Mediterranean Wetlands Observatory

THEMATIC COLLECTION
SPECIAL ISSUE
2

Land Cover

Spatial dynamics in Mediterranean coastal wetlands from 1975 to 2005

Ramsar

MedWet

TOUR DU VALAT

The MWO, which is coordinated by the Tour du Valat, was created in 2008 within the framework of the MedWet initiative to monitor and evaluate the status and trends of Mediterranean wetlands, and to further the knowledge of their multiple benefits. Its ultimate goal is to improve wetland conservation and management by providing information to as many people as possible, in particular political decision-makers and the general public, in line with axis 1 of the MedWet strategic vision. The MWO operates thanks to a group of partners who are committed to this vision, the Plan Bleu, EKBY, UNEP-WCMC, Wetlands International and many others - www.medwetlands-obs.org.

MedWet is a regional initiative of the Ramsar Convention, which includes in particular the 27 countries surrounding the Mediterranean. Its aim is to promote and implement the protection and rational use of Mediterranean wetlands - www.medwet.org.

The Tour du Valat, a non-profit foundation, has been developing multidisciplinary research programs on the functioning of Mediterranean wetland for over 50 years. The teams have the mission "to stop the loss and destruction of these ecosystems and their natural resources, to restore wetlands and to promote their rational use" - www.tourduvalat.org.

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This work may be cited as:

Mediterranean Wetlands Observatory, 2014. Land cover - Spatial dynamics in Mediterranean coastal wetlands from 1975 to 2005. Thematic collection, issue #2. Tour du Valat, France. 48 pages. Translated by Charles La Via and Adam Clark. ISBN: 2-910368-60-2.

ISBN: 2-910368-60-2

Photography credits:

Cover: Hellio & Van Ingen (main photo and upper band), Tour du Valat (back cover).

Layout: Atelier Guillaume Baldini

Impression : Printed on Balance recycled paper by Pure impression (October 2014).

FOREWORD

Although they are among the ecosystems that globally contribute the most to human well-being, wetlands are also the most severely threatened by human activities and the effects of climate change. In spite of decades of wetland conservation action, they continue to disappear more rapidly than other ecosystems.

We need to be able to map and quantify these losses to raise the awareness of policy makers and the general public about the situation of these exceptional habitat areas. Satellite imagery provides a powerful tool that is often indispensable for achieving these objectives, but which had not yet been used at the scale of a big region like the Mediterranean Basin.

For over a decade, the European Space Agency has been committed to helping the Ramsar Convention and its contracting parties learn how satellite tools can be used to monitor wetlands. I am pleased to see that this long-term project, which we initiated with the Ramsar Convention Secretariat and its scientific and technical review panel (STRP), has resulted in a regional project as ambitious as GlobWetland II. We have been able to train people from southern Mediterranean countries and the Mediterranean Wetlands Observatory (MWO) on how satellite imagery and remote sensing can be used to monitor the various habitat areas in Mediterranean wetlands. Today, this important undertaking, initiated by the GlobWetland II project, has an impact beyond the 10 countries initially concerned, and now covers 22 of the 27 Ramsar MedWet Initiative countries. Our partnership with the MWO has made it possible to establish the first precise and quantitative report on Land Use / Land Cover (LULC) change in over 200 coastal wetlands in the Mediterranean Basin.

The results obtained through this joint GlobWetland II-MWO project, which are essentially based on remote sensing, are in no way incompatible with the field work required to validate and complete the satellite information. Remote sensing and field surveys are complementary and together provide a precious set of tools for monitoring wetlands. We can optimistically expect a significant improvement in these reports, thanks to the Sentinel satellites that are currently being placed in orbit. The Sentinels are part of the European Copernicus programme, which aims to provide Europe with the operational capacity and autonomy to observe and monitor the Earth, and especially to provide the continuous and accurate satellite data that are essential for monitoring the environment and ensuring the safety of its citizens. These satellites will provide cutting edge monitoring instruments for the precise and continuous monitoring of our fragile wetlands.

The basic research conducted by the MWO confirms the importance of urban pressure and agricultural practices on coastal wetlands. In addition, the land cover change observed in Mediterranean coastal wetlands from 1975 to 2005 explains many of the changes observed in their biodiversity, which were described in a previous MWO study.

This research is the fruit of close collaboration between the European Space Agency and the MWO, which has enabled us to show that the GlobWetland II project is indispensable for the Ramsar Convention and its MedWet regional initiative. It has also given the MWO and MedWet national focal points a tool for measuring the effective management of protected natural areas (Ramsar sites), and is a precious decision making aid tool for major territorial issues such as agricultural development, coastal planning, and sustainable water abstraction management.

MARC PAGANINI
European Space Agency (ESA)

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CASE STUDIES

SUMMARY

*NB: All terms marked by an * are defined in the glossary at the end of this report.*

Thirty years of land cover change in Mediterranean coastal wetlands

Wetlands are essential for biodiversity and to the people who make use of their resources or benefit from the numerous services they provide. Yet, they are disappearing throughout the world. For example, in the Mediterranean Region, nearly 50% of total wetland area disappeared in the 20th century. Coastal wetlands are some of the most important in terms of size and biodiversity, but they are also under very significant pressure. The highly urbanized Mediterranean coast, indeed, has a high population density and a concentration of human activities.

In this report, the Mediterranean Wetlands Observatory presents land cover change in Mediterranean coastal wetlands from 1975 to 2005, according to a methodology developed by the GlobWetland-II project. Maps of 214 coastal wetlands, in 22 Mediterranean countries, were created for 1975, 1990, and 2005 using satellite imagery. These maps were then used to calculate indicators, which provide information on the changing area of the various habitats they contain.

How did Mediterranean wetland habitat area change from 1975 to 2005?

- The area of natural Mediterranean wetland habitats decreased by 10% from 1975 to 2005 (a total loss of 1,248 km² for the 214 sites). There was a steady loss throughout the period studied. Marshes and wet meadows appear to be the most significantly affected habitats (a loss of 10% and 43% respectively). However, the large bodies of water were not always spared: for instance, the Egyptian lagoons in the Nile delta, so important for biodiversity, lost a dramatic 398 km², and other major Mediterranean lakes were also transformed.
- At the same time, the area of artificial wetland habitats increased by 54% (661 km² for the 214 sites). This artificialisation occurred especially from 1975 to 1990, with the rapid development of artificial water reservoirs (+700%).
- The area of natural non-wetland habitats decreased by 20% from 1975 to 2005 (a total loss of 686 km²), mainly from 1975 to 1990. This decline may have a negative impact on the natural functioning of wetlands, by disconnecting them from a broader network of natural habitats.
- For methodological reasons, the losses discovered represent minimum values, and are probably underestimated.
- These land cover changes may be linked to the decreasing populations of certain species dependent on the natural wetland habitats that have been the most depleted. In addition, the increase in artificial wetland habitats partly explains the decline in specialist species* observed in Mediterranean wetland bird communities. Although they may be beneficial to certain waterbirds, artificial wetland habitats do not host the same levels of biodiversity as natural habitats.

Why was there such a transformation of wetland habitats during these 30 years?

- During the study period, agriculture was the primary direct cause of natural wetland habitat loss: 7% of the natural wetland habitats present in 1975 in the sites studied had been converted into agricultural areas by 2005. Irrigated agriculture expanded significantly during this period: wetlands are flat, with fertile soil and abundant water that are favourable areas for developing this kind of agriculture.
- Urbanization had less direct impact on natural wetland habitats. Only 0.75% of the natural wetland habitats present in 1975 in the sites studied were urbanized. Urbanization is understood in the broad sense of the term, which includes the development of cities as well as transportation infrastructure, and commercial and industrial areas. Nonetheless since 1990, urbanization seems to be the principal driving force behind the changes we observed. It has especially eaten into peri-urban agricultural areas, and we observed that these lost agricultural areas were displaced to surrounding natural wetlands. More generally speaking, this process concerns all natural habitat areas.
- Water is a rare and unevenly distributed resource in the Mediterranean region, and the increasing abstraction of water and intensified water management practices have a major impact on natural wetland habitats. Some of the changes documented in this study include the transformation of wetland hydrological regimes, conversion of natural wetlands into artificial wetlands, and decreased flows in watercourses.

- The receding coastline, which is the result of the combined effects of rising sea level due to climate warming and the lack of sediments provided by rivers, has already resulted in the disappearance of some coastal wetlands that have been submerged. This process, which affects human activities on the coast, may also be an opportunity to renaturalise* certain areas that were used for farming or to re-flood degraded natural wetland habitat areas.
- Our study shows that having a wetland listed as a Ramsar site does not necessarily ensure the conservation of its natural habitat areas. This fact is an argument in favour of providing legal protection for Ramsar-listed sites, and implementing an effective management plan.
- The restoration* of degraded natural wetland habitats can help to recover a certain level of biodiversity.

Recommendations

Given the modifications observed during the 30-year study period, and based on our analysis of their causes, we would like to make the following recommendations:

- Wetland inventory techniques should be developed and implemented such that they can be applied on a large scale and regularly updated, in order to continuously monitor any changes in the area of Mediterranean wetlands. The use of satellite imagery and topographic data to define potential wetlands, combined with field work to validate these data, seems to be a promising approach.
- The natural functioning of Mediterranean wetlands should be preserved in order to maintain their typical habitats, and artificial wetland habitats should be renaturalised.*
- Effective management should be provided for protected natural areas and Ramsar sites.
- Priority should be placed on conserving the most highly threatened habitats such as marshes and wet meadows.
- Water abstraction in natural habits should be managed sustainably, particularly by reducing the water lost in hydraulic networks.
- Coastal planning should be reconsidered collectively in order to adapt to the receding coastline, including through the restoration* of natural buffer zones between the coast and areas where there are human and economic activities.
- Natural wetland habitats should be restored based on restoration* ecology techniques.

↗ *Mouth of the Gravona and the Prunelli, Ajaccio (France)*
(© T. Galewski / Tour du Valat)

> 1. MONITORING MEDITERRANEAN COASTAL WETLANDS

1.1 MEDITERRANEAN COASTAL WETLANDS: HABITAT AREAS UNDER PRESSURE

From mangroves to marshes, deltas, peat bogs, lakes, and coral reefs, all sorts of wetlands can be found throughout the world in all kinds of climates. In spite of the lack of reliable and definitive figures on their extent, converging evidence suggests that there are at least 10 million km² of wetlands in the world (Box 1). However, wetlands are shrinking everywhere *(MEA, 2005)*.

Many kinds of wetlands can be found in the Mediterranean Region, including temporary ponds, marshes, oases, lakes, deltas, lagoons, rivers, reservoirs, and rice fields.
According to a recent study by the Mediterranean Wetlands Observatory (MWO) their extent is 18.5 (± 3.5) million hectares, or nearly 1.5% of the wetlands in the world *(MWO, 2012a; Perennou et al., 2012)*. This study also demonstrates the loss and degradation of these habitat areas: 50% of their surface area disappeared in the 20th century, and water quality declined, with a loss of biodiversity and a decrease in the services provided to local communities. Nevertheless, they have attracted increasing attention in recent decades, which has resulted in local wetlands rehabilitation projects.

In the Mediterranean region, the coastal area is subject to extremely high pressure. It is the top tourist destination in the world *(UNEP MAP / Plan Bleu, 2009)*, receiving 275 million tourists in 2007. This tourism is mainly concentrated on the coast, often in seaside raesorts, which has led to the development of extensive infrastructure since the 1960s. Built firstly in Spain, Italy, and France, it was subsequently extended throughout the Mediterranean Basin. At the same time, infrastructure for heavy industry was developed on the coast, including petrochemical and steel plants, ports, airports, and roads. All these took advantage of the relative flatness, ease of access, and location between the sea and the land.

The spatial convergence of major economic and ecological issues explains why the Mediterranean wetlands closest to the coast have changed differently and are being given particular attention (Box 2).

Wadis with oleanders (Anti-Atlas mountains, Morocco), a type of temporary wetland found especially in the southern and eastern parts of the Mediterranean Basin, as well as in some places in southern Europe (© C. Perennou / Tour du Valat).

Box 1 The loss of wetlands in the world

There is no complete set of data today on the total extent of wetlands in the world. This is the result of major methodological differences and of how what is considered to be – or not to be – a wetland is defined in the different inventories. For example, based on national and regional inventories, Finlayson & Davidson (1999) concluded that there were at least 748 to 1,276 million hectares (Mha) of wetlands at the end of the 20th century, stating however that the true figures must be considerably greater. According to these authors, approximately 50% of total wetland area disappeared during the 20th century.

Meanwhile Lehner & Doll (2004) estimated that the total surface area of wetlands was 1,120 – 1,320 Mha (including lakes and reservoirs, but excluding various types of artificial wetlands). This area represents 8.6% to 10% of the Earth's surface, excluding the ice sheets of Greenland and the Antarctic.

Using satellite images, Prigent *et al.* (2012) estimated that the maximum total surface area of open water is 566 Mha. That figure represents about half of the total area of wetlands identified by Finlayson & Davidson (1999) and Lehner & Doll (2004). However, by targeting open water areas, this study probably underestimates the marshes covered by vegetation and floodable forests, as well as temporarily flooded habitats. In addition, it concludes that there was a net loss of 33.2 Mha of open water from 1993 to 2007 (5.9% in 15 years), corresponding to a more substantial loss from 1993 to 2000, followed by a slight increase until the end of 2007.

Finally, with satellite imagery, Chen & Chen (2014) estimate that the total surface area of wetlands was 756 Mha in 2010. They observe losses in area of 1.77% for open water, and 2.64% for other wetlands from 2000 to 2010.

Box 2 Converging trends in coastal and interior wetlands

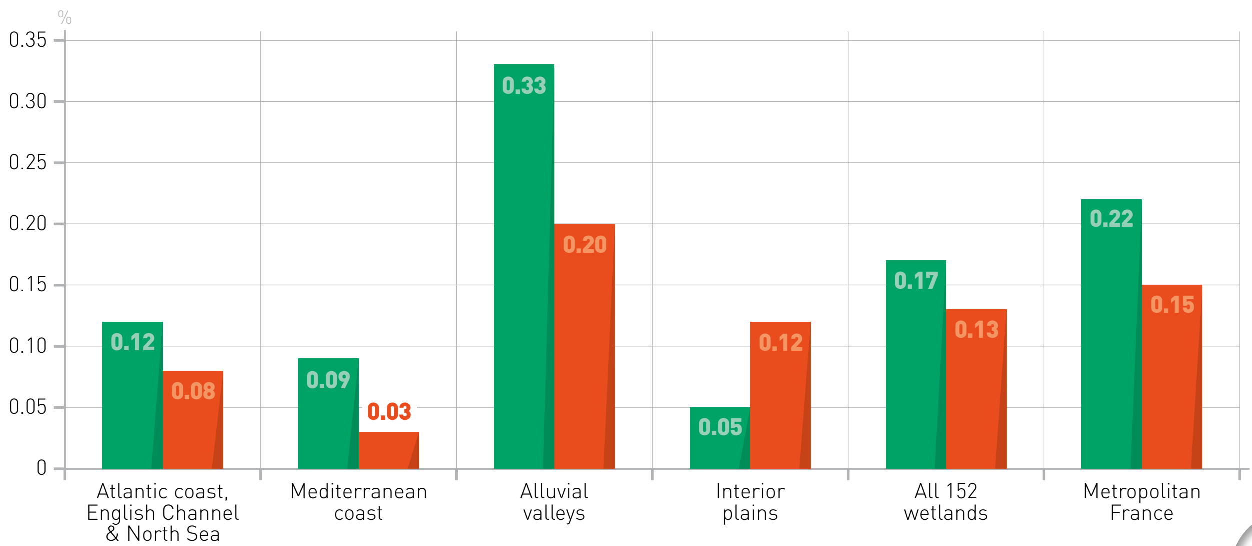
In some Mediterranean countries, studies enable a distinction to be made between changes in coastal wetlands and those in interior wetlands. In France, wetlands in the two coastal areas were generally less artificialized than the national average from 1990 to 2006 (Figure 1.1), or than wetlands in alluvial valleys *(IFEN, 2008; SOeS, 2009)*. However, the principal wave of coastal developments (industrial and tourist) date from the 1950s to 1970s, and they are therefore not taken into account in this study.

In response to the pressure affecting the coast, politicians have taken protective measures such as the establishment of the French Coastal Protection Agency (Conservatoire du Littoral) in 1975.

One fourth of the area of coastal municipalities is protected today *(MEDDE-MNHN, 2013)*, compared to an average of 13.8% in metropolitan France. The decrease in the loss of coastal wetlands since 1990 is probably due to such policies.

FIGURE 1.1

Percentage of the area of 152 French wetlands urbanized from 1990 to 2000 (green), and from 2000 to 2006 (orange): figures for Metropolitan France, for illustrative purposes only and covering the entire national territory
(Sources: IFEN, 2008; SOeS, 2009).



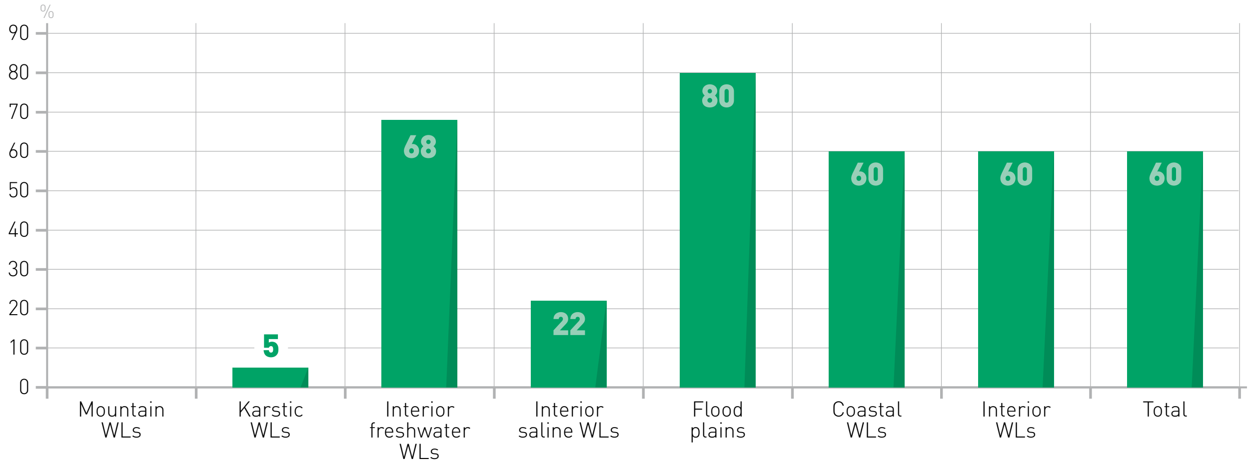
CONT. P. 10

Box 2 Converging trends in coastal and interior wetlands (cont.)

The inventory of wetlands in Spain (*Casado & Montes, 1995*) shows that during the 19th and 20th centuries, losses affected coastal wetlands as much as interior wetlands (Figure 1.2). However, in absolute values, the losses were much greater for coastal habitats, because they accounted for 85% of total wetland area in 1800. Some types of interior wetlands, such as flood plains and other freshwater wetlands, were more affected than coastal wetlands (Figure 1.2). Thus, there are other contrasts besides the dichotomy between coastal and interior wetlands, including freshwater/salt water habitats and mountainous/plain areas.

FIGURE 1.2

Percentage of losses of different types of wetlands (WLs) from 1800 to 1990 in Spain *(Source: Casado & Montes, 1995).*

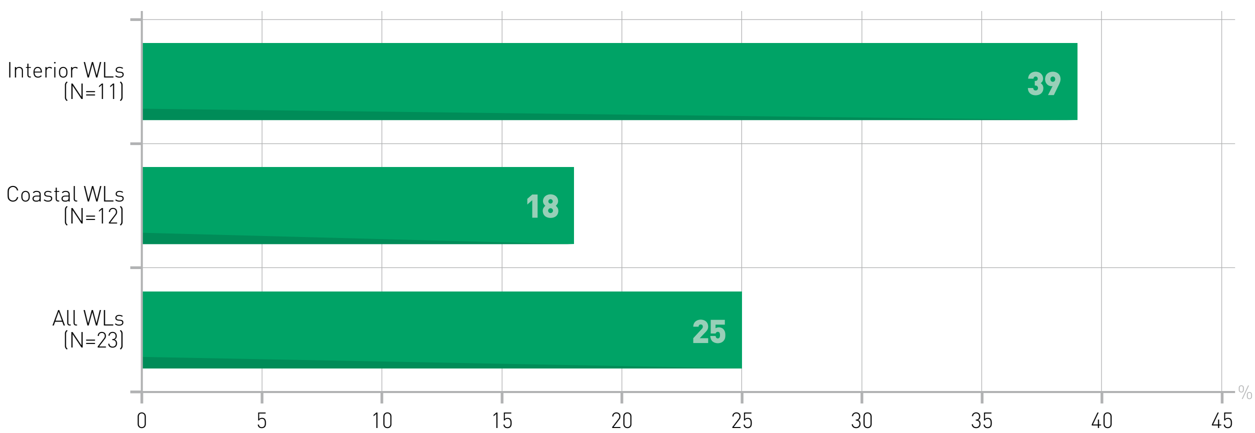


In Morocco, Green *et al.* (2002) quantified changes in the area of 23 wetlands from 1978 to 1999. One fourth of their area disappeared in 21 years (Figure 1.3). The loss of interior wetlands (39%) far surpasses that of coastal wetlands (18%) (NB: defining criteria = located less than 100 km from the coast).

Therefore, the evidence does not show that coastal wetlands have suffered more than inland wetlands, despite the high pressure on the coastal areas. However, these three studies focus on extremely variable time frames, and the geographic distribution of the different sources of pressure has changed over time, e.g. with the successive phases of development of coastal tourism in the Mediterranean region. In addition, coastal wetlands often cover large surface areas, which means that their net losses were actually more significant.

FIGURE 1.3

Rate of loss of wetlands (WLs) in Morocco from 1978 to 1999 *(Source: calculated based on Green et al. 2002).*



1.2 ESSENTIAL HABITAT AREAS FOR PEOPLE AND BIODIVERSITY

The biggest and most attractive wetland sites are found in coastal wetlands, such as the Nile, Po, and Rhone deltas. They host a significant amount of plant, invertebrate, fish, and amphibian biodiversity, including some species found nowhere else in the world *(CEPF, 2010)*.

This exceptional biodiversity is due to several reasons. Wetlands are among the most productive habitats on Earth, and are thus able to support large numbers of wildlife. In particular, hundreds of millions of birds migrating from Eurasia to Africa stop in Mediterranean coastal wetlands to rest and feed. In addition, at the crossroads of three continents, the Mediterranean Basin benefits from fauna and flora coming from each of them. In addition, its turbulent geological and climatic history has led to the long isolation of certain regions, and this isolation is responsible for the high rate of endemism* of certain groups such as fish, molluscs, and plants. Finally, the civilisations that have developed in the Mediterranean Basin for several millennia have created extensive and diverse semi-natural habitats, where numerous species can thrive.

Wetlands are highly productive and therefore essential for human populations that can make direct use of their abundant resources, harvesting plants, fishing and hunting, using the prairies to raise livestock and the fertile soil to grow crops. They are also a veritable natural infrastructure, enabling hydrological flows to be regulated. They also provide many free services such as protection against floods and droughts, groundwater recharge, and water treatment. Although they only cover 1.5% to 3% of the Earth's surface, wetlands provide 45% of the total ecological services assessed *(Coates, 2010)*.

Long perceived in negative terms because of the diseases associated with them, which still are in many parts of the world (in particular, malaria), today, in an increasingly urbanized world, the landscapes and biodiversity found in wetlands have become attractive. Along with leisure activities such as hunting and fishing, sustainable tourism, based on enjoying the pleasures of preserved natural habitats and observing their fauna and flora, has become very popular. Contrary to mass tourism, ecotourism is an environmentally friendly economic activity, which generates employment opportunities and significant income for local authorities, while allowing traditional rural activities to be maintained.

Mediterranean Tree Frog (Hyla meridionalis), *a species endemic to the western part of the Mediterranean Basin (© O. Pineau)*

1.3 SATELLITE IMAGERY FOR MONITORING CHANGES IN MEDITERRANEAN WETLANDS

The good management and preservation of wetland biodiversity and related ecological services requires knowledge of their status and trends. However, biodiversity is a complex notion, which ranges from genes to ecosystems, and given the stakes, the human and financial means employed to understand it are still inadequate. To make up for this lack of resources, biodiversity is now assessed using summary indicators, which enable a realistic image of the situation to be obtained despite incomplete data. To be useful for the purposes of conservation, these indicators must also provide information on the pressures and driving forces behind the decline in biodiversity, and on the various solutions proposed by different societies *(Butchard et al., 2010)*.

To improve the sustainable management of wetlands by drawing attention to their status and trends, the MWO has adopted a set of complementary and consistent indicators corresponding to a widely-used model "driving forces, pressures, state, impacts, responses" (Figure 2) (used by the Convention on Biodiversity, European Environment Agency, and others). In this study, a method for monitoring wetland ecosystems and habitats was developed by using data from satellite images. Regularly available since 1972, these images make it possible to go back in time. Analysed and combined with field data, they provide land cover maps. Based on these maps, status indicators were calculated, which characterise the area of wetland ecosystems, as were pressure indicators, characterising land management. This approach was developed through the GlobWetland-II project (GWII, Box 3).

Box 3 The GlobWetland-II project

Launched in 2010 by the European Space Agency (ESA), GlobWetland-II (GW-II, 2010-2014) was a regional pilot project aiming to facilitate the use of techniques for observing the Earth for the management and conservation of Mediterranean wetland habitats. Its principal objective was to help set up a Global Wetlands Observing System (G-WOS), in accordance with the Ramsar Strategic Plan for wetlands. The spatial indicators for monitoring wetland habitats were devised to feed data into the Mediterranean Wetlands Observatory (MWO) database.

To meet this objective, a monitoring and evaluation system was developed, based on land cover mapping and a study of how land cover changed from 1975 to 2005. Three dates were used: 1975, 1990, and 2005, so that our project would correspond to the European land cover monitoring programme (Corine Land Cover).

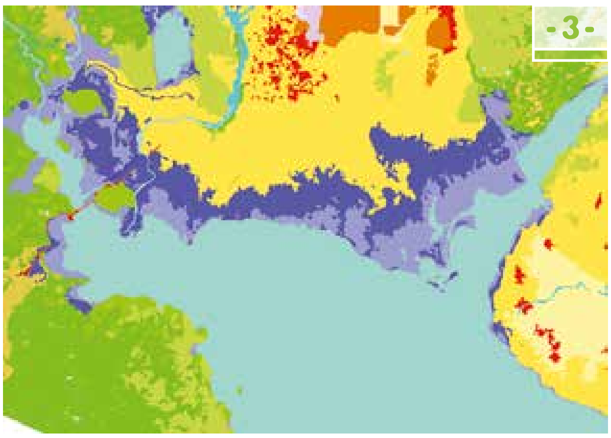
The GW-II approach was based on three components:

- A remote sensing component: pre-processing of satellite images, classifying land cover, and detecting changes;
- A geographical information system (GIS) component: the calculation of spatial indicators including the total area of wetland habitats, changes over time, flooded areas, and anthropogenic pressures;
- A web-based GIS component: permanent access to the products developed (maps and indicators) via an internet site.

Images were captured using Landsat satellites *(MSS, TM and ETM)* and the mapping approach was based on object oriented classification and image segmentation (Figure 3). This land cover classification system is based on the one used for the Corine Land Cover programme in Europe, but further refined for classes corresponding to wetlands (as defined by the Ramsar Convention).

FIGURE 2

Example of the methodological approach used (segmentation / classification) for land cover mapping (GW-II project): 1) raw image, 2) segmentation*, and 3) classification: map.



* *Automated operation that segments space in homogeneous zones, before assigning them a land cover class (2nd 'classification' operation)*

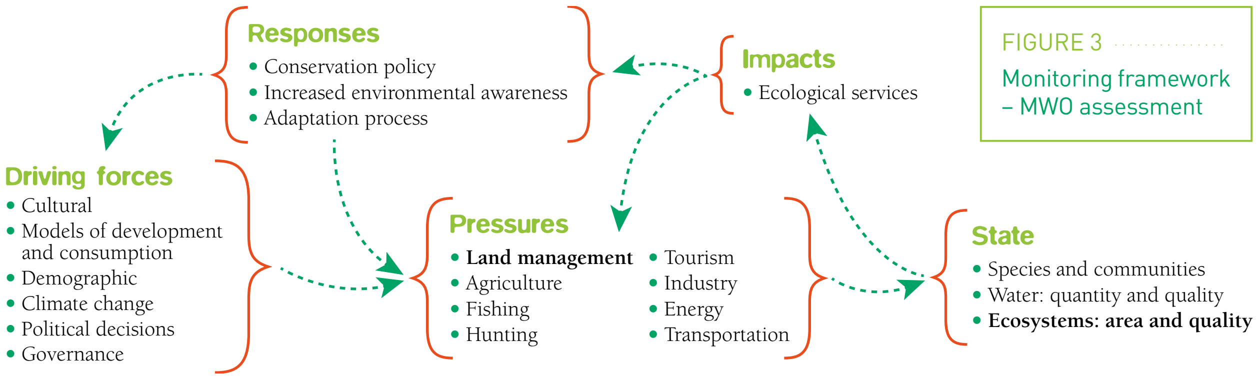


FIGURE 3
Monitoring framework – MWO assessment

1.4 214 COASTAL WETLANDS MONITORED FROM 1975 TO 2005

Within the framework of the GW-II project, an initial group of 200 sites were mapped, in 10 countries in the south-eastern parts of the Mediterranean Basin (from Morocco to Syria). The work was then extended to the northern shore (from Turkey to Portugal), for 84 other sites. With no complete inventory of Mediterranean wetlands available for choosing the sites to be mapped (Box 4), existing databases were used to fill the information gaps (Ramsar sites, BirdLife International Important Bird Areas, and bibliographic resources).

In order to focus on changes in only coastal wetlands, a sample of 214 sites, in 22 countries, was selected from the original group of 284 sites analysed. Wetlands were chosen using a dual criterion: they had to be less than 100 km from the coast, and at an altitude of less than 700 m (Map 1).

The area of these sites ranges from 0.27 km² (Sidi Abdelmoneem Dam, Tunisia) to 1,261 km² (Burullus Lagoon, Egypt), with an average area of 142 km² for a total of 30,511 km², which was mapped in 1975, 1990, and 2005. 12,634 km² of this total area were natural wetland habitats in 1975. In other words, our sample represents 5.7 to 8.4% of the estimated area of natural wetland habitats in the Mediterranean region.

Sampling was not balanced among the different countries. The northern shore was much less well represented than the southern and eastern shores (80 sites vs 134). However, within each of these 2 groups, the disparities between countries are a good reflection of the geographic reality, with regions featuring numerous coastal wetlands (Tunisia, Libya), and others where there are very few (Syria).

The 214 study sites are wetland complexes and their adjacent environments. There are 82 Ramsar sites, 125 Important Bird Areas (IBAs), some that are both, and 54 neither Ramsar sites nor IBAs. Site boundaries were based on administrative documents if they exist (Ramsar site, IBA, or natural area boundaries). When there were no administrative boundaries, the study site limits correspond to those of the wetlands complex.

Among these sites, there are five major habitat types grouping the different habitat classes:

- Natural wetland habitats: watercourses, wet meadows, wetland forests including riverine woodlands*, interior and marine marshes, peat bogs, intertidal zones*, marine shores, bodies of water such as permanent and temporary lakes, freshwater or brackish, lagoons, estuaries, and deltas;
- Artificial wetland habitats: excavated areas (for example, gravel pits and mine shafts), rice fields, salt marshes, canals, fish farming ponds, wastewater treatment sites, and reservoirs ranging from small water storage reservoirs for agriculture to major lakes behind dams;
- Natural habitats that are not wetlands: forests, areas with shrubby vegetation (scrub, garrigue) or herbaceous plants like grasslands, and open areas with little or no vegetation like cliffs and semi-desert areas;
- Agricultural areas that are not wetlands: arable land (except for rice fields), permanent crop areas, dry prairies, and heterogeneous agricultural areas with mosaic landscapes dominated by agricultural activities;
- Urban areas that are not wetlands: urbanized, industrial, and commercial areas; transportation networks, mines, dumps and building sites (except for excavated areas), urban green area, and sports facilities.

The initial mapping results were validated in the field to quantify the overall rate of error linked to the methodology used. In all, validation was conducted on 28 sites (approximately 10% of all sites). For the 48 habitat classes (1,380 total points verified), the overall rate of error was 12.3%. This figure drops to 10.6% for the 23 types of wetlands concerned by this operation (662 points verified). Ultimately, with an overall validation rate of 87.7%, the results can be considered to be close enough to reality to be useful (*Thomlinson et al., 1999*).

The map of the sites studied is on the following double page spread (pages 14 and 15)


GRANDE CAMARGUE
(FRANCE)
LLOBREGAT DELTA
(SPAIN)
EBRO DELTA
(SPAIN)
AVEIRO LAGOON
(PORTUGAL)
DOÑANA
(SPAIN)
SADO ESTUARY
(PORTUGAL)
SIDI ABDELMONEEM DAM (TUNISIA)
GHAR EL MELH
(TUNISIA)
MACTA MARSH
(ALGERIA)
BAS-LOUKKOS WETLANDS COMPLEX
(MOROCCO)
MOHAMMED V DAM
(MOROCCO)
0
500
1000
2000km
N

MAP 1

The 214 sites studied (in orange). Sites indicated are those used as examples in this report (text and boxes).

Box 4 Wetland inventories in the Mediterranean region

Wetland inventories are a good way to assess the current extent of these habitats, and by means of successive inventories to track past changes. The level of completion of inventories in the Mediterranean varies from country to country. For example, Greece, Slovenia, Portugal, and Tunisia have an almost complete inventory. Other countries, such as France and Italy, have several local inventories at the administrative department and catchment area level, but they are not coordinated with each other. Meanwhile, countries like Algeria apparently have an inventory, but their results are inaccessible. Finally, various countries like Egypt and Syria have no inventories, only highly incomplete information in major international inventories, which only cover the most important sites (Figure 4).

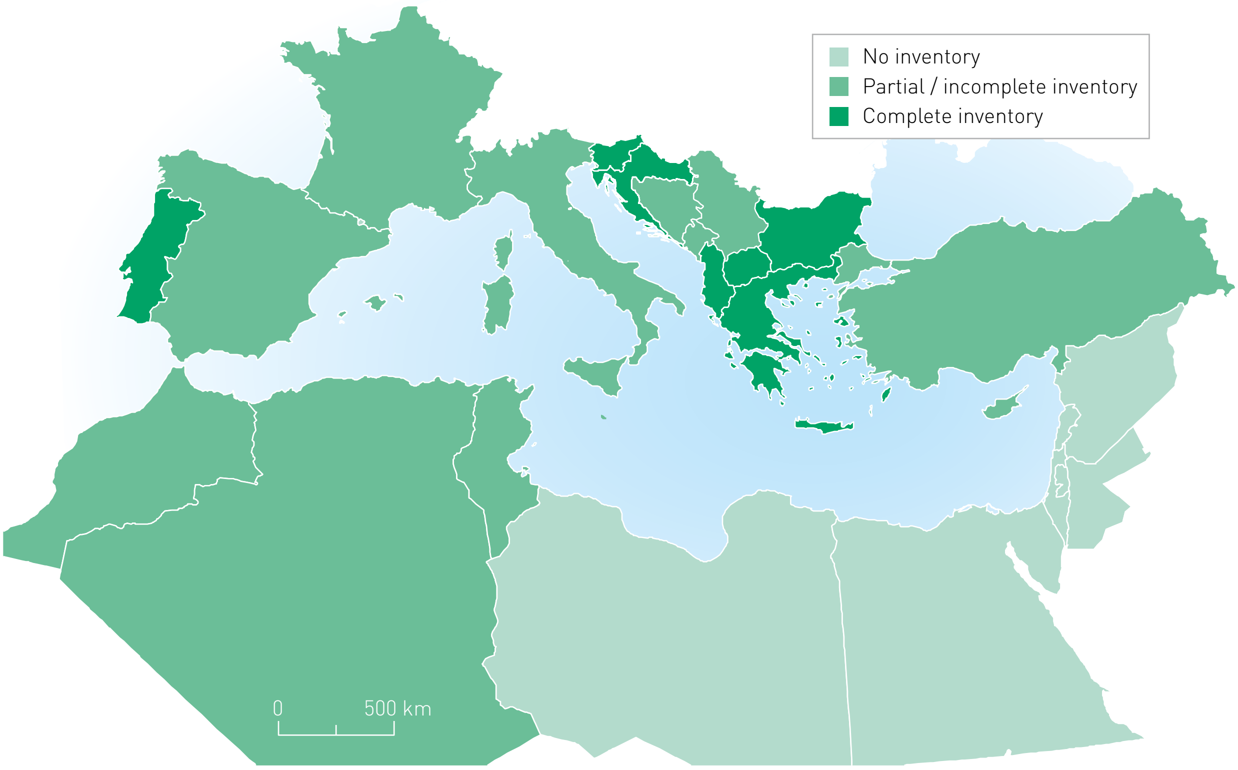
The situation by country has been summarised by Nivet and Frazier (2004) for Europe and Caessteker (2007) for the Mediterranean Basin. The principal difficulties in obtaining an overall and standard vision for the region are:

- Different definitions of what should or should not be considered to be a "wetland" Some countries only include natural habitats, others all wetlands including artificial wetlands, and still others only areas that have an ornithological value. The same applies to the inclusion or non-inclusion of lakes, rivers, and streams;
- Different study methods and dates;
- Variable scales of precision and threshold levels for inclusion (for example, only wetlands over 1 ha, 10 ha, etc.).

A synopsis of the best available information, attempting to correct inter-country biases, was produced by Perennou *et al.* (2012). It concluded that there were 15 to 22 million hectares of wetlands in the Mediterranean Basin at the end of the 20th century, 23% of which were artificial. This study also revealed the loss of about 50% of wetlands during the 20th century.

FIGURE 4

Map of existing inventories in 2012, with three categories: national inventory complete or almost (9 countries); regional or provincial inventories of good quality but incomplete, not synthesised, or lacking coordination (10 countries); no inventory accessible except for very incomplete international wetland inventories (8 countries).



2. HOW DID WETLAND HABITATS CHANGE FROM 1975 TO 2005?

2.1 A CONSTANT DECLINE IN NATURAL WETLAND HABITATS FROM 1975 TO 2005

Losses in natural wetland habitats at the 214 sites studied

For the 214 sites studied, the total area of natural wetland habitats decreased by 10% from 1975 to 2005 (Figure 5), representing a loss of 1,248 km². These natural wetland habitats are made up of wet meadows, wetland forests including riverine woodlands*, interior and marine marshes, peat bogs, rivers and their estuaries and deltas, intertidal habitats, permanent and temporary lakes, and lagoons. We broke down the study period into two sub-periods: 1975-1990 and 1990-2005. From 1975 to 1990, 747 km² of natural wetland habitats disappeared (6% of the total area in 1975), and 502 km² from 1990 to 2005 (4% of the total area in 1975). Although the loss of area was lower during the second period, the decrease in the rate of loss is not statistically significant.

FIGURE 5

Total area of natural wetland habitats in the 214 study sites (in km²).

- 1975 - *12,634 km²*

- 1990 - *11,887 km²*

- 2005 - *11,386 km²*

These results confirm the scattered data from the past, which indicate the progressive disappearance of wetlands in the world and in the Mediterranean Basin (Box 1). The magnitude of these figures is, however, different from one study to the next, which may be due to methodological differences and what is monitored (for example, natural wetland habitats or open water areas). The Mediterranean is not an exception in the world: 28% of the intertidal wetlands* along the Yellow Sea in the Far East disappeared between 1980 and 2010 *(Murray et al. 2014)*.

Results that accentuate the massive losses of natural wetland habitats before our study

Numerous wetlands were destroyed or degraded well before 1975, the start of the period studied in this report. Although long-term monitoring of natural habitats was less well developed in the past, partial information is available locally.

For example, a paleogeographical study, based on the analysis of sedimentary layers in the Nile Delta, the biggest wetland in the Mediterranean Basin, shows that major transformations linked to the presence of human beings began very early *(Stanley & Warne, 1993)*. The vast zone of marshes in the middle of the delta and the lagoons in the north were already modified in ancient times. In particular, certain branches of the Nile were maintained through excavation, in parallel to the development of irrigated agriculture, which was made possible by the drainage of wetlands. Drainage and crop growing intensified in the southern part of the delta during the first millennium of the Common Era. At the beginning of the 19th century, there were still big zones of lagoons and marshes in the northern part of the delta, but demographic pressure increased the need for irrigation water and land for urbanization and agriculture. The processes of draining wetlands and harnessing water for people's needs intensified. Major ecological changes also occurred: the Suez Canal was completed in 1869, the first Aswan Dam was finished in 1902, and the High Dam in 1960, which completely modified the dynamics of the river, and therefore the Delta. Satellite imagery shows that this transformation of natural wetland habitats continued between 1975 and 2005. Indeed, the four remaining coastal lagoons, with the exception of the Maryut Lagoon, are among the sites studied that lost the most natural wetland habitat area: -264 km² for the Burullus Lagoon, -184 km² for Manzala, and -74 km² for Idku.

For a more recent period, a study conducted on the coastal plain in Israel with historical maps also showed there were spectacular losses: today only 9% of the natural wetland habitats present at the end of the 19th century remain *(Levin et al., 2009)*. 82% of the sites have simply disappeared, while the others have shrunk in size. In this study, a British military map from 1943 shows that a large portion of these modifications took place before that date. Here again, the changes were due to drainage for growing crops and the construction of urban and transportation infrastructure.

An underestimation of the losses for the period studied

Our study very likely underestimated the rate of loss of natural wetland habitats for the period studied. First, our sample only included sites that were still wetlands in 2005, excluding any wetland that had completely disappeared during the period studied, such as Lake Amik in Turkey *(Kiliç et al., 2006)*.

In addition, the sites chosen were wetlands that are known and listed, either in Ramsar site or Birdlife databases (Important Bird Areas) or in the literature, and are therefore more likely to be protected. These wetlands were also big enough to be monitored with the Landsat satellite imagery used for this project (at least 0.25 km² = 25 ha).

The resolution of the satellite images used was 60 m in 1975, and 30 m in 1990 and 2005. It was therefore impossible to understand the dynamics of all the small wetlands such as temporary ponds and small marshes, as well as watercourses, which are potentially some of the most highly threatened habitats *(Rhazi et al., 2012)*. For the same technical reason, certain changes in the wetlands could not be detected. For example, if 1 ha of marsh was transformed into a rice field, this change concerns an area that is too small to be detected. The figures advanced are therefore likely to be conservative.

Marshes and wet meadows are threatened habitats

Among natural habitats, marshes and wet meadows experienced rate of loss from 1975 to 2005. Marshes (2,848 km² in 1975) receded by 293 km² in the wetlands studied, or 10% (Box 5). At the same time, wet meadows (142 km² in 1975) decreased by 62 km², or 43% (Box 6). These habitats, which are temporarily flooded and often located around big wetlands or in the flood plains of streams and rivers, are the first areas affected when they are converted into farmland or urban areas.

These results agree with a national study conducted on the principal wetlands in France: wet meadow is one of the natural wetland habitats that declined the most from 2000 to 2006 *(SOeS, 2012)*.

Water bodies shrinking at an alarming rate

Small temporary wetland habitats are not the only ones disappearing, and some large bodies of water are also experiencing a significant decline. In the Nile Delta, 398 km² of lagoons were lost from 1975 to 2005 in Burullus, Manzala (Box 7), and Sinnéra and San El-Hagar (Box 9).

Some permanent lakes are also shrinking. In all, 129 km² of these natural wetland habitats were lost between 1975 and 2005 for all of the sites studied. In Turkey, Lake Kuş and Lake Uluabat have experienced major hydrological modifications, which has resulted in increased sedimentation, a drop in their depth and natural fluctuations in water level, as well as the development of marshes on the shores where there used to be open water (Box 8).

An islet used to grow crops on what was part of a wetland in the Camargue (France) (© L. Chazée).

Box 5 Decline and fragmentation of natural wetland habitats in the Macta marshes (Algeria)

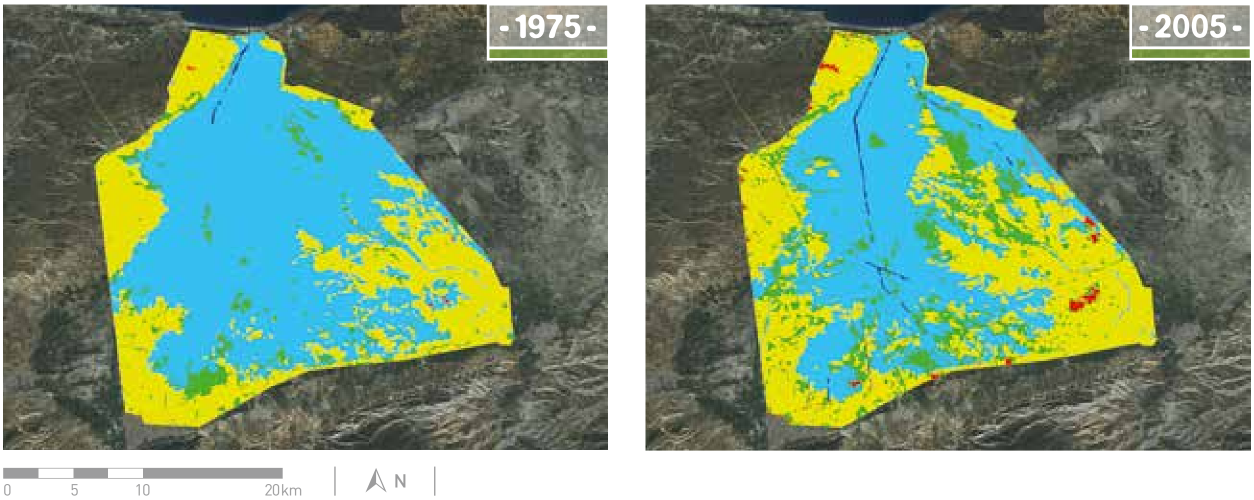
Located in north-western Algeria, the Macta marshes were listed as a Ramsar site in 2001. This exceptionally rich ecosystem *(Ghodbani & Amokrane, 2013)* is made up of three major areas: the marshes themselves, an area of natural vegetation, and crops. The first is the wettest area and includes the lagoons, ponds, and marshes of the lowland plains, river mouths, branches of wadis*, alluvial meanders, and saline lakes. It favours the development of specific invertebrates, waterbirds, and fish. The second area is not as wet and is covered by halophilic flora*, with rare habitats for species endemic* to North Africa. Finally, the Macta region has significant economic potential, which is essentially based on agriculture (it is the top olive- and critrus-growing region in western Algeria) and herding, with major transhumance involving nomadic herders from the south *(Direction de l'Agriculture, 2009)*.

This site experienced a significant loss of natural wetland habitats from 1975 to 2005. They dropped from 272 km² to 194 km² (from 61% to 44% of the total area mapped, see Figure 6). This decline is linked to hydrological developments upstream from the site and the expansion of agriculture and livestock farming (Figure 6). For example, from 1970 to 1992, three new dams were built in the Macta catchment area (in addition to the two already existing dams, see Figure 7). Combined with the effects of an increasingly long annual drought, this has resulted in less water flowing into the marshes, dried up land, and a loss of natural wetland habitats *(Meddi et al., 2009)*. The increasing sedentarisation of the local nomad communities, which is followed by the transformation of the dried up land into livestock raising or crop growing areas, is a major threat for the site. Indeed, in addition to the loss of natural wetland habitats, natural habitats are fragmented by these transformations, with a negative impact on biodiversity.

FIGURE 6

Change in land cover in the Macta marshes (Algeria) from 1975 to 2005 *(© GlobWetland II / ESA)*.

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats
- Artificial wetland habitats
- Sea and ocean



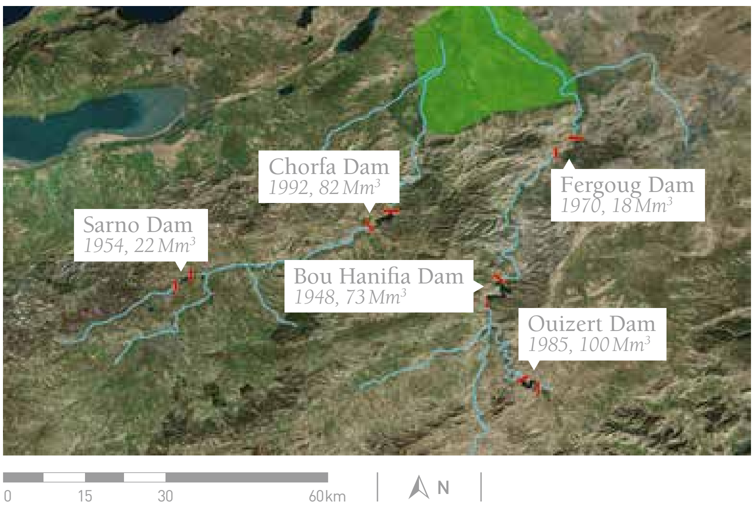


FIGURE 7

Location of dams in the Macta catchment area (Algeria).

Box 6 The Bas-Loukkos Marsh (Morocco): wet meadows pay the heaviest toll for development

This site on the Atlantic coast of Morocco is a unique complex of estuary habitats, shallow marine water, marine and freshwater marshes, and wet meadows and forests. There are also artificial wetland habitats, such as rice fields and salt works areas. Listed as a Ramsar site since 2005, it is home to protected and/or threatened wildlife species such as the Marbled Teal, Ferruginous Duck, Marsh Owl, and Eurasian Otter. This site also plays an important role in absorbing flood water from the Loukkos river. The principal activities near the site are agriculture, livestock raising, salt production, and tourism *(El Agbani et al., 2003)*.

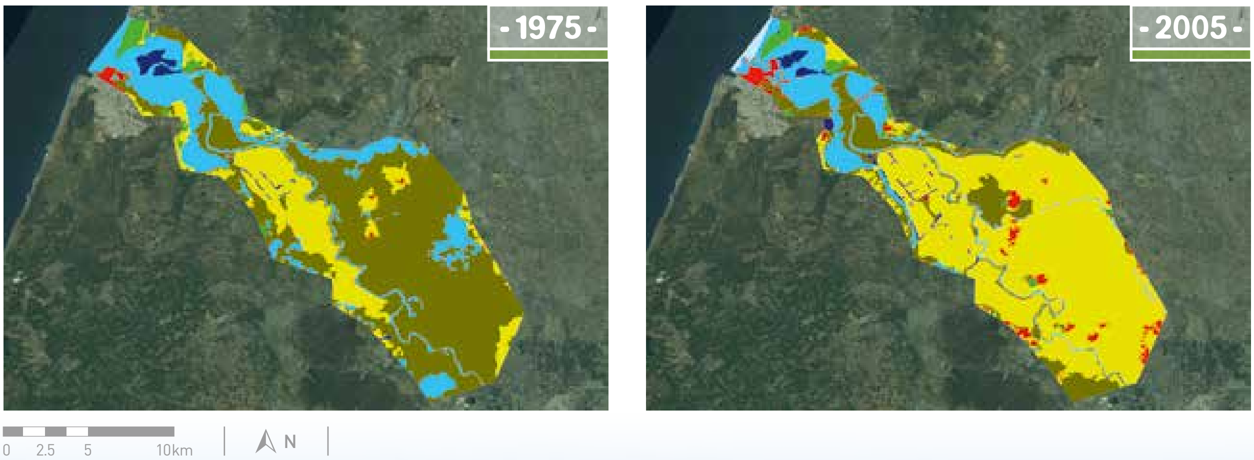
There was a general decline of natural wetland habitats, most of which were converted for agricultural uses on dry land. They dropped from 45 km² in 1975 to 17 km² in 2005. Wet meadows experienced the most significant net losses, going from 31 km² in 1975 to 8 km² in 2005 (-70% in 30 years), and their proportion of all natural wetland habitats decreased from 65% to 47% (Figure 8).

This degradation is due to multiple causes, including water retention upstream from the catchment area, overgrazing, filling in marshes, and urban development, however, the principal causes remain the drainage of wetland habitats and agricultural development. Indeed, in the 1970s, Morocco made the economic choice to intensify its irrigated agricultural programme, with its "One million irrigated hectares" project, which enabled agricultural production to be increased by nearly 8% per year from 1960 to 2000 *(Jouve, 2002)*. In the area studied, major investments were made to that effect in the 1970s and 80s, such as the construction of dams (in all nine dams were built in the catchment) and hydro-agricultural facilities enabling the drainage of wetlands and the irrigation of the land just converted into farm fields *(Vercueil, 1982)*.

FIGURE 8

Shrinking of wet meadows due to agriculture from 1975 to 2005 (Bas-Loukkos wetlands complex in Morocco) *(© GlobWetland II / ESA)*.

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats
- Wet meadows
- Artificial wetland habitats
- Sea and ocean



Filling in the Bas-Loukkos marshes (Morocco) (© P. Grillas / Tour du Valat).

Box 7 Lake Manzala, a shrinking lagoon in the Nile Delta (Egypt)

The Lake Manzala site features the biggest lagoon in Egypt and peripheral natural wetland habitats. Located in the north-eastern part of the Nile Delta, between the cities of Port-Saïd and Damiette, its average depth is 1.3 m and its salinity gradient increases from south to north.

It includes four principal types of natural habitats: the lagoon itself, and marine marshes along its edges, marshes with aquatic vegetation (phragmites and typha), and dune habitats that form the coastal barrier that separate it from the Mediterranean Sea. Considered to be the most important wintering site for waterbirds in Egypt, it is also an important stopover site for numerous migratory species and a potential place for sea turtles to lay their eggs. Mammals typical of wetland habitats are found there, such as the Jungle Cat (*Felis chaus*).

In spite of its importance, this site is not protected by any measures, except for a small part about 35 km² in the north-eastern part of the lagoon (Ashtoum El Gamil), listed as a protected area in 1988 *(Baha El Din, 1999)*. From 1975 to 2005, the site experienced a decline in its natural wetland habitats (Figure 9), with a net loss of approximately 144 km² (-16%).

Lagoon habitats were the most severely affected, dropping from 722 km² in 1975 to 528 km² in 2005 (-27% in 30 years), part of which were transformed into marshes.

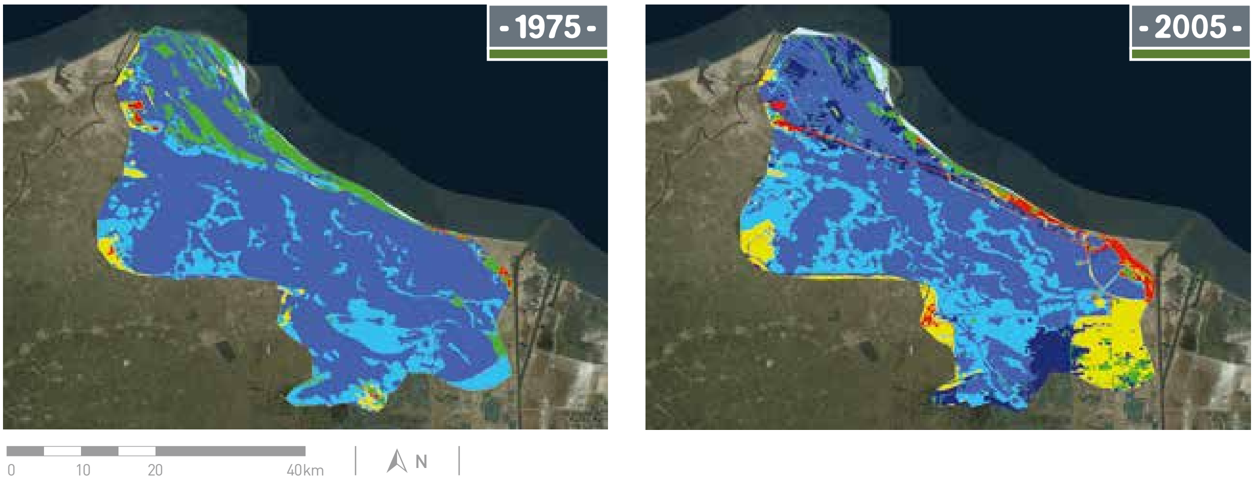
Most of these lagoon habitats were converted into agricultural areas, fish farming ponds (artificial wetland habitats), and urban areas (respectively 29%, 14% and 0.05% of the lagoons lost).

The conversions into agricultural areas can be explained by the land management policies implemented in Egypt in recent decades *(Dinar et al., 1995)*. Due to the lack of farmable land outside of the Nile delta and valley, the intensification of agricultural activities in these areas has become a major economic issue. For this reason, a significant part of Lake Manzala (west and south) was drained starting in the 1970s to encourage farmers to settle there. However, this project was an economic failure. The soil was saline, and the agricultural production was less profitable than fishing, which was the principal activity for local communities before this part of the lake was drained *(Ibrahim, 2003)*.

FIGURE 9

Lagoon habitat loss from 1975 to 2005 (Lake Manzala, Egypt). *(© GlobWetland II / ESA)*

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats except lagoons
- Lagoons
- Artificial wetland habitats
- Sea and ocean



Box 8 Silting up of Lake Uluabat (Turkey)

This freshwater lake is located in northern Turkey, to the south of the Sea of Marmara. It is principally fed by water from the Mustafakemalpaşa (or Kirmasti) River, which flows into it at the southern shore, where it forms a mini-delta. In addition to the purely lacustrine habitats (open water), natural wetland habitats include marshes with helophytes (reeds) and tamarisk, all along the shores. Fishing is the dominant activity practised by people living along the shoreline. Agriculture is also common, with olive groves and irrigated land around the site. Lake Uluabat is an Important Bird Area due to the significant communities it harbours (*Magnin & Yarar, 1997*). It has also been a Ramsar site since 1998, which in Turkey means a relatively high degree of protection.

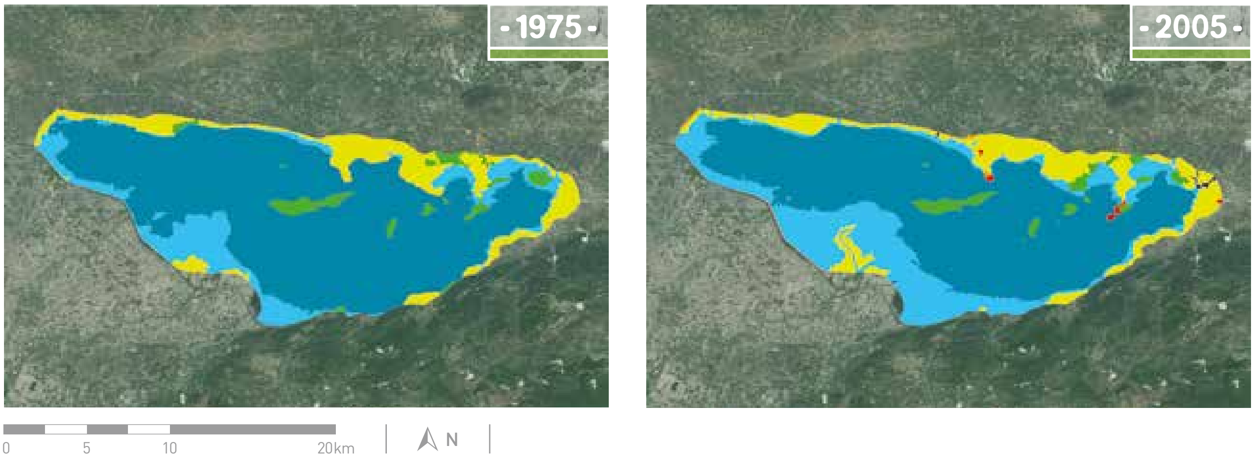
There was almost no change in the total area of natural wetland habitats from 1975 to 2005 (160 km² to 158.5 km²). However, the "permanent natural lake" habitat, which covered 134 km² in 1975, lost more than 15% of its area (21 km²). Most of this area was converted into marsh habitats, which nearly doubled in size (from 24 km² in 1975, to 43 km² in 2005). These transformations were observed especially in the south and south-western parts of the lake (Figure 10).

The principal cause of these changes is linked to the significant sedimentation occurring in the lake. Water from the Mustafakemalpaşa River contains a high amount of suspended particles due to mining activities and erosion in its catchment area, and the extraction of sand from the river bed. This matter falls out of suspension into the lake, especially at the mouth of the river, thereby enlarging the mini-delta. The loss of depth near the shore is favourable to the development of a band of helophytes, which also contribute to the accumulation of sediments in the peripheral areas of the lake. The development of reed beds (mapped in marshes) is occurring to the detriment of free water, i.e., the "permanent natural lake" habitat. However, compared to the 1970s, the amount of matter in suspension has decreased in recent decades (*Lammens & Van den Berg, 2001*).

FIGURE 10

Modification of natural wetland habitats from 1975 to 2005 due to sedimentation (Lake Uluabat, Turkey).

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats (except permanent lakes)
- Permanent natural lakes



2.2 AT THE SAME TIME, AN INCREASE IN ARTIFICIAL WETLAND HABITAT AREA

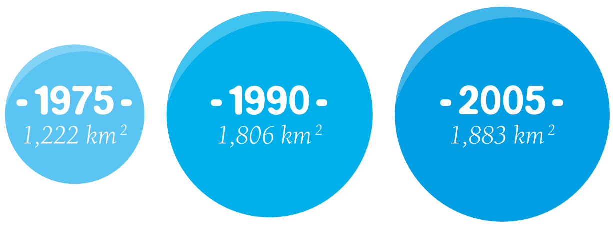
Progression of artificial wetland habitats in the 214 sites studied

Artificial wetland habitats include canals, rice fields, salinas, fish farming ponds, excavation areas like gravel pits, wastewater treatment sites, and dam reservoirs and lakes.

For all of the 214 sites studied, artificial wetland habitats expanded by 54% from 1975 to 2005, which represents an increase of 661 km² (Figure 11). The expansion was slower from 1990 to 2005, but not to an extent that is statistically significant.

FIGURE 11

Total area of artificial wetland habitats in the 214 sites studied (in km²).



Increase in reservoirs, fishponds and other artificial ponds

This expansion can be seen in particular in the increased area of reservoirs, fishponds and other artificial ponds, which progressed from 66 to 523 km² between 1975 and 2005 (almost 700%). This progression is mainly due (90%) to the massive increase in fish farming and agriculture in the Egyptian lagoons (progression of 415 km², Box 9). The rest can be explained by small developments such as wastewater treatment plants, small reservoirs in agricultural and industrial areas, and the development of fish farming in the northern and southern Mediterranean regions.

There was a local decline in artificial wetland habitats from 1990 to 2005. It corresponds mainly to a decrease in the size of the big lake behind the Mohammed V Dam in Morocco, due to a high degree of sedimentation in the lake and droughts *(Snoussi et al. 2002)*, as well as to the conversion of fish farms into irrigated agricultural areas in certain Egyptian lagoons.

2.3 A DRASTIC DECLINE IN OTHER NATURAL HABITATS

The 214 sites concerned by this study are made up of a mosaic of natural and artificial wetland habitats, as well as natural non-wetland habitats, and agricultural and urban areas. Natural non-wetland habitats include dunes, forests, garrigue, scrub, grasslands and steppes.

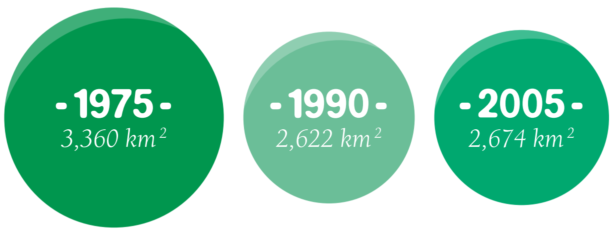
Whether or not they were wetlands, all of the natural habitats in the sites studied experienced a net loss in area. Natural non-wetland habitats decreased in size by 20% from 1975 to 2005, which corresponds to a loss of 686 km² (Figure 14, Box 10). Most of this loss occurred between 1975 and 1990, then the total area remained stable after 1990 (Figure 12).

The loss of natural non-wetland habitats around wetlands is a preoccupying conservation issue. It is indeed important for natural wetland habitats to remain connected to a broad network of natural habitats. Numerous wetland species only spend part of their lives in wetland habitats, and therefore need other natural habitats. For example, various kinds of gulls and terns use wetland habitats when they breed to protect themselves from predators, but do not always feed in these areas.

In addition, amphibian larvae, such as the European Tree Frog, depend on wetland habitats, but adults also use other non-wetland habitats.

FIGURE 12

Total area of natural non-wetland habitats in the 214 sites studied (in km²).



On the other hand, the ecological functioning of wetlands (hydrology, sediment and nutrient transfer, etc.) is influenced by the surrounding habitats located in the nearby catchment area. The increasing artificialisation of the edges of wetlands is therefore likely to encourage various disturbances such as filling in by sediments, and eutrophication*.

Box 9 Transformation of the Sinnéra and San El-Hagar lagoons (Egypt) into areas for aquaculture production and farming

The Sinnéra and Sanel Hagar delta lagoons are in the north-eastern part of the Nile Delta, to the east of the Damiette branch and to the south of Lake Manzala. They host fauna and flora adapted to the freshwater ecosystems fed by the Nile, where the vegetation forming the natural aquatic habitats is principally made up of phragmites, reeds, and typhas *(Hughes & Hughes, 1992)*.

However, our observations for this site are alarming: from 1975 to 2005, natural wetland habitats (Figure 13) plummeted from 317 km² to only 0.28 km² (a 99.9% loss). A large proportion of these lagoons disappeared due to the conversion of natural lakes and marshes into areas for fish farming (102 km²) and agriculture (114 km²).

This drastic transformation of these delta habitats in Egypt is linked to the country's fish farming development policy. According to the FAO (2010), aquaculture has become the biggest supply of fish in Egypt (51% of the consumption).

This activity began in the 1970s, with the launch of a vast national development programme. It really took off at the end of the 1990s (Figure 14), when intensive fish farming practices (smaller but more productive ponds) were introduced in the aim of replacing traditional or semi-intensive fish farms. The extension of intensive aquaculture was also devised to counter the expansion of crop farming, which was taking away land from extensive aquaculture (fish farming area lost 56 km² to crop farming between 1990 and 2005) *(FAO, 2010)*.

In addition to the conversion of natural wetland habitats (lakes and marshes) into artificial habitats (fish farming ponds), intensive aquaculture is also dangerous to ecosystems due to pollution, linked to the use of fertilisers, antibiotics, and artificial feed to increase production, and because of the accumulation of organic waste.

FIGURE 13

Transformation of natural wetland habitats into artificial wetland habitats from 1975 to 2005 (Sinnéra and San El-Hagar, Egypt) *(© GlobWetland II/ESA).*

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats
- Artificial wetland habitats

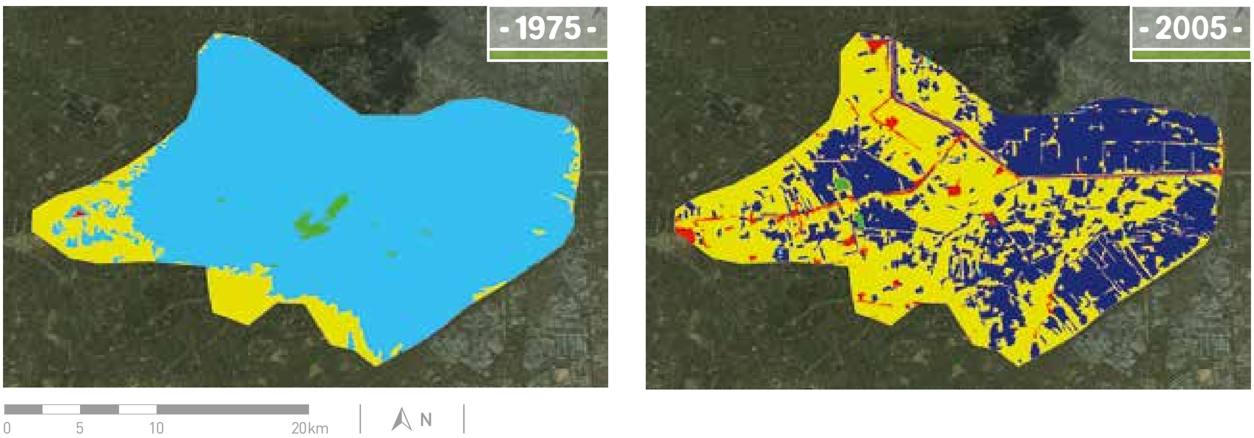
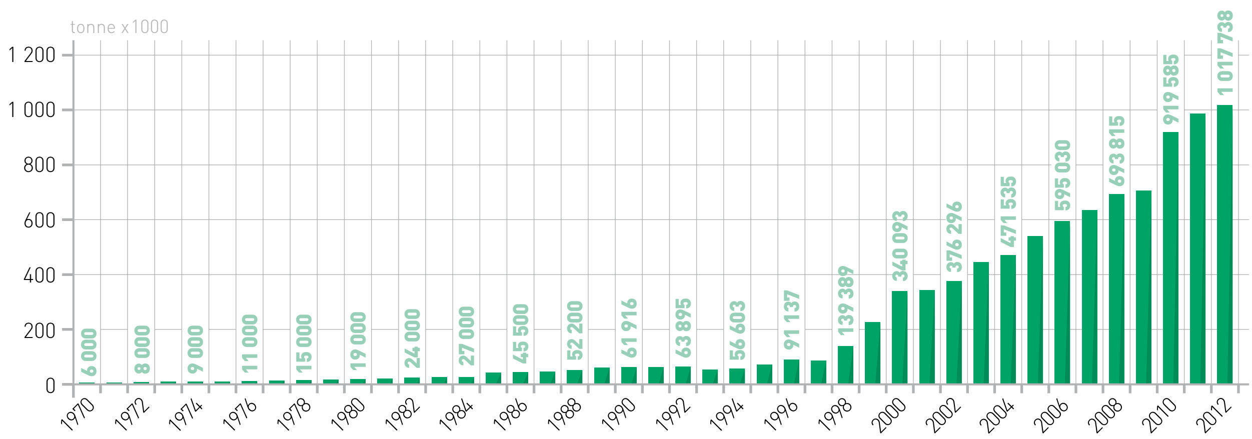


FIGURE 14

Evolution of aquaculture production in Egypt in thousands of tonnes *(Source: FAO, 2012).*



Box 10 Disappearance of natural non-wetland habitats in the Sado Estuary (Portugal)

The Sado river has the second largest estuary in Portugal. Wetland habitats in it are mainly composed of marine or freshwater intertidal marshes, reed beds, wetland forests (riverine woodlands*), rice fields, fish farming ponds, and some salt works ponds. Most of the estuary is a natural reserve, except the areas near the city of Setubal and its port zone (in the north-western part of the site). It has also been a Ramsar site since May 1996, because of the significant biodiversity it harbours *(Caeiro et al., 2002)*.

In 1975, of the 276 km² mapped, natural habitats (wetland and non-wetland) covered about 200 km² (more than 72% of the total area, see Figure 15). This figure dropped to 180 km² in 1990 (about 65%), and 179 km² in 2005, which means that the decline was nearly arrested from 1990 to 2005. 88% of the natural habitat lost in the first 15 years were natural non-wetland habitats, mainly forests converted into agricultural or agroforestry areas (-18,6 km² of a total loss of 21 km² of natural habitats).

These significant anthropogenic pressures on the natural habitats are due to the strategic importance of this site in the local and national economy. Many industries have been installed in the north-western part of the estuary since the end of the 1960s, creating a major industrial port area to the detriment of farming areas and natural habitats *(Catarino et al., 1997)*.

In addition, from 1975 to 2005, intensive agriculture took over nearly 28 km² in the southern and eastern parts of the site. Some of these activities degrade the ecological functioning of the site, especially water quality, and result in increased sedimentation because of the large amount of untreated waste *(IH, 1993)*. The significant increase in the concentration of certain pollutants in the environment, such as heavy metals and pesticides, bioaccumulate first in fishing and aquaculture products, then in people.

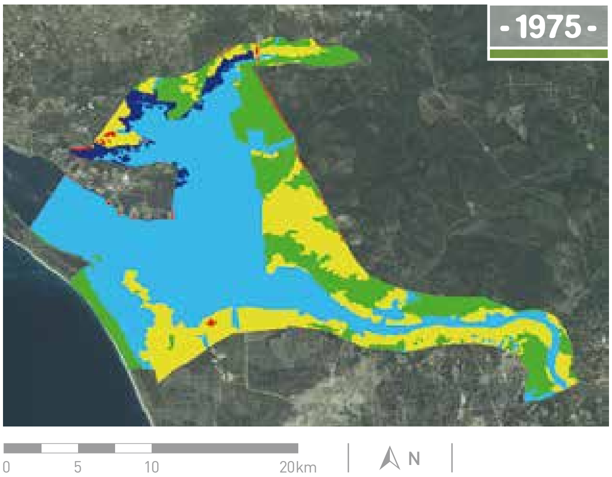
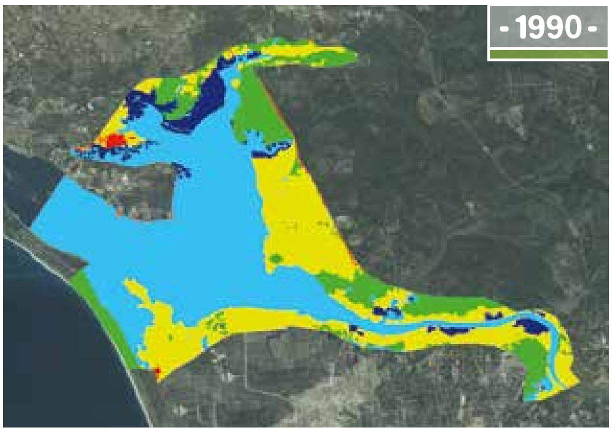
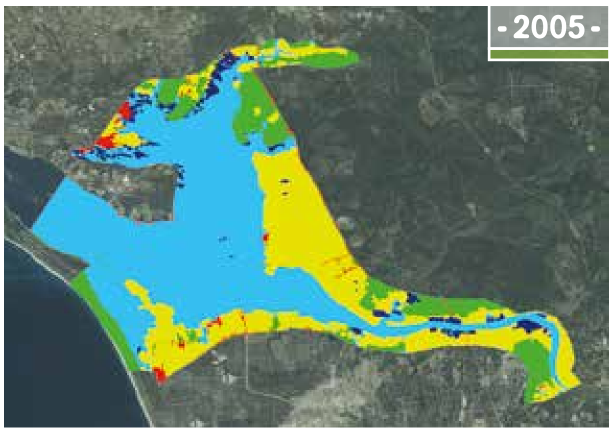


FIGURE 15

Expansion of agriculture to the detriment of non-wetland natural areas from 1975 to 1990 with a slowing down from 1990 to 2005 (Sado Estuary, Portugal).

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats
- Artificial wetland habitats
- Sea and ocean





2.4 IMPACTS ON MEDITERRANEAN WETLAND SPECIES

A decline in species dependent on marshes and wet meadows

The particularly significant disappearance of marshes and wet meadows confirms the MWO's initial results on biodiversity in Mediterranean wetlands *(MWO, 2012b)*. Indeed, a high number of amphibians, reptiles, insects, and aquatic plants are among the threatened species in the Mediterranean region, and they are strongly linked to marsh and wet meadow habitats. Meanwhile, waterbird numbers are generally increasing in the Mediterranean Basin, however, certain species continue to decline, which is particularly true of specialist species* dependent on marshes, such as the Eurasian Bittern, the Little Bittern, and three species of crakes.

The Eurasian Bittern, a species dependent on reed beds (© T. Galewski).

A decline in waterbirds in the eastern part of the Mediterranean Basin

From 1970 to 2010, waterbird populations decreased in the eastern part of the Mediterranean Basin, while they increased in the western part *(MWO, 2012b)*. Likewise, this study shows that natural habitats disappeared significantly in the large Egyptian lagoons as well as in certain big lakes in Greece and Turkey. The Nile Delta, in particular, is the biggest wetland area in the entire region, and one of the rare wetlands in the south-eastern Mediterranean. Its significant degradation undoubtedly has a negative effect on migratory birds before and after they cross the Sahara and/or the Mediterranean.

Contrasting impact of artificial wetland habitats on species

Artificial wetland habitats have expanded rapidly and to the detriment of natural wetland habitats. However, in terms of conservation, they are not equivalent. Sites where there are the most artificial wetland habitats are those in which there is the most water management (canals, reservoirs, salt works, and rice fields), and where the hydrological regime is therefore different than in a wetland made up of natural wetland habitats. Due to the annual distribution of rainfall in the Mediterranean, normal hydrological patterns show a minimum amount of rainfall in the summer and a maximum in the autumn and winter. These patterns can be completely modified, or even reversed, to increase productivity, either for the purposes of hunting (flooding in the summer to attract ducks and dried out in the spring) and farming (dam lakes in which there is always water, irrigation of rice fields in the spring and summer). At a time in which natural wetland habitats are declining and there is less and less water available in ecosystems, artificial bodies of water enable some species, especially waterbirds, to find substitute habitats that are important for their survival *(Afdhal et al. 2012, Navedo et al, 2012)*. This would explain why, despite the disappearance of natural wetland habitats, several species of waterbirds show a significant increase *(MWO, 2012b)*. However, these habitats are less favourable to numerous species of plants and invertebrates *(Green et al., 2002)*, and amphibians *(Baker & Halliday, 1999)*, in particular those requiring a precise set of ecological conditions. In addition, these habitats are not designed to host biodiversity: most reservoirs are habitats that have been too simplified to enable the reconstitution of ecosystems close to natural wetland habitats, and are therefore only used by generalist species*, capable of living in a broad range of habitats.

An explanation for the loss of specialist species* observed in Mediterranean wetlands?

In Mediterranean wetlands, waterbird communities are increasingly dominated by generalist species*, which are capable of adapting and surviving in different types of habitats, and there are less and less specialist species*, dependent on a particular habitat *(MWO, 2012b)*. This replacement of specialist species* by generalist species*, which are often widely distributed geographically, is called biotic homogenisation*. It has been widely documented in a large number of ecosystems and for different taxonomic groups throughout the world *(Olden et al. 2004)*. Empirical data and modelling results show that the replacement of specialist species* by generalist species* is more probable in disturbed and fragmented habitats *(Marvier et al., 2004; Devictor et al., 2008)*. In the case of Mediterranean wetlands, we can thus suppose that there is a strong link between the biotic homogenisation* of waterbird communities and land cover changes. In particular, the loss of natural wetland habitats and their replacement by artificial wetland habitats could be a key factor.

The Yellow-legged Gull, a typical generalist species (© C. Perennou).

3. WHY HAVE WETLAND HABITATS CHANGED SO MUCH IN 30 YEARS?

3.1 AGRICULTURE, THE MOST SIGNIFICANT DIRECT PRESSURE ON WETLAND HABITATS

Two indicators were used to understand the importance of agriculture in the transformation of the sites studied. The first measures the gain or loss in agricultural area on the site between two dates, while the second corresponds to the rate of conversion of natural wetland habitats into agricultural areas between two dates, and measures the direct impact of agriculture on natural wetland habitats.

A rapid expansion of agricultural areas from 1975 to 1990

From 1975 to 2005, agricultural areas expanded by a total of 12% for all of the sites studied (a gain of 982 km² in 30 years, see Figure 16). The expansion of agricultural areas was concentrated between 1975 and 1990, with an increase of 13% in agricultural areas (1,062 km²). Meanwhile, from 1990 to 2005, the total surface area of agricultural areas was stable, with even a slight decrease of 79 km² (Figure 16).

FIGURE 16

Total surface area of agricultural areas on the 214 study sites (in km²)

- 1975 - 8,279 km²

- 1990 - 9,341 km²

- 2005 - 9,262 km²

A heavy impact on natural wetland habitats

From 1975 to 2005, 891 km² of natural wetland habitats were converted into agricultural areas (7% of the natural wetland habitats in 1975 on the sites studied, see Figure 17). The loss of natural wetland habitats represents nearly 90% of the increase in the surface area of agricultural areas during the period studied. The rate of conversion was rather stable from 1975 to 1990 and from 1990 to 2005 (Figure 17).

FIGURE 17

Conversion of natural wetland habitats into agricultural areas (in km²). NB: Because of complex temporal dynamics, the changes from 1975 to 2005 may be lower than the sum of all changes during the two successive sub-periods.

1975 › 1990: 670 km²

1990 › 2005: 535 km²

1975 › 2005: 891 km²

Intensive agriculture in the Neretva Delta in Croatia (© L. Chazée).

Wetlands, highly coveted for agriculture

Agriculture is considered to be the principal cause of wetland habitat loss in the world. It is estimated that in 1985, 55 to 65% of the wetlands that had existed in Europe and North America at the beginning of the 20th century had been drained and replaced by intensive agriculture, 27% in Asia, and 2% in Africa *(Finlayson & Davidson, 1999)*.

In the Mediterranean region, where rain-based agriculture is the most common form of farming (80% of the land farmed), the surface area of arable land and permanent crops stabilised or decreased from 1961 to 2005. However, during this same period, the total surface area of irrigated land doubled and in 2005 represented 26 million hectares, 20% of farmed land, see *(UNEP / MAP-Plan Bleu, 2009)*. In absolute values, the greatest increases were recorded in Turkey (3.1 Mha), France (2 Mha), Spain (1.5 Mha), Greece, Syria, and Egypt. This expansion was also considerable in the Maghreb (1.53 Mha - 0.56 Mha in Morocco, and 0.34 Mha in Algeria) *(Mediterra, 2009)*. Meanwhile, conditions in wetlands are perfect, making them the ideal place for irrigated agriculture, if the water available is well managed. They are flat areas with often fertile soil and abundant organic material. This development was sometimes supported by national plans, because it requires major investments (construction of dams, and drainage and irrigation networks, see Box 6). In Morocco, vast coastal plain areas where natural wetland habitats are common have been developed for growing crops *(Rhazi et al., 2012)*.
In addition to the direct destruction, the increase in the amount of irrigated land also has an indirect impact on the wetland habitats that are not destroyed. For example, 64% of the fresh water abstracted in the Mediterranean Basin is used for agriculture *(UNEP / MAP - Plan Bleu, 2009)*. Considered to be fresh water reservoirs, natural wetland habitats can therefore be considerably modified simply because of excessive water abstraction. The case of Lake Koronia illustrates this process. It used to be the fourth biggest natural lake in Greece, but has decreased in size due to the development or irrigated farming in this region (Box 11).

3.2 IS URBANIZATION THE DRIVING FORCE BEHIND THESE TRANSFORMATIONS?

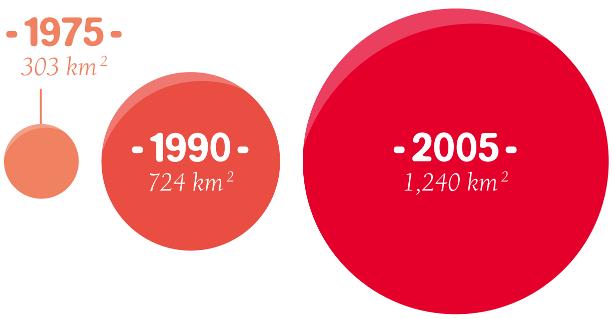
The sites studied also include various urbanized areas: urban, industrial, and commercial zones; transportation networks, mines, dumps, and building sites (not including excavated areas), urban green areas, and sports facilities. To analyse their dynamics and impacts on natural wetland habitats, two indicators were used that are equivalent to the ones used for agricultural areas. The first calculates the net variation (gain or loss) in area urbanized on a site between two dates. The second is the rate of conversion of natural wetland habitats in urbanized areas between two dates, that is, the direct impact of urbanization on the natural wetland habitats on the site.

A regular increase in the amount of land urbanized from 1975 to 2005

From 1975 to 2005, the surface area urbanized increased by 309% (+937 km² for all the sites studied). This urbanization process was steady from 1975 to 1990, and 1990 to 2005 (Figure 18).

FIGURE 18

Total surface area urbanized on the 214 sites studied (in km²).

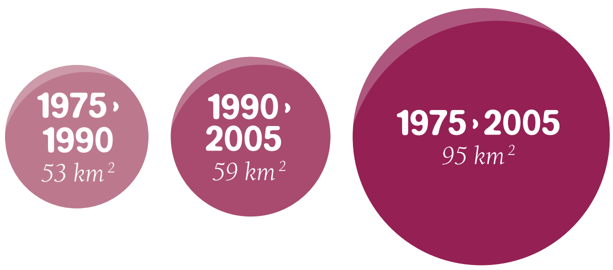


A direct impact on natural wetland habitats less significant than agriculture

From 1975 to 2005, 95 km² natural wetland habitats were converted into urban areas (0.75% of natural wetland habitats existing in 1975 on the sites studied, see Figure 19). This figure is significantly less than the 7% of natural wetland habitats transformed into agricultural areas during the same period. The rate was similar during the two sub-periods studied.

FIGURE 19

Conversion of natural wetland habitats into urban areas (in km²). NB: Because of complex temporal dynamics, the changes from 1975 to 2005 may be lower than the sum of all changes during the two successive sub-periods.



Box 11 Hydrological modification of lake Koronia (Greece) due to agricultural development

Lake Koronia together with Lake Volvi form a wetlands complex that has been listed as a Ramsar site since 1975. Located in northern Greece, in the 1950s it was considered to be one of the most productive Greek lakes for fishing. Since this time, its surface area has shrunk by two-thirds, and its average depth went from 5 m in the 1970s to less than 1 m, resulting in the almost complete disappearance of fish communities *(Grammatikopoulou et al., 1996)*.

Various studies demonstrate this significant loss in area (Figure 20).The surface area of the "permanent natural lake" habitat dropped from 44 km² in 1975 to 16 km² in 2005 (-64%). The proportion of this habitat within all the natural wetland habitats plummeted from 92% to 34%, and was replaced by marshes and a new habitat listed as a "temporary lake".

During this same period, the surface area of agricultural areas increased by more than 31% in the zone mapped (from 24 km² to 35 km²). Although in spatial terms these transformations were especially to the detriment of natural non-wetland habitats, their indirect impact on the lake has been proven. A large part of the flows that were feeding it (surface water runoff and groundwater) were diverted for irrigation, resulting in a dramatic drop in its level in a few years, which was not related with the variations in rainfall (Figure 21). The drop in water level was followed by a series of cyanobacteria blooms, caused by the artificial nutrient enrichment of this area by fertilisers, and industrial wastewater. These changes subsequently led to an anoxic crisis (lack of oxygen in water), causing the death of macrofauna in the lake in 1995 *(Mitraki et al., 2004)*.

FIGURE 20

Disappearance of wetland habitats from 1975 to 2005 (Lake Koronia, Greece).

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats apart from permanent lakes
- Permanent natural lakes

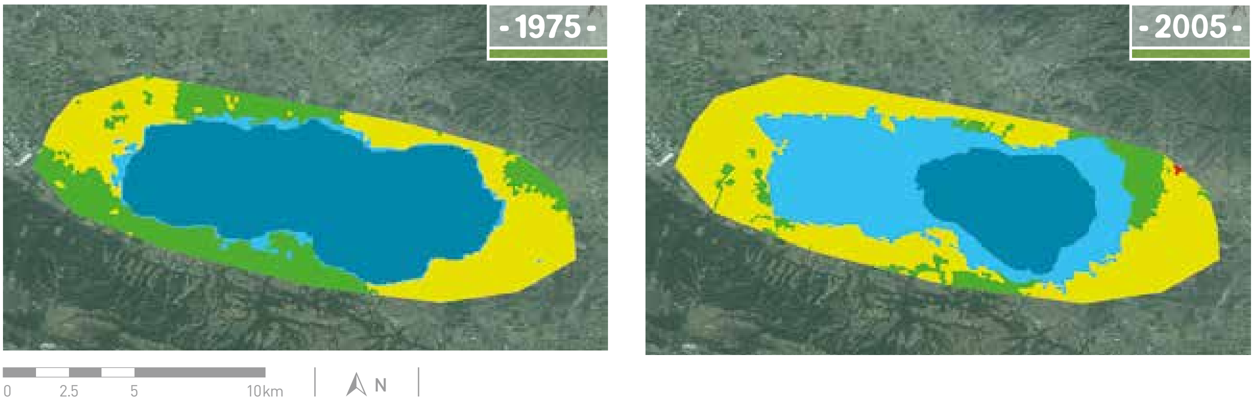
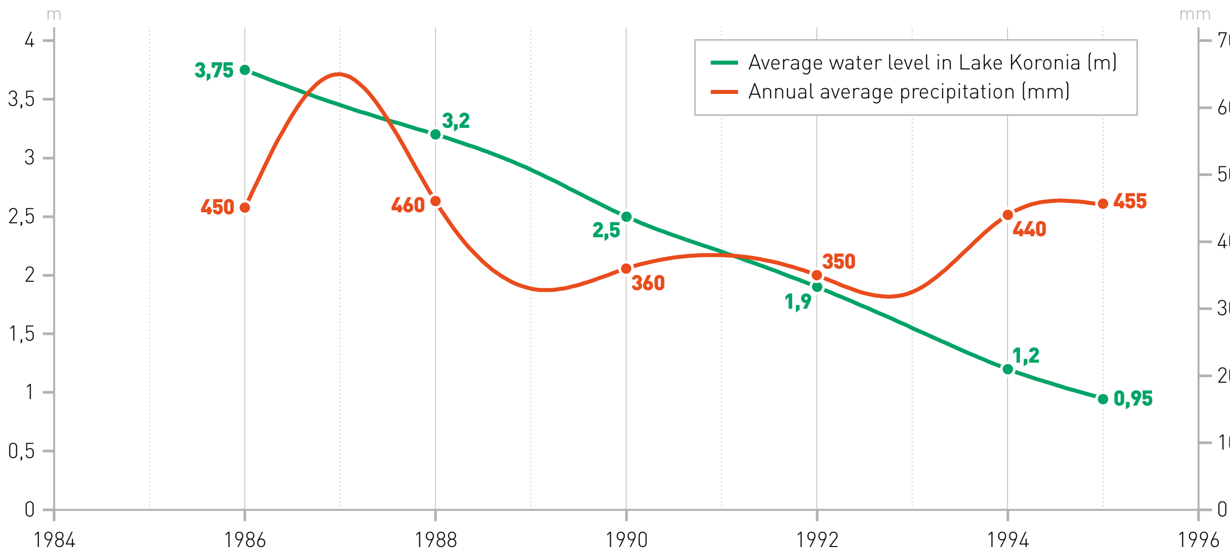


FIGURE 21

Evolution in average water level in lake Koronia from1986 to 1995 *(Source: Mitraki et al., 2004)*.



↖ *Urbanization for tourism in the Camargue (France) (© L. Chazée).*

"Coastalisation" in the Mediterranean

In the Mediterranean region, urbanization is particularly intense along the coast, where most people and the principal human activities are concentrated (industry, tourism, and agriculture). In 2000, population density was three times higher in the coastal regions than the average density of the countries concerned *(UNEP/MAP-Plan Bleu, 2005)*, and 40% of the Mediterranean coast was urbanized *(UNEP/MAP-Plan Bleu, 2005, 2009)*. This process of concentrating people in coastal regions is known as "coastalisation" *(UNEP/MAP-Plan Bleu, 2005)*, and combines two phenomena.

First, cities are expanding. In 1995, 62% of the total population lived in an urban area in the Mediterranean coastal zone, and forecasts are 72% for 2025, with a stronger increase in the countries in the southern and eastern parts of the basin *(UNEP/MAP-Plan Bleu, 2009)*. This expansion of cities is linked to strong demographic growth and a significant rural exodus in these same countries. To the north of the Mediterranean, while demographic growth is low, urban development policies are based on intensive land use: housing estates, economic activity zones, and commercial areas have developed rapidly on the outskirts of cities *(EEA, 2013)*. Sometimes this urban expansion has a direct negative effect on natural wetland habitats (Box 12).

Second, the Mediterranean Basin is the most popular tourist destination in the world, attracting one third of the worldwide total of international tourists *(UNEP/MAP-Plan Bleu, 2009)*. As a result, infrastructure for accommodations, transportation, and wastewater treatment has developed rapidly on the coast. This infrastructure is sometimes built directly on natural wetland habitats, as was the case for the extension of the Barcelona airport, which was built on part of the Llobregat Delta.

Urbanised agricultural areas eroding natural wetland habitats

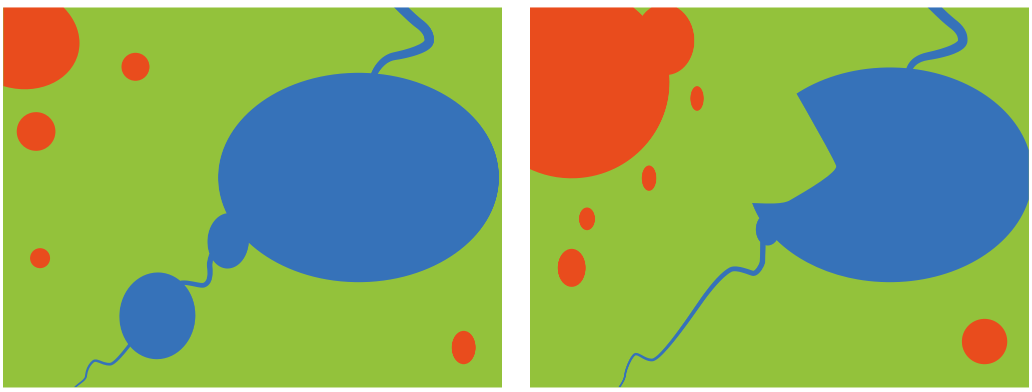
As we have already seen, the surface area of natural wetland habitats converted into agricultural areas (7%) is far greater than what was converted into urban areas (0.75%) from 1975 to 2005. Agriculture thus appears to be the most important direct cause in the loss of natural wetland habitats.

However, as of 1990, the expansion of agricultural areas decreased strongly, whereas the rate of conversion of natural wetland habitats remained stable. Natural wetland habitats are thus continuing to be destroyed, principally by being converted into agricultural areas, but with no net gain in these areas, which implies that agricultural areas are expanding and being partially destroyed at the same time. In fact, urbanized areas are expanding to the detriment of agricultural areas in peri-urban zones, and these agricultural areas are in turn taking over natural wetland habitats (Figure 22). Since 1990, urban expansion has therefore been a significant driving force in the destruction of natural wetland habitats (Box 13).

This process has been observed throughout the Mediterranean Basin and Europe. Indeed, the expansion of cities mainly consumes suburban agricultural areas, and these lost agricultural zones are then taken over nearby natural or semi-natural areas *(Méditerra 2008, 2009)*.

FIGURE 22

Simplified diagram of replacement of agricultural areas (in green) by urbanized areas (in orange), and the taking over of natural wetland habitats (in blue) by the outward displacement of agricultural areas.



Box 12 Urban expansion in the Famagusta wetlands complex (Cyprus)

This site is a wetlands complex located north of the city of Famagusta, in northern Cyprus. It is made up of three principal zones characteristic of the main wetland habitats typically found at the mouths of Mediterranean rivers:

1. Glapsides in the north, which is located on part of the mouth of the Pedieos river, is essentially made up of alluvial plains and marshes.
2. Gülseren, in the centre, is the zone closest to the coast. It includes plain marshes, maritime marshes, and natural non-wetland habitats.
3. Ayluga, in the south, is principally made up of marshes surrounded by aquatic vegetation (reeds) and saline meadows.

In 2008, the site was listed as a protected area and placed on the list of potential Natura 2000 sites. Nearly 44% of the initial 570 ha of natural wetland habitats on the site were lost between 1975 and 2005 (Figure 23).

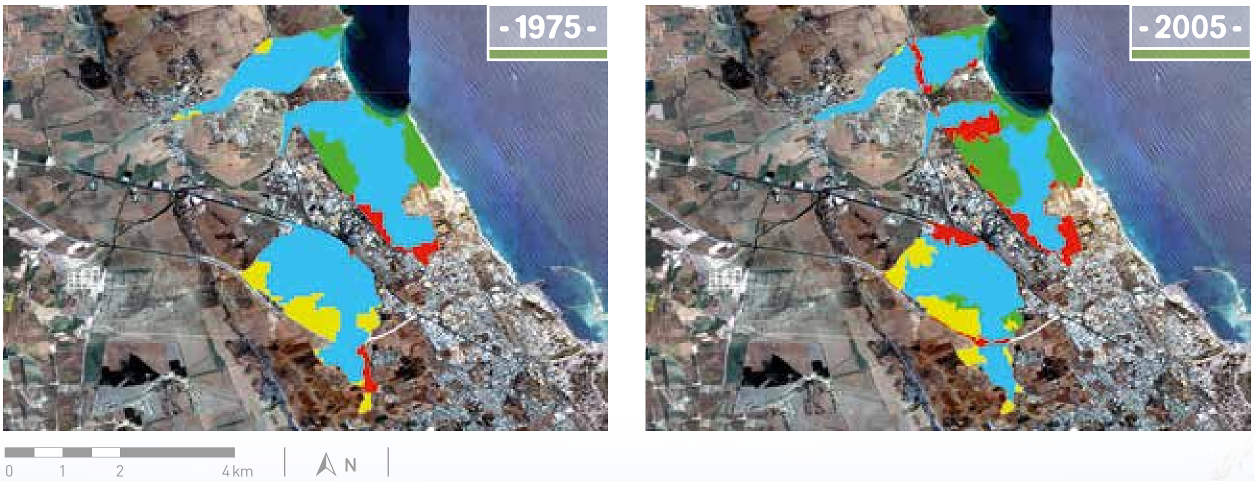
This loss was largely due to the rapid growth of urban areas, which nearly tripled in size (+67 ha). More than half of the natural wetland habitats lost were urbanized, the rest of the constructions took over agricultural areas (5 ha) and natural non-wetland habitats (7 ha). The increased urbanization resulted in the fragmentation of the natural wetland habitats.

These figures confirm that urbanization is indeed the principal threat facing ecosystems in Cyprus. Since the division of the country and the migration of Turkish Cypriots from the south of the island to the north in 1974, the city of Famagusta has continually expanded toward the north (*Seffer et al., 2011*). This urban boom peaked in the early 1980s, with the construction of the university campus and an industrial and commercial zone between the sites of Gülseren and Ayluga. In addition, two motorways separate the sites of Glapsides (in the north) and Ayluga (in the south), increasing the fragmentation of the wetland habitats.

FIGURE 23

Expansion of the city of Famagusta (Cyprus) and decrease in the surface area of natural wetland habitats from 1975 to 2005.

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats
- Sea and ocean



↗ *Famagusta wetlands complex in northern Cyprus (© A. B. Çiçek / Eastern Mediterranean University).*

Box 13 Displacement of agriculture onto wetlands in the Aveiro Estuary (Portugal) due to pressure from urbanization

Located on the northern coast of Portugal, south of Porto, the Ria Aveiro Estuary is made up of various natural wetland habitats, including lagoons; intertidal, salt and freshwater marshes; wet meadows and forests, salt works areas and fish farming ponds. It is the principal mouth of the catchment area of the Vouga river toward the Atlantic Ocean.

This site is of major biological importance: it is a spawning area for numerous species of fish, a breeding site for amphibians, and hosts a great diversity of molluscs and shellfish. It is also a wintering and nesting area for many migratory waterbirds *(Reis, 1993)*, and is listed as a natural reserve and an Important Bird Area.

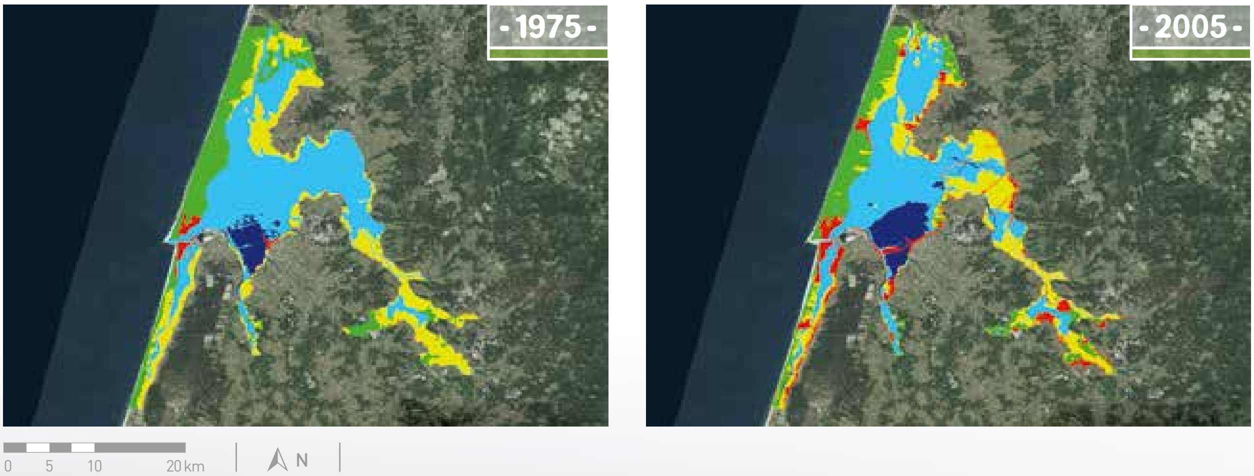
From 1975 to 2005, the site lost more than 16% of its total surface area of natural wetland habitats, which dropped from 147 to 123 km². But the most remarkable point is not as much the net loss in natural wetland habitats, as its direct and indirect causes. More than 80% of the losses (nearly 20 km²) were due to the conversion of wetlands into agricultural areas. Meanwhile, at the same time, agricultural areas were also experiencing important losses (about 18 km² during the same period), principally due to the incredible expansion of urban areas, which experienced a six-fold increase in area from 1975 to 2005 (from 4.8 km² to 30.7 km²) (Figure 24).

These growing anthropogenic pressures also affect the estuary, in particular the fish spawning zones, in the form of agricultural, urban, and industrial wastewater *(Lopes et al., 2007)*.

FIGURE 24

Conversion of natural wetland habitats into farmland, which was eaten away by urbanization (1975 to 2005, Ria Aveiro, Portugal).

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats (except watercourses)
- Artificial wetland habitats
- Sea and ocean



Ria de Aveiro (Portugal) (© Zacarias da Mata).

3.3 ARTIFICIALIZED MANAGEMENT AND INCREASED WATER ABSTRACTION

With 3% of the world resources, the Mediterranean is a region with a low supply of freshwater *(UNEP/MAP-Plan Bleu, 2009)*. This water is also very unequally distributed in the Mediterranean Basin: 71% of the annual surface and groundwater flows are in the north, 9% in the south, and 20% in the east *(Margat, 2008)*. Water is increasingly rare due to demographic growth, climate change, and economic and social changes, and its management is a major issue for the 21st century.

Water resources are currently overexploited in numerous countries (Map 2). In the Mediterranean Basin, on average, 64% of freshwater is used for agriculture, 22% for industry, and 14% for domestic uses *(UNEP/MAP-Plan Bleu, 2009)*. Irrigated agriculture is the sector that uses the greatest amount of water in the Mediterranean region *(Mediterra, 2009)*. Due to the unequal availability of water, its distribution between different sectors is highly variable from one country to another: 75 to 100% is used for irrigated agriculture in the south, in the east, and in Spain, compared to less than 2% in certain Balkan countries (Slovenia, Montenegro, and Croatia).

Some wetlands serve as freshwater reserves. Water is often taken from them, sometimes resulting in a drastic decrease in the amount of water available for ecosystems. As a result, the flows of rivers emptying into the Mediterranean Sea have decreased *(Ludwig et al., 2003)*, principally because of direct water abstraction. The Nile, in Egypt, is a good example, since it no longer brings almost any water to the Mediterranean, because of the Aswan Dam and the water abstracted for agriculture *(Bohannon, 2010)*. The Ebro, which is the biggest Spanish river, saw its flow decrease by 29% in the 20th century, 90% of this decrease was due to water abstracted for irrigation *(Ibàñez et al., 1996)*. The total quantity of freshwater brought by all rivers into the Mediterranean Sea dropped by nearly 45% from 1920 to 1995 *(Ludwig et al., 2003)*.

However, the use of water resources for human activities has consequences that go beyond those caused by water abstraction. The number of dams and reservoirs, which have a major impact on wetlands, continually increased throughout the 20th century *(MWO, 2012a)*. These dams are sometimes built at the outflow point of natural lakes to provide secure access to water resources for the surrounding area. A natural lake is thereby transformed into an artificial lake, as is the case for Lake Kuş (or lake Manyas) in Turkey. In order to develop agriculture and provide electricity, two sills were built at the two principal mouths of the lake, and dykes were built on the downstream shore to raise and stabilise the water level so as to increase the storage capacity of the lake. The subsequent water level has been extremely high, especially in the summer, and the sediments that are now trapped fall out in the lake. These phenomena have led to the degradation, and even disappearance of fringe wetland habitats (flooded forests and marshes) *(Magnin & Yarar, 1997)*.

Some dams have been built directly on rivers. In this case, the initially present natural wetland habitats (rivers, wet meadows and marshes) are to a large extent flooded by the water behind the dam, which leads to the creation of artificial wetland habitats. This is what happened when the Lebna dam was built in 1986 in Tunisia in the bed of a wadi* (Box 14).

Ultimately, dam construction has a major impact on the wetlands located downstream and in particular deltas, which are dynamic environments. The sediments transported by a river and deposited in its delta when there is a flood tend to enlarge the delta; whereas marine currents and storms take back and redistribute these sediments and tend to erode the coast. The construction of a dam in the catchment basin of a river radically alters this process by blocking the sediments in the dam reservoir, and by decreasing the frequency and intensity of floods.

MAP 2

Exploitation index of renewable water resources *(Source: UNEP/MAP-Plan Bleu, 2009)*.

Box 14 Construction of the Lebna Dam (Tunisia) in the bed of a watercourse

The lake created in 1987 behind the Lebna Dam *(the largest dam in this region, see photo p. 43)* is a hillside lake located almost at the tip of the Cap Bon peninsula, in north-eastern Tunisia. It was build upstream from the Lebna Wadi*, at the confluence of the two wadis* that feed it, El Ouidyen and Bou Dokhan.

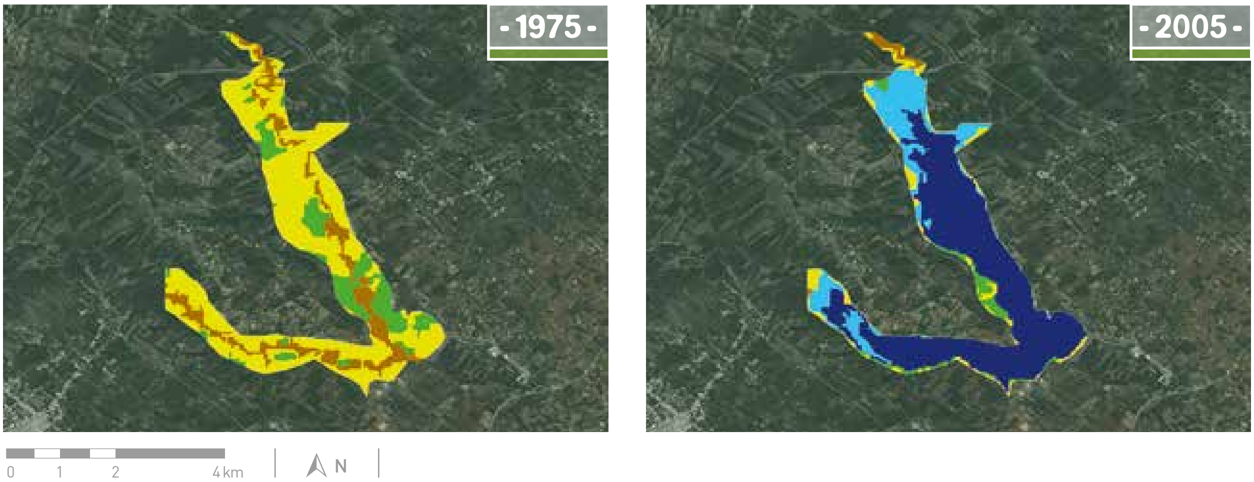
From 1975 to 2005, the total surface area of natural and artificial wetland habitats increased by nearly 500% in this site, from 1.33 km² to 6.35 km² (Figure 25). This rapid expansion concerned especially artificial wetland habitats, which went from 0% in 1975 to over 75% of the total wetland habitats in 2005. Natural wetland habitats also grew a bit (+20 ha in 30 years), but their nature was modified. The class "watercourse", which accounted for 100% of the wetland habitats in 1975, nearly disappeared from the area studied (-90%). This habitat was essentially replaced by "reservoirs and dams" (80%), and for the rest, by the classes "agriculture" (11%) and "marshes with aquatic vegetation" (9%). Phragmites and typha beds are among the largest and densest that can be found in Tunisia. The site also hosts a large number of waterbirds (nearly 20,000 individuals), including vulnerable and / or threatened species such as the Marbled Teal, White-headed Duck, and Ferruginous Duck. Because of this species diversity, it has been listed as an Important Bird Area and Ramsar site *(Romdhane, 2012)*.

The Lebna Dam is far from being an isolated case in Tunisia of transforming a wadi* into a water reservoir site. The country has one of the largest amounts of farmland per inhabitant in Africa: nearly 5 km² per 1,000 inhabitants *(FAO, 2005)*; however, the irrigation rate remains very low (< 7%). To remedy this situation, the government adopted a policy aiming to harness more than 95% of the country's water resources. Thirty-six major dams were built to increase the proportion of irrigated land (27 of them after 1980), and agriculture use 82% of the water in these dam reservoirs.

FIGURE 25

Construction of a dam in the bed of a watercourse from 1975 to 2005 (Lebna Dam, Tunisia). *(© GlobWetland II/ESA)*.

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats (except watercourses)
- Watercourses
- Artificial wetland habitats



3.4 THE RECEDING COASTLINE

The receding coastline, a combination of the rising sea level and coastal erosion

The last IPCC report *(2013)* estimates that if nothing is done to reverse the trend in greenhouse gas emissions, the sea level could rise by 98 cm before 2100 and 3 m by 2300. From 1901 to 2010, the sea level already increased by 19 cm on average, and the rise has been nearly twice as rapid in the past 20 years compared to the entire 20th century *(IPCC, 2013)*.

The rising sea level has been combined with increasing coastal erosion on certain parts of the Mediterranean coast. This erosion can be explained mainly by the decreasing amount of sediment particles in rivers, which is due to sediment trapped by dams, the reforestation of certain catchment areas, and a decrease in the flow of water arriving at the sea. Yet, the sediment particles in rivers are essential for providing nutrients to the coastal plains during floods, and in this process compensate for the natural compaction (subsidence)* of these plains and the coastal erosion due to marine currents.

Coastal wetlands such as lagoons, maritime marshes, and deltas are located in areas that are rather flat, and at a low altitude or even below sea level. The rising sea level, coastal erosion, and provision of less sediments expose these habitats to submersion by the sea, and a receding coastline *(Nicholls, 2004)*.

One of the most striking examples is the Nile Delta in Egypt. 24,000 km² in size and more than 1,000 inhabitants per km², it is the largest Mediterranean wetland, and one of the most densely-populated areas in the Mediterranean Basin. The Aswan Dam, built in 1902, and the High Dam, built in 1960 block sediments upstream, whereas before their construction, 100 million tonnes of sediment arrived at the sea every year. Dams also prevent rivers from flooding, which used to deposit 1 mm of silt per year throughout the delta, and compensate for subsidence*. Today, no sediments compensate for the erosion caused by marine currents, which is exacerbated by the rising sea level due to climate change. The coastline in this delta has receded significantly, and there has been an inflow of saline water onto the land, which has affected agricultural production. Even if it is difficult to make precise estimates of the future configuration of the delta, due to its complex dynamics and topography, a one-metre rise in sea level could result in the submersion of one third of the delta, with dramatic consequences for people *(Bohannon, 2010)*.

Likewise, in Spain, the construction of 287 dams in the Ebro catchment area during the 20th century decreased the sediment load in the river by 99% *(Ibàñez et al, 1996)*. This decrease had very significant consequences on the delta: there was widespread coastal erosion and the coastline receded, resulting in the loss of natural wetland habitats at the mouth of the river (Figure 26).

FIGURE 26

Changing coastline at the mouth of the Ebro (Ebro Delta, Spain) from 1975 to 2005 *(Source : MWO)*.

Changing coastline
(image 2010)

- Coastline in 1975
- Coastline in 1990
- Coastline in 2005

Consequences for natural wetland habitats in coastal regions

We may speak of two types of consequences. First, natural wetland habitats in coastal regions may be re-flooded by inflowing sea water. Meanwhile, some sites suffer from excessive water abstraction in the catchment basin and recurring droughts, particularly in the Maghreb and the Middle East. Consequently, they are less and less often flooded. The rising sea level will enable these habitats to be flooded more regularly; however, with salt water, whereas there is an excessive abstraction of fresh water. To give an example, a 50 cm-rise in sea level could result in a 2,000 ha extension of the Ghar El Melh Lagoon In Tunisia *(Ayache et al., 2009)*.

In France, the rising sea level is transforming the Rhone Delta (Camargue). Some land used for salt production has become too expensive to protect against inflowing sea water with a system of dykes. Faced with these costs and the continually rising sea level, the Salins du Midi salt works company, owner and operator of this site, sold part of its land to the French Coastal Protection Agency (Conservatoire du littoral). The new management plan calls for the progressive re-naturalization* of these artificial wetland habitats, thanks to marine inflows during winter storms and the provision of fresh water from the neighbouring artificial wetland habitats.

On the other hand, the receding coastline can result in the disappearance of certain natural wetland habitats that are submerged. This phenomenon can be observed in the Karavasta lagoon in Albania (Box 15). It is also what has been forecast for the Ebre Delta in Spain, due to the rising sea level and the increasingly frequent extreme events such as ocean storms *(Sánchez-Arcilla et al., 2008)*.

Territorial development must be rethought in coastal areas

The coastline is already starting to recede in the coastal plain areas. Political action is now necessary to rethink their development.

For example, on the French coast, the Languedoc-Roussillon coast is made up of major lagoon complexes. Essentially sandy and low, it is very exposed to the risks entailed by the receding coastline. The Region is planning and implementing a "strategic retreat" in some areas struck by the two phenomena – the rising sea level and the coastal erosion linked to the decreased amount of sediments provided by the Rhone. Given the amplitude of the changes, the high economic cost and relatively low effectiveness of protection provided by traditional methods (dykes, groynes, and artificial sandbanks) are not justified in areas where the economic and human stakes are low to moderate. New types of management to deal with marine erosion have thus been put in place: restoration* of dune barriers to protect the coast, combined with a strategic retreat (moving roads and other infrastructure, relocating activities, etc.). These solutions are less costly, and also enable ecosystem functions to be restored* and maintain their attractiveness for tourists. In this context, thanks to their hydrological characteristics, coastal wetlands could play an important role in mitigating the effects of rising sea water *(MEA, 2005)*. However, to achieve this goal would require a significant amount of work to inform people, and extensive concertation with inhabitants and wetland users to make them adhere to the project, or even co-construct it.

Breach in the dyke at Saint-Anne's Lagoon, Camargue (France). It is enabling the progressive re-naturalization of the former salt works area, which is now connected to the sea (© M. Thibault / Tour du Valat).

Box 15 Receding coastline in the Karavasta Lagoon (Albania)

Hemmed in between the Shkumbin river to the north and the Seman to the south, the Divjaka mountains to the east and the Adriatic sea to the west, Karavasta is the largest coastal lagoon in Albania. It is part of the Divjake-Karavasta National Park, which is a complex of wetland and non-wetland habitats principally made up of lagoons, marshes, canals, beaches (sand and dunes), scrub, pine forest, and agricultural areas. The site is home to a wealth of wildlife biodiversity rarely seen, such as the Dalmatian pelican, a threatened species which breeds there. The principal anthropogenic activities in this area are fishing, agriculture (grain, fodder, and market garden crops) and summer tourism *(Salathé, 1996)*.

From 1975 to 2005, 49.25 km² disappeared of the total natural wetland habitat area studied (a net loss of 37% in 30 years). For the most part, this decline corresponds to conversions for agriculture (57%), especially in the southern part of the lagoon near the mouth of the canal (Figure 27).

In addition, nearly 14% of the losses are due to coastal erosion. Although the coastline has extended due to sedimentation in certain areas, the overall sediment balance is negative, with 4.9 km² gained, but 6.73 km² lost. These losses are especially visible in the southern part of the Godulla lagoon (Figure 28), with more than 4 km² of lagoon habitat and marshes engulfed by the sea, which means it is likely to be transformed into a semi-open marine bay, separated from the Adriatic Sea by a narrow sand bar *(Ciavola, 1995)*.

FIGURE 27

Loss of natural habitats in the Divjake-Karavasta National Park (Albania) from 1975 to 2005.

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats (except lagoons)
- Lagoons
- Artificial wetland habitats
- Sea and ocean

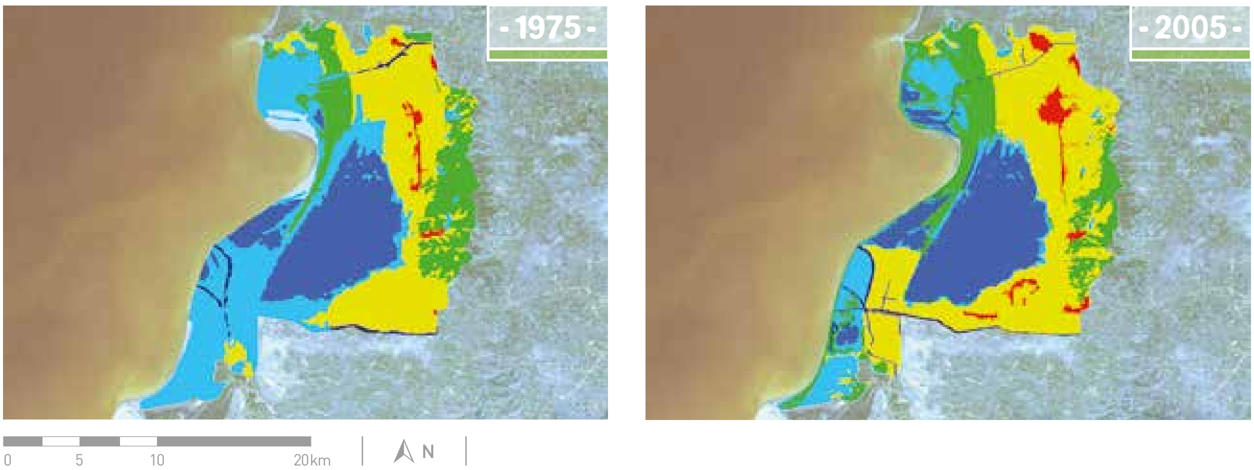
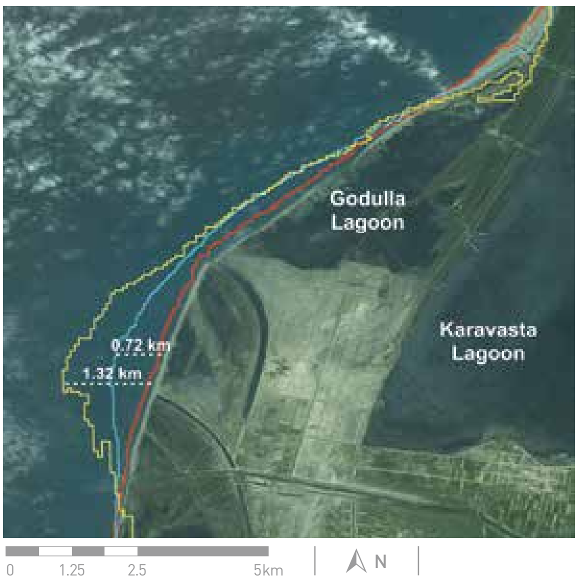


FIGURE 28

Changing coastline in 1975, 1990, and 2005 (Godulla lagoon, Albania).

- Coastline in 1975
- Coastline in 1990
- Coastline in 2005



3.5 HOW IS A WETLAND AFFECTED WHEN IS DESIGNATED AS A RAMSAR SITE?

What is the Ramsar Convention?

The Ramsar Convention is an intergovernmental treaty that is the framework for national action and international cooperation for the conservation and wise use of wetlands. It was adopted in 1971, in Ramsar, Iran, and came into force in 1975. It permits the 168 contracting parties to officially place their principal wetlands on the list of wetlands of international importance, called the "Ramsar List", and to ensure their effective management. All the countries in the Mediterranean region have signed the Ramsar Convention. Together with the Palestinian Authority, they are on the MedWet Committee, a regional initiative for the conservation of wetlands. At the end of 2013, there were nearly 400 wetland sites on the Ramsar list.

The mouth of the Wadi Massa Ramsar site in Morocco (C. Perennou).

The number of Ramsar sites continues to increase in the Mediterranean Region *(MWO, 2012a)*. Of the 214 sites in this study, only six were listed as Ramsar sites in 1975, 35 in 1990, and 82 in 2005. However, although the Convention encourages the signatories to implement a management plan and measures of protection for the designated sites, there is no legal obligation. Therefore, in terms of protection, having a wetland placed on the Ramsar list has no legal consequences. Certain countries, like Turkey, have however integrated the Ramsar site status into their nature protection legislation, thus providing legal protection to the sites designated under the convention.

A comparable rate of loss of natural wetland habitats in Ramsar and other sites

There was no significant difference in the rate of loss of natural wetland habitats from 1990 to 2005 in the 35 sites already on the Ramsar list in 1990, and the 132 that were not on the list in either 1990 or 2005.

This fact suggests that merely placing a site on the Ramsar list does not ensure the conservation of the natural wetland habitats within it. Korichi & Treilhes (2013) had already demonstrated in the Mediterranean region that neither putting a wetland on the Ramsar list nor designating it as a protected area would ensure its conservation, and that is was only the effective implementation of a management plan that made the difference. However, this finding seems to be contradicted by a recent study on Moroccan wetlands *(Kleijn et al., 2014)*. The reasons behind these divergences are not clear, so additional broad-based studies are needed to clarify the situation. The differences between these two studies may be due to the sampling size and to the major differences between countries and regions.

Beyond designation

While increasing number of Ramsar sites in the Mediterranean Region is a positive sign showing the contracting parties' heightened awareness of the importance of wetlands, it is not enough. For these sites, as more generally for protected areas *(Leverington et al., 2010)*, it is necessary to devise a management plan and have the financial and human resources necessary to implement it effectively. Unfortunately, we do not have access to reliable information on the management measures actually implemented at all of the sites studied for this report.

3.6 RESTORATION OF NATURAL WETLAND HABITATS

Restoration ecology* and ecological engineering are rapidly expanding disciplines. By restoration* we mean re-establishing the reference state of an ecosystem, which has been degraded, damaged, or destroyed. Even if we cannot completely recreate the original ecosystem, because it was the result of evolution and complex interactions, certain elements can be rehabilitated, and the essential biodiversity typical of these natural habitats can recolonize the ecosystem.

Restoration* is not a substitute for the protection of already existing natural habitats, rather it is complementary and is intended to improve degraded habitats. It can help to counterbalance a bit the losses of natural wetland habitats.

There are encouraging examples of natural wetland habitat restoration* in the sites we studied. For example, Doñana in the Guadalquivir Delta in Spain (Box 16), and the 12,000 ha Lake Karla (Greece), which was totally drained between 1959 and 1964 to enable agricultural development, but has been partially restored since 2000 (3,800 ha), following a drop in agricultural productivity in the 1980s due to soil salinisation and the nuisances caused by water pollution *(Dodouras et al., 2014)*.

Box 16 Restoration of natural wetland habitats in Doñana (Spain)

Created in 1969, the Doñana National Park is one of the largest natural protected sites in Europe (540 km²). Located in Andalusia (south of Spain), in the heart of the Guadalquivir Delta of which it covers a bit less than one third, it is along the right bank of the river and its estuary. Wetland habitats in it are extremely diverse: marshes (with and without vegetation), lagoons, temporary ponds, wet meadows and forests, salinas and rice fields. There are also natural non-wetland habitats including beaches, dunes, scrub, and forests with leafy trees and conifers. Listed as a Ramsar site since 1982, it harbours wildlife biodiversity that is exceptional and unique in Europe. Over 500,000 waterbirds winter there every year *(Garcia-Novo, 2006)*. It is also one of the last refuges of two particularly vulnerable species: the Iberian Lynx and the Spanish Imperial Eagle.

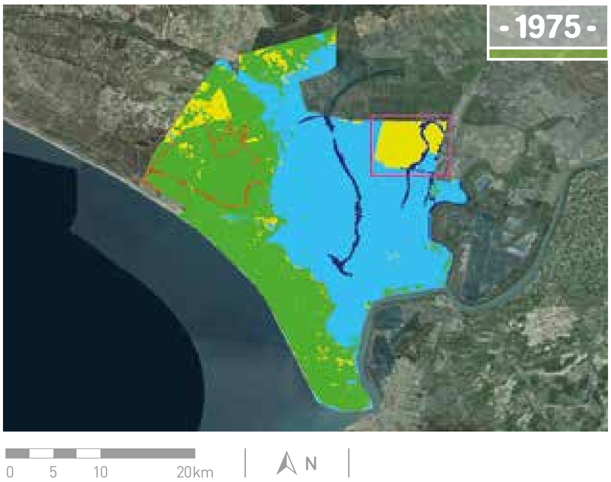
From 1975 to 2005, the area of natural wetland habitats increased from 194 km² to 242 km². Thus, they increased in size by about 24% in 30 years, especially in the northern part of the park, in Los Caracoles estate, 22 km² (Figure 29).

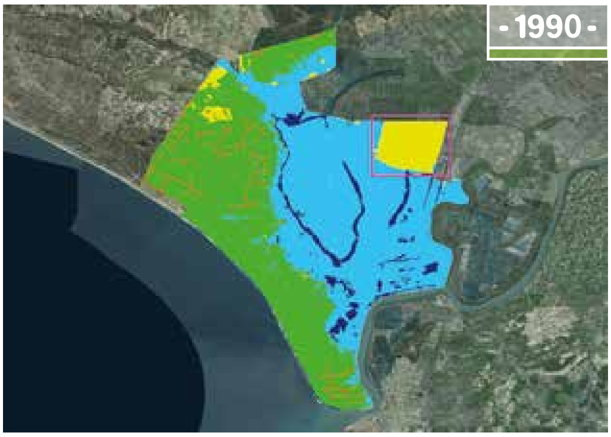
This gain corresponds principally to the restoration* of natural wetland habitats from agricultural areas.
This transformation took place in the framework of one of the largest wetland habitat restoration* projects in Europe, the "Doñana 2005" programme. This programme was initiated after the spilling of 6 hm³ of toxic waste and acidic wastewater into the Guadiamar river, a tributary of the Guadalquivir, in 1998 after cracks formed in the retaining wall of the basin containing tailings from the Aznalcollar mine. For the Los Caracoles estate, the project included hydrological and biological restoration* work, in particular the reopening of the Travieso canal (disappeared from the map in 1990; reappeared in 2005). This work has enabled the ecosystem to regain part of its ecological functions by returning to a more natural flooding cycle *(Diaz-Delgado et al., 2003)*. In parallel, the "Guadiamar Green Corridor" project has helped to reduce pollution and restore* the aquatic and terrestrial ecosystems in and around the river following the ecological catastrophe, and to re-establish its function as an ecological corridor.

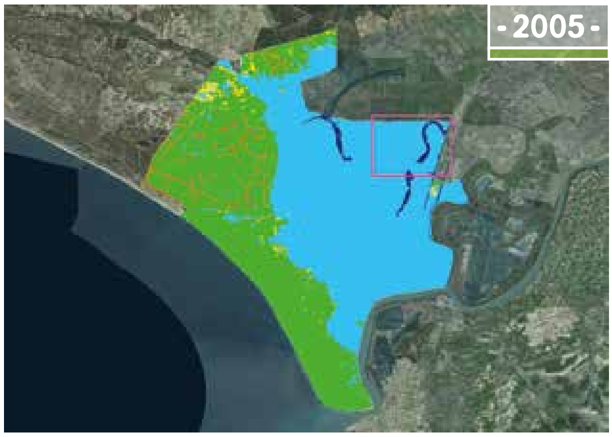
FIGURE 29

Conversion of an agricultural area into a natural wetland habitat (surrounded on the maps) from 1975 to 2005 (Doñana, Spain).

- Urbanized areas
- Agricultural areas
- Natural non-wetland habitats
- Natural wetland habitats
- Artificial wetland habitats
- Sea and ocean







> 4. CONCLUSION

Our analyses of satellite images from 1975 to 2005 show a constant decrease in the size of natural Mediterranean wetland habitats during these 30 years (-10%). Marshes and wet meadows were the most significantly affected, but major bodies of water (Egyptian lagoons, big lakes around the basin, etc.) were not always spared. At the same time, the area of artificial wetland habitats increased considerably, especially from 1975 to 1990, with the major development of artificial reservoirs (+700%). Natural non-wetland habitats also shrunk in size, principally from 1975 to 1990, which can have a negative impact on the functioning of wetlands by disconnecting them from a broader network of natural habitats.

There are many underlying causes for these changes. Agriculture was the primary cause for the direct disappearance of natural wetland habitats, particularly due to the development of irrigated agriculture. Urbanization had a less direct impact direct, but since 1990 seems to have become the principal catalyst of the changes observed. Urbanization eats up especially peri-urban agricultural areas, which means that the lost agricultural areas are displaced to the outlying natural wetland habitats. Increased water abstraction and artificialized water management also have a major impact on natural wetlands. They modify the hydrological regime of the natural wetland habitats, and transform them into artificial wetland habitats, or reduce the flow of watercourses. Finally, the receding coastline has already resulted in the disappearance of coastal wetlands, which have been submerged due to the rising sea level and the lack of sediments delivered by rivers.

-10 %

THE DECREASE IN TOTAL SURFACE AREA OF MEDITERRANEAN NATURAL WETLAND HABITATS FROM 1975 TO 2005.

+700 %

THE INCREASE IN TOTAL SURFACE AREA OF ARTIFICIAL RESERVOIRS FROM 1975 TO 1990.

Nonetheless, some improvements to the condition of natural wetlands have been observed. For example, the receding coastline has provided the opportunity to renaturalise* certain areas that used to be farmed, or to flood some degraded natural wetland habitats. The restoration* of degraded habitats enables an adequate level of biodiversity to be re-established if ambitious programmes are developed. On the other hand, having a site placed on the Ramsar list does not necessarily ensure the conservation of its natural wetland habitats. This fact is an argument in favour of providing legal protection for Ramsar-designated sites, and implementing an effective management plan.

Dam lakes (here on the Mujib Wadi in Jordan) have often replaced natural wetlands in valleys (© M. Renaudin / Tour du Valat).

5. RECOMMENDATIONS

Based on the changes observed during the 30 years studied and our analysis of the causes responsible for them, we would like to make the following recommendations:

5.1 DEVELOP WETLAND INVENTORIES AND STRENGTHEN MONITORING SYSTEMS WITH SATELLITE IMAGERY

At the current time, there is still no complete and accessible inventory of Mediterranean wetlands (Box 4), whereas this work is the foundation required to correctly measure changes in the various kinds of wetlands. Such a project lacks the financial and human resources needed to complete a field inventory. Nevertheless, improved satellite imagery and remote sensing tools are making such an inventory realistic. These techniques have been tested in various projects (GlobWetland-II and RhoMeO projects in France). Combining data from satellite images and topographical data enables potential wetlands to be delimited, and therefore to limit the amount of field work in them. Once the wetlands have been geolocated and mapped, monitoring can then be conducted every 5 or 10 years.

One third of Mediterranean countries still do not have an inventory of their wetlands (here the Greek inventory) (© C. Perennou / Tour du Valat).

Of course, this technique has it limits. It cannot be used to monitor the smallest or most complex wetlands, to detect all temporary wetlands in the Mediterranean climate, in which there is irregular precipitation, or to make a distinction between a floodable zone and a wetland zone. Additional field monitoring is therefore required, so it is important to strengthen the teams of local technicians capable of conducting regular monitoring operations in natural and artificial habitats.

As we wait for such a Mediterranean inventory to be created and then updated, we must build on the current study. Although it establishes an initial assessment of the trends for a sample of coastal wetlands in the Mediterranean Basin, it is only a preliminary analysis and a more complete picture of the situation is required. To that effect, we must:

- Compare the changes in interior wetlands with those in coastal wetlands;
- Refine our analysis of the effects of putting a site on the Ramsar list, establishing legal protection for a site, and effectively implementing a local management plan;
- Increase the number of sites monitored and include smaller and/or less well-known sites, but which are important for the functions and services they deliver.

In addition to monitoring land cover, we must also assess the quality of habitats. The first level of analysis is to more precisely delimit habitats, by mean of more precise satellite images and field data. The second level is to obtain additional data that can characterise the functioning of the habitats mapped: water quality and flows, etc.

5.2 CONSERVE THE NATURAL FUNCTIONING OF WETLANDS AND "RENATURALISE" ARTIFICIAL WETLAND HABITATS

The natural functioning of wetland habitats must be conserved as much as possible. The increase in the area of artificial wetland habitats in thirty years was significant, particularly to the detriment of natural wetland habitats. The impact can be very strong, particularly in terms of the system's hydrological regime with no more dried-out period in the summer, an increase in sedimentation due to the modification of hydrological flows, etc. These changes considerably disrupt the organisation of the ecosystems and thus the services provided, with potentially significant consequences on various populations. This artificialisation of wetlands must be stopped to conserve typical Mediterranean wetland habitats, some of which are today in decline and protected in Europe by the Habitats Directive (Mediterranean temporary ponds, *Cladium mariscus* marshes, etc.), as well as their associated species.

5.3 ENSURE EFFECTIVE MANAGEMENT OF PROTECTED NATURAL AREAS AND THE CONSERVATION OF THE MOST HIGHLY THREATENED HABITATS

Care must be taken to effectively implement management plans in natural protected areas, because they are one of the essential wetlands conservation tools. Technical and financial resources are therefore required for this purpose. Marshes, temporary ponds, and wet meadows are the first natural wetland habitats that must be protected because they have suffered significantly from land cover changes. They must be given priority both in terms of the new natural protected areas created, and in the management plans of already existing protected areas.

5.4 SUSTAINABLE WATER ABSTRACTION MANAGEMENT

The overexploitation of fresh water is one of the principal causes of the degradation and disappearance of natural wetland habitats. The development of irrigated agriculture is largely responsible, and it should therefore be better used. This aim can be achieved by reducing the amount of water needed by crops (using specific species and varieties) and by improving irrigation practices: decreasing the amount of water lost in irrigation networks, opting for water-saving techniques such as drip irrigation, and wastewater recycling.

Prior to these steps, more politicians must acknowledge that some of the fresh water must remain in natural ecosystems to enable them to function correctly (the "environmental demand"). In Tunisia, following the ecological degradation of Lake Ichkeul, one of the principal wetlands in the country, which affected the community of fishermen, a political decision was made to release some of the fresh water in the catchment area to conserve its ecological condition. However, this decision has never been applied during a dry year. In France, during negotiations on water abstraction rates, the notion of "environmental flow" for watercourses obliges the State to be sure that enough water remains for ecosystems and for flooding to occur, which enables the regimes of fluvial systems to be partially restored*.

5.5 COLLECTIVELY RETHINKING COASTAL PLANNING

In the Mediterranean coastal plains, the retreating coastline is going to affect natural habitats as well as agricultural and urbanized areas, with growing consequences on the economy and people. This profound and inexorable modification that will occur if nothing is done at the global level to diminish greenhouse gas emissions, must also be considered as an opportunity to rethink the development of these regions based on a dynamic adaptive approach that avoids irreversible developments.

In such an approach, wetland habitats and their hydrological regime must be given preference in the plans for mitigating future impacts. To that effect, they must not only be considered as structural adjustment variables allowing other areas used for human activities to be maintained. On the contrary, they must enjoy a spatial and temporal dynamic that enables them to be reconstituted behind the coast.

5.6 RESTORING NATURAL WETLAND HABITATS

The loss of wetlands was very significant in the last century, and in its final decades in particular, and those that remain have been greatly damaged. These losses and degradations have had various impacts on natural resources, affecting water quality, and the abundance of fauna and flora. We must engage in the restoration of natural wetland habitats that have been degraded, damaged, and destroyed. Even if we cannot completely recreate the original ecosystem, because it was the result of evolution and complex interactions, certain elements can be rehabilitated by ecological engineering techniques, and the essential biodiversity typical of these natural habitats can on the whole recolonize the ecosystem.

> GLOSSARY

- **BIOTIC HOMOGENISATION:** the replacement of specialist species by generalist species.
- **ENDEMISM:** when a species only exists in a certain restrict area on Earth.
- **EUTROPHICATION:** enrichment of a system with nutrients (nitrates, phosphates, etc.), which causes algae to proliferate that are harmful to the rest of the fauna and flora, as well as to human activities.
- **GENERALIST SPECIES:** a species capable of thriving in a great number of environmental conditions, and which can make use of a wide variety of resources. For example, the Yellow-legged Gull.
- **HALOPHILE:** a species that is tolerant to highly saline conditions.
- **INTERTIDAL ZONES:** wetlands on the seashore, covered at high tide and uncovered at low tide (mud flats).
- **RENATURALISE:** to undertake development activities that return a site considered to be degraded by human activities to more natural ecological and landscape conditions.
- **RESTORE:** to rehabilitate back to a reference state an ecosystem that has been degraded, damaged or destroyed. This reference state can be a state before or after anthropogenic disturbances. Even if we cannot totally recreate the original ecosystem, because it was the fruit of evolution and complex interactions, certain constituents can generally be rehabilitated.
- **RIVERINE (OR RIPARIAN) WOODLAND:** floodable forest along a watercourse.
- **SPECIALIST SPECIES:** a species that can only thrive in a narrow range of environmental conditions and with a specific diet. For example, the Eurasian Bittern, a species that only breeds in homogeneous reeds that are not very dense, and shallow clear water (10 to 15 cm).
- **SUBSIDENCE:** sinking of land through natural compaction.
- **WADI:** “river” in Arabic, term used to designate watercourses in North Africa.

Lebna Dam (© H. Azafzaf).

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Lagoons (here the Qarun Lagoon in Egypt) are some of the most important wetlands for fisheries (© L. Chazée).

ACKNOWLEDGEMENTS

THE MEDITERRANEAN WETLANDS OBSERVATORY WOULD LIKE TO THANK THE FOLLOWING PEOPLE FOR THEIR CONTRIBUTIONS TO THIS REPORT:

1. The experts who contributed to this research, by analysing part of the data for their countries or by contributing to the methodology developed:

S. Al Hachem ; M. Al Koudmani ; A. Aloui ; H. Azafzaf ; O. Ballereau ; N. Ben M'Barek ; N. Benessaiah ; G. Bessah ; E. Bonino ; J. Bustamante ; M. Chafik ; B.A. Çiçek ; M. Dakki ; N. Davidson ; A. Diku ; A. Dindeleux ; H. El Yadari ; M. Faber ; T. Ferah ; E. Frankenberg ; E. Fytoka ; H. Guidara ; N. Hamidan ; H. Hansen ; M. Haran ; L. Hilarides ; H.I.M. Nashnoush ; M. Keil ; A. Knop ; F. Krzewinski ; E. M. Bouras ; I. Melotte ; N. Moh'D Abidelbari Boulad ; T.S. Mohamed Ismael ; P. Ouedraogo ; M. Paganini ; F. Pirot ; H. Rodriguez ; K. Salem ; M. Schwarz ; S. Taupin ; W. Tefiani ; A. Tiéga ; M. Tobaschus ; E. Van Valkengoed ; K. Weise ; B. Wolf.

2. The following organisations for their technical and strategic support:

Association des Amis des Oiseaux / Birdlife, Tunisia, Birdlife International, Directorate of Forests (Algeria), Directorate of Forests (Tunisia), DLR / DFD (Germany), Doñana Biological Station (Spain), Eastern Mediterranean University (Cyprus), EEAA (Egypt), European Space Agency, Greek Biotope / Wetland Centre (EKBY), Greece, Environment General Authority (Libya), Image Consult, IUCN Centre for Mediterranean Cooperation, Spain, Jena Optronik, KeyObs, MedWet, Ministry of the Environment (Lebanon), Ministry of Environmental Affairs (Palestine), Ministry of Irrigation (Syria), Ministry of the Environment (Israel), Nature and Parks Authority (Israel), Royal Society for the Conservation of Nature (Jordan), Ramsar Secretariat, TerraSphere Imaging & GIS BV, Tour du Valat, Tunisian Environmental Protection Agency, University of Rabat (Morocco), Wetlands International, WWF - Dinaric Arc Parks (Albania).

3. Our financial partners:

Prince Albert II of Monaco Foundation, Total Foundation, MAVA Foundation, Pro Valat Foundation, Ministry of Ecology, Sustainable Development and Energy (France), European Space Agency.

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With the financial support of:

FONDATION PRINCE ALBERT II DE MONACO · FONDATION D'ENTREPRISE TOTAL · MAVA FONDATION POUR LA NATURE · Région PACA · ProVALAT Fondation · esa

The MWO's institutional and technical partners:

2010 Biodiversity Indicators Partnership · EKBY · esa · med•ina · plan bleu · The Royal Society for the Conservation of Nature · SOCIETY FOR THE PROTECTION OF PRESPA for Man and Nature · WETLANDS INTERNATIONAL