk.

6.4 Flora

Mainly sand reed, blue sea holly and European sea rocket (Figure 6.3a) grow on the sand bar, while cordgrass (Figure 6.3b) and other phanerogams grow below the high tide level and are regularly submerged. In the young dune valleys behind the sand bar is where you'll find elderberry and sea-buckthorn and the older dunes provide fertile soil for rarer species such as the orchid. There is a more diverse vegetation in the older dunes on the north and south banks. Mostly crowberry and polypodium grow on the north bank whilst the south bank attracts more crustose lichen. The dune planes are mostly covered in heather. Grassland can be found in many varieties. Agricultural grassland consists mainly of perennial rye-grass and weeds such as chickweed and rumex.



(a) Eurasian spoonbill
By Creando, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=252998>



(b) Harbour porpoise
By AVampireTear, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=3935343>



(c) Harbor seals
By Mhaesen, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=4592045>

Figure 6.2: Fauna of the Wadden Sea



(a) European sea rocket
By Jürgen Howaldt, CC BY-SA 2.0 de, <https://commons.wikimedia.org/w/index.php?curid=379490>



(b) Cordgrass
By Jürgen Howaldt, CC BY-SA 2.0 de, <https://commons.wikimedia.org/w/index.php?curid=1329193>

Figure 6.3: Flora of the Wadden Sea

6.5 Human interactions

Long before the beginning of the modern era, there were already humans inhabiting the Wadden area. Up to 800 AD, most inhabitants lived on terpen (artificial mounds). Around 1000, dike construction began. Monks were instrumental in this activity, among others those of the monastery of Aduard. But earlier attempts had been undertaken to dam the sea. At the present time, the Wadden Sea is one of the world's seas whose coastline has been most modified by humans via systems of dikes and causeways on the mainland and low-lying coastal islands. Texel is the largest and most populated of these islands (Figure 6.4a). The Wadden Sea draws a high volume of tourists in many forms, including but not limited to island visitors, game fisherman, boating and mudflat walking excursionists (Figure 6.4b), and commercial operations. Commercial activities include industrial fishing for commercial fish and shellfish; recently aquaculture for shellfish has been introduced. One of the objectives of the application of protected area status to the Wadden Sea is to limit the degree of exploitation by the commercial shellfish industry whose high degree of pressure through mussel extraction has significantly impacted the system's capacity to support the large volume of migratory birds.



(a) Texel's Lighthouse

Public domain, <https://it.wikipedia.org/w/index.php?curid=696972>



(b) Camping in Ameland

By TomAlt, Public domain, <https://commons.wikimedia.org/w/index.php?curid=1346076>

Figure 6.4: Human presence in the Wadden Sea

6.6 ECO POTENTIAL

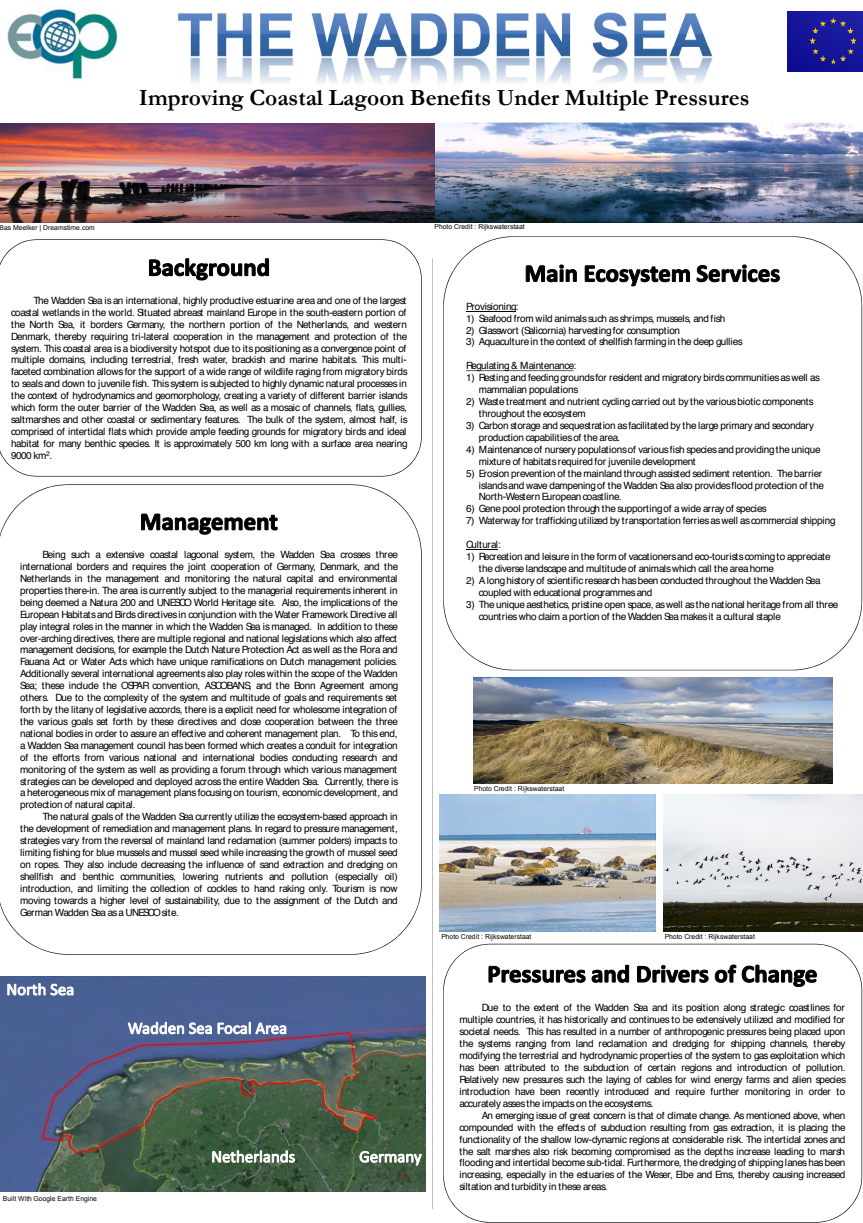


Figure 6.5: The Wadden Sea is an ECOPOTENTIAL study site.

6.7 Web links

- <http://www.ecopotential-project.eu/protected-areas/25-the-wadden-sea-dutch-delta-area>
- <https://www.deltares.nl/en/>
- <https://www.waddensea-worldheritage.org>
- https://en.wikipedia.org/wiki/Wadden_Sea



7. Glossary

1

- Bog** A bog is a wetland that accumulates peat, a deposit of dead plant material—often mosses, and in a majority of cases, sphagnum moss (Keddy, P.A. 2010. *Wetland Ecology: Principles and Conservation*, (2nd edition). Cambridge University Press, ISBN 978-0521739672).
- Delta** A river delta is a landform that forms from deposition of sediment carried by a river as the flow leaves its mouth and enters slower-moving or standing water (Elliot, T. 1986. *Deltas*. in H. G. Reading (ed.). *Sedimentary environments and facies*. Backwell Scientific Publications, Oxford).
- Dune** A dune is a hill of loose sand built by aeolian processes (wind) or the flow of water (first edited by Fowler, H.W.; Fowler, F.G. (1984). Sykes, J.B., ed. *The Concise Oxford Dictionary of Current English* (7th ed.). Oxford: Clarendon Press. ISBN 0-19-861132-3).
- Ecosystem** An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system (Tansley (1934); Molles (1999), p. 482; Chapin et al. (2002), p. 380; Schulze et al. (2005); p. 400; Gurevitch et al. (2006), p. 522; Smith & Smith 2012, p. G-5).
- Estuary** An estuary is a partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea (Pritchard, D. W. (1967). "What is an estuary: physical viewpoint". In Lauf, G. H. *Estuaries*. A.A.A.S. Publ. 83. Washington, DC. pp. 3–5).
- Lagoon** A lagoon is a shallow body of water separated from a larger body of water by barrier islands or reefs (Davis, Richard A., Jr. (1994). *The Evolving Coast*. New York: Scientific American Library. pp. 101, 107. ISBN 9780716750420).
- Marsh** A marsh is a wetland that is dominated by herbaceous rather than woody plant species (Keddy, P.A. 2010. *Wetland Ecology: Principles and Conservation* (2nd edition). Cambridge University Press, Cambridge, UK. 497 p).
- Meadow** A meadow is a field habitat vegetated by grass and other non-woody plants (grassland) (Maryland Department of Natural Resources, "Maryland's Wild Acres." Retrieved June 18, 2013).
- Mudflat** A mudflat, also known as tidal flats, are coastal wetlands that form when mud is deposited by tides or rivers. Most of the sediment within a mudflat is within the intertidal zone, and thus the flat is submerged and exposed approximately twice daily.

¹Chapter image: Reed flamingo coot tamarix stilt. By Jean Jalbert



- Pond** A pond is a body of standing water, either natural or artificial, that is usually smaller than a lake (*"Definition of POND". www.merriam-webster.com*).
- Spit** A spit or sandspit is a deposition bar or beach landform off coasts or lake shores. It develops in places where re-entrance occurs, such as at a cove's headlands, by the process of longshore drift by longshore currents *Duane, D.B. and James, W.R., 1980, "Littoral transport in the surf zone elucidated by an Eulerian sediment tracer experiment." Journal of Sedimentary Petrology. vol. 50, p. 929-942*.
- Swamp** A swamp is a wetland that is forested. Many swamps occur along large rivers where they are critically dependent upon natural water level fluctuations (*Keddy, P.A. 2010. Wetland Ecology: Principles and Conservation (2nd edition). Cambridge University Press, Cambridge, UK.*).
- Wetland** A wetland is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem (*Department of Environmental Protection State of Florida Glossary". State of Florida. Retrieved 2011-09-25.*).





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