

**Estación Biológica de Doñana (EBD) - Agencia Estatal Consejo Superior de
Investigaciones Científicas (CSIC)
Doñana Biological Station - Spanish National Research Council**

The Doñana Biological Station is a public Research Institute belonging to the Spanish National Research Council in the area of Natural Resources. Our fundamental mission is to carry out multidisciplinary research of the highest standard directed to understanding, from an evolutionary viewpoint, the way in which biodiversity is generated, maintained and how it deteriorates, as well as the consequences of its loss and the possibilities of its conservation and restoration. An inseparable derivative is also to promote the transfer of this knowledge to society.

The Institute is formed by its main building in Seville and two field stations, the Doñana Biological Reserve ICTS (Doñana Natural Space, Almonte, Huelva) and the Roblehondo Field Station (Sierras de Cazorla, Segura y las Villas Natural Park).

La Reserva Biológica de Doñana (RBD) - Doñana Biological Reserve

The Doñana Biological Reserve (RBD, Almonte, Huelva) is situated 89 kms away from the head office. It was created in 1964 thanks to the vision of Dr. José Antonio Valverde, the support of the Spanish National Research Council (CSIC), and funds provided by the World Wildlife Fund (WWF). It is located within the Doñana National Park and consists of two estates. The Doñana Biological Reserve itself covers 6,794 hectares, which are owned and managed by the CSIC. The Guadiamar Biological Reserve, with 3,214 hectares, property of WWF/ADENA and managed by CSIC. The Doñana Biological Station therefore oversees an area of 10,008 hectares within Doñana National Park. By law, the legally appointed director of Doñana Biological Station coordinates all research projects undertaken in the Doñana National Park (52,000 hectares) and the entire protected area "Doñana Natural Space" (National and Natural Parks, 104.970 hectares in total). Doñana Biological Reserve forms the core of Doñana National Park and the wider Doñana Natural Space.

In April 2006 it was recognised by the Spanish Ministry of Education and Science as a Singular Scientific and Technological Infrastructure (ICTS). RBD-ICTS offers up-to-date communication infrastructures and scientific equipment, including automated monitoring of natural processes and long-term monitoring of key and endangered species in Doñana area.

It also gives access and logistic support to the Spanish and international scientific community in their research activities within Doñana Natural Space. The RBD contains a total of 31 buildings, including the Palacio de Doñana, field laboratories and service facilities, providing logistic and technical support to research projects within the conditions of the Park and the restrictions on its use, accommodation for scientists, including meals, laundry service etc.

Espacio Natural Doñana (END) Doñana Natural Space

The Doñana Natural Space (END) is the official name used to refer to all areas with some legal protection in the delta of the Guadalquivir river and its neighbourhood, and is formed mainly by the Doñana National Park, Doñana Natural Park, and buffer zones.

Doñana National Park is a natural reserve in the Autonomous Community of Andalucía, southern Spain in the provinces of Huelva, Sevilla and Cadiz. It covers 537 km² of which 135 km² are a protected area. It contains the largest wetland in Western Europe, an intricate matrix of marshlands (270 km²), phreatic lagoons, and a 25 km-long dune ecosystem with its respective shoreline, and representative Mediterranean terrestrial plant communities. The park is an area of marshes, shallow streams, and sand dunes in the delta where the Guadalquivir river flows into the Atlantic Ocean. It was established as a protected area in 1969 when the National Park was declared. The ecosystem has been under constant threat by the drainage of the marshes, the use of river water to boost agricultural production by irrigating land in the interior, and the expansion of tourist facilities along

the coast. It is named after Doña Ana de Silva y Mendoza, wife of the seventh Duke of Medina-Sidonia.

Doñana National Park has a biodiversity that is unique in Europe, although there are some similarities to the Rhône river delta in France, which contains the Parc Naturel Régional de Camargue, with which Doñana Park is twinned. The park features a great variety of ecosystems and shelters wildlife including thousands of European and African migratory waterfowl, and endangered species such as the Marbled teal, Spanish Imperial Eagle and Iberian Lynx.

The Doñana nature reserve includes both the Doñana National Park, established in 1969, and the Natural Park, created in 1989 and expanded in 1997, creating a buffer zone of protection under the management of the regional government. The two parks, national and natural, have since been classified as a single natural space. Due to its strategic location between the continents of Europe and Africa and its proximity to the Strait of Gibraltar, Doñana's large expanse of seasonal freshwater marshes is a breeding ground as well as a transit point for thousands of European and African birds (aquatic and terrestrial), and hosts many species of migratory waterfowl during the winter. Over 300 different species of birds may be sighted there annually. Considered the largest nature reserve in Europe. The area was designated **Ramsar wetland** in May 4, 1982 and declared as a Biosphere Reserve and **World Heritage Site** by Unesco in 1994.

Doñana has a typical Mediterranean climate: the hydrological cycle starts in September and usually reaches maximum inundation levels during February, mainly driven by the rainfall regime. In late spring, evaporation becomes the most important factor in the water balance, and the marshes dry up slowly until they are completely dry by the end of July. At this time, the aquifer plays a central role in maintaining water levels and permanent lagoons. As is the case for most continental wetlands, interannual variability is driven by meteorological patterns.

Biodiversity Monitoring

Vaughan et al. (2001) defined integrated monitoring as monitoring that uses detailed sets of ecological information, unlike simple monitoring, survey monitoring and proxy monitoring. Although many of the periodical surveys carried out at Doñana acquired relevant data on population condition and breeding success, by the end of the 1990s, the need for an integrated program of long-term ecological monitoring was evident. Therefore, in 2001, a meeting held among EBD-CSIC and Doñana National Park (DNP) heads led to the proposal for a joint project to set up the integrated ecological long-term monitoring of DNP. Representatives from both institutions (EBD-CSIC and Spanish National Parks Network) agreed on the main features to be monitored according to conservation priorities. The main goal was to achieve long-term knowledge on the dynamics of Doñana natural processes and the conservation management effects on its biodiversity. The conceptual approach focused on monitoring the following features: species, habitats and ecological processes. The species level monitoring focused on the endangered and threatened species, while the foci habitats were mostly the representative and under-represented ones. Finally, the ecological processes did not only include the natural processes interlinking ecosystem functioning and structure but also the human driven impacts (resulting from management decisions – including the conservation measures). Thus, the joint project, entitled “Design and refinement of the integrated programme for monitoring natural processes and resources in Doñana National Park”, was initiated in 2002 and devoted 3 years of research to the validation of monitoring protocols and the conceptual model of long-term ecological monitoring. The specific goals of the project were:

1. To achieve an exhaustive bibliographical review of available, up-to-date and standard protocols for the selected features to be monitored.
2. To designate scientific supervisors with recognised expertise in the ecological monitoring targets.
3. To propose feasible monitoring protocols and test their validity and adequacy for monitoring the proposed targets.

4. Final adoption/rejection of the tested methodological protocols and the features proposed for monitoring.

Originally, both institutions agreed on a number of proposed features for monitoring (Tables 1 & 2). The conceptual approach led to addressing the features under three main monitoring themes and 11 monitoring targets. In addition to flora, fauna, management and geophysical monitoring, a landscape scale monitoring approach was proposed to monitor broad-scale processes in the DNP and in its surroundings (unprotected area, see Fig. 1). The rationale behind this relies on the need for understanding underlying ecological processes such as connectivity, fragmentation or habitat loss at the landscape scale. Thus, the main purpose of the programme was to assess individual features using a set of proposed indicators, usually relevant informative variables such as relative and absolute abundance, species distribution, species richness and life condition.

<i>Monitoring theme</i>	<i>Target</i>	<i>Feature</i>	<i>Features description</i>
Biological Monitoring	Vegetation	NPP	Grass biomass
		Plant cover & structure	Grass biomass Pine, cork oak & juniper woodlands, shrubland, marshland & riparian vegetation (*)
		Flora	Aquatic plant distribution and richness Rare threatened plant spp. distribution and abundance Singular trees inventory Alien spp. distribution and abundance (*)
	Fauna	Terrestrial invertebrates	<i>Coprophagus</i> coleoptera abundance Diurnal butterflies Insect blooms
			Aquatic invertebrates abundance and richness Red crayfish abundance and distribution
			Fish spp. communities & abundance
		Amphibians	Amphibians spp. communities & abundance
		Reptile	Greek tortoise distribution Greek tortoise population structure Native turtle distribution Exotic turtle distribution
			Lizard spp. distribution & abundance
			Birds
			Vulnerable and endangered birds Passerine communities Breeding bird spp. Wintering bird spp.
		Birds key spp.	Red-legged partridge and Eurasian coot abundance and distribution
		Mammal key spp.	Rabbit and hare abundance

<i>Monitoring theme</i>	<i>Target</i>	<i>Feature</i>	<i>Features description</i>
Geophysical Monitoring	Climate	Mammals	Wild ungulate abundance (red deer, fallow deer and wild boar) Water vole abundance & distribution Carnivore abundance Otter abundance and distribution
		Meteorology	Meteorological stations
		Atmosphere	Pollutant & aerosol concentration
	Surface water	Flooding	Marshland flooding dynamics (*) Temporary pools
		Water quality	water quality
	Underground water	Water table	water table level
Management Monitoring	Geomorphology	Erosion & sedimentation	Sedimentation on marshland / Dunar system dynamics / shoreline dynamics (*)
	Hydrology	Water management	Water management evaluation Managed artificial pools Doñana 2005 marshland restoration programme
			Plant mowing effects
			Shrubland clearing effects Silvicultural activities Reforestation with autochthonous plant spp.
	Fauna management	Management effects	Alien spp. eradication Fauna response to silvicultural activities Iberian lynx population: breeding success and mortality
			Imperial eagle population: breeding success and mortality
			Cattle management Pine nuts harvest management Pilgrimage activities and effects Traffic and public access Beekeeping management Wedge shell fishing activities
	Land uses and services		Land use change around Doñana Natural Space (*) Game management

Table 1: The Geophysical and Management Monitoring themes, identified targets and features of Doñana Integrated Long Term Ecological Monitoring Programme. Asterisks indicate the features approached at landscape scale.

Donana LTSER Platform in the ILTER and LTER Europe Networks

In 2006, DBS joined the European Network of Excellence named ALTERNet (A Long-Term Biodiversity, Ecosystem and Awareness Research Network). ALTER Net aims to establish a lasting infrastructure for integrated ecosystem research.

This combines ecological and socio-economic approaches, with emphasis on communication with the relevant audiences focusing on the CBD (Convention on Biological Diversity) target of attaining a significant reduction of the current rate of biodiversity loss by 2010. Many of the partner research institutions also participated in the ILTER network (International Long-Term Ecological Research Network) and its regional section of LTER-Europe. During the project development, the LTER-Europe constitution in 2007 proposed the first nine LTSER (Long-Term Socio-Ecological Research) pilot platforms based on selected criteria.

The Doñana LTSER platform emerged from this process as a relevant place to investigate socio-economic drivers and pressures on biodiversity following the DPSIR framework. The Doñana LTSER platform includes DNS and the immediate surrounding area, conforming to Doñana County (see Fig. 28.1), in order to assess the effects of human drivers and pressures on biodiversity. The Doñana LTSER platform has started to contribute by developing the socio-ecological long-term research and implementing the DPSIR framework. Doñana, together with two other LTSER platforms (Pleine-Fougères in Brittany and Islands of Breila in Romania) have recently reported on an early assessment of EU regulations (Common Agricultural Policy) of unexpected effects on local biodiversity (unpublished ALTERNet Report). The Doñana LTSER platform has also successfully collaborated in the proposal of a conceptual socio-ecological model for LTSER platforms (Haberl et al. 2009) that will soon be implemented and tested. Both experiences are helping in spreading the LTSER concepts. Since then, DBS has played a major role in setting up the LTER process in Spain. Thus, LTER-Spain was formally accepted as an ILTER and LTER-Europe member in 22nd August 2008. It currently comprises 10 sites, including the Doñana LTSER platform. These sites represent the main ecosystems present in the Iberian Peninsula. LTER-Spain has agreed on the minimum common ecological parameters to be monitored by every LTER-site of the network. These parameters cover abiotic variables, primary producers, consumers and other relevant parameters. To date, meteorological variables are the most widely monitored at every LTER-Spain site, closely followed by forestry parameters, birds, invertebrates, soil characteristics, atmospheric deposition, phenology and water body characteristics.

Ecosystem Services

There have been several studies by researchers of the Universidad Autónoma de Madrid on ecosystem services provided by Doñana wetlands their monetary estimation and criteria for their valuation (Martín-López, Montes & Benayas 2007; Martín-López, Montes & Benayas 2007; Martín-López *et al.* 2009) and their spatial distribution (Palomo *et al.* 2012, 2013). Also there has been a preliminary review on the ecosystem services provided by waterbirds (Green & Elmberg 2014)

Remote Sensing

The Remote Sensing and GIS Lab of Doñana Biological Station (LAST-EBD) has been using remote sensing data to study the Doñana wetlands since 2003. We have a data bank of more than 500 satellite images of the Doñana area of different satellite and airborne sensors like Landsat-MSS, Landsat-TM, Landsat-ETM+, SPOT, CHRIS-PROBA, ASTER, DEIMOS, IRS, EAGLE & HAWK, AHS, CASI-1500, HYPERION, ALI. A majority of the images correspond to images from Landsat 5-TM and Landsat 7-ETM+ for the scene 202/34 that covers the Doñana area from 1984 to 2013 (Table 2). This time series has been co-registered, radiometrically corrected and normalized, and has been used to estimate the temporal evolution of flooded surface, water turbidity, water depth and aquatic vegetation cover.

Satellite	# images	Time series
Landsat 1	25	1973-1976
Landsat 2	43	1976-1981
Landsat 3	6	1978-1982
Landsat 4	22	1983-1991
Landsat 5	369	1984-2011
Landsat 7	149	1999-2013
Landsat 8	14	2013
SPOT VEGETATION	471	1998-2011
SPOT	10	2005-2009
CHRIS-PROBA	22	2006-2011
ASTER	8	2001-2002
DEIMOS	8	2010-2011
IRS	1	1999
EAGLE & HAWK	1	2007
NOAA AVHRR (mundo)	720	1981-2001
NOAA AVHRR (España)	674	1986-2005
RADARSAT	6	2002
AHS	4	2004, 2008, 2010, 2011
CASI	2	2010-2011
EO1-HYPERION	4	2002, 2008
EO1-ALI	7	2006-2009
CORONA	101	1962, 1963, 1972

Table 2: LAST-EBD image bank

Other synoptic variables of the marshes have been derived like hydroperiod duration and its change for the last three decades, flooding date or dry-up date

We also keep products from MODIS y SEAWIFS specially designed for monitoring terrestrial and oceanographic variables:

Satellite	Product	# images	Temporal resolution	Spatial resolution	Time series
MODIS	GPP	72	monthly	0.05°	2006-2011
MODIS	VI (MOD13Q1)	66	fornightly	250 m	2010-2012
MODIS	VI (MOD13A3)	152	monthly	250 m	2004-2005
SEAWIFS	Chl-a	63	monthly	9 km	1997-2002
MODIS AQUA	Chl-a	123	monthly	4 km	2002-2012
MODIS AQUA	Chl-a	40	seasonal	4 km	2002-2012
MODIS AQUA	Chl-a	437	weekly	9 km	2002-2012
MODIS AQUA	SST	123	monthly	4 km	2002-2012
MODIS AQUA	SST	437	weekly	4 km	2002-2012

Table 3: Satellite data bank of products derived from MODIS and SEAWIFS images

Literature

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