# Caracoles

## a new laboratory for science and wetland restoration

Luis Santamaría *, Andy J. Green **
Ricardo Díaz-Delgado ***
Miguel Ángel Bravo ***
Eloy M. Castellanos ****

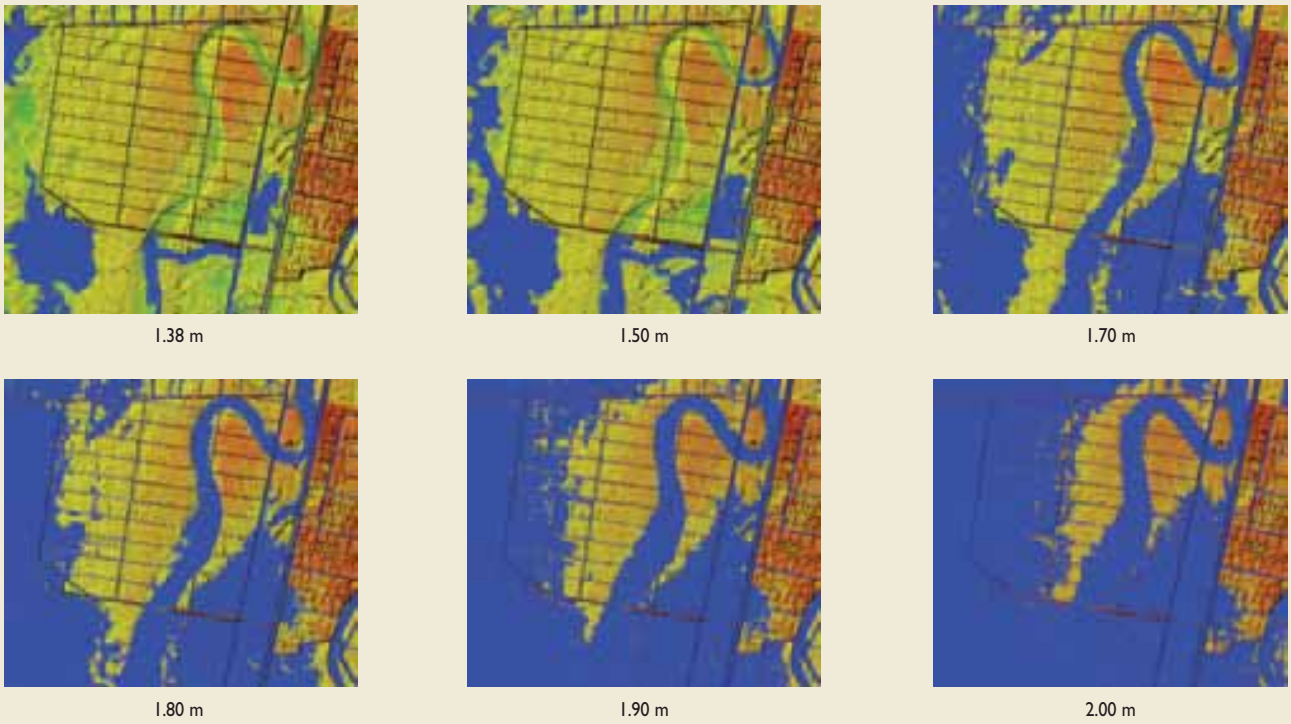
Action number 6 of the Doñana 2005 Project, aimed at restoring an area of marshes ("marismas") that had been turned into farmland in the 1960s, and to restore the hydrology of the Travieso channel (*Caño Travieso*), is one of the most far-reaching scientific and experimental challenges that the National Park currently faces. The Almonte-Marismas Transformation Plan diverted the waters of the River Guadiamar, channelling them along the Entremuros canal and, as a result, draining the Caño Travieso channel and the adjacent flood plains, including the Los Caracoles estate, for farming.

The estate is on the northern boundary of the National Park, bordered by the Entremuros canal and the Cangrejo Chico and Cangrejo Grande "lucios" (shallow, seasonal lakes). To the south, the estate borders on to the Marilopez "lucio" and the Travieso Nuevo canal. It also borders with El Lobo "lucio" to the west and with the FAO wall built in the 1970s to the north. In preparation for planting cereals, the marshes were drained by installing a drainage system of permeable pipes one metre below ground all over the estate. These drained into the network of drainage canals visible in aerial photographs.

The full restoration of these 27 km² is one of the largest wetland restoration projects in Europe. It is an initiative that will restore the water cycle based on ecological criteria and, at the same time, develop restoration models that can serve as tools for other restorations in coastal and estuarine environments.

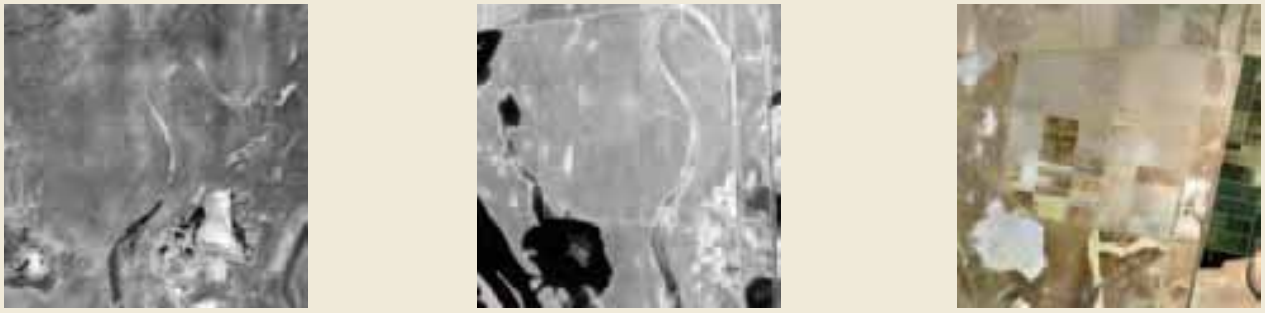
The restoration of wetlands of this kind has to meet two basic requirements: recover the functional, hydrological and ecological functions and to establish spatial distribution patterns for habitat types and biodiversity. The results of the actions to be undertaken must ensure that the new spatial structure can opti-

* *Mediterranean Institute of Advanced Studies (IMEDEA).*
** *Doñana Biological Station.*
*** *Monitoring Team of Natural Processes of the Doñana Biological Station.*
**** *Department of Environmental Biology and Public Health, Faculty of Experimental Science, University of Huelva.*




Sequence of rainfall-induced flooding of the marshes in the Caracoles estate, based on the Digital Terrain Model. The depths quoted are the depths at point N28 in the Los Ánsares "lucio".

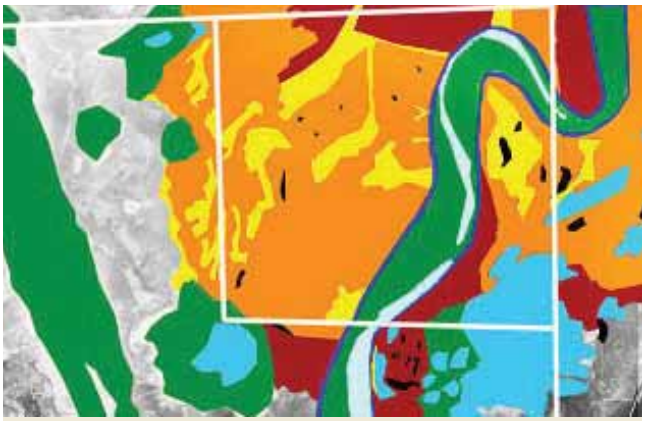
Images: Monitoring Team of Natural Processes/R.Díaz-Delgado




Historic transformation of Caracoles in a series of photographs taken in October 1956 (first American flight), May 1972 (panchromatic images from the CORONA satellite) and July 1999. This short history shows the process of clearing the original marshes for farming and the channelling of the Guadiamar River, with the consequent elimination of the Travieso channel. In the 1972 image, the start of construction work on the perimeter wall around the estate and the Entremuros Canal can be seen. Fifty years later, the waters are starting to return to their original channel.

Images kindly supplied by Laboratorio de SIG y Teledetección-EBD/R. Díaz-Delgado.

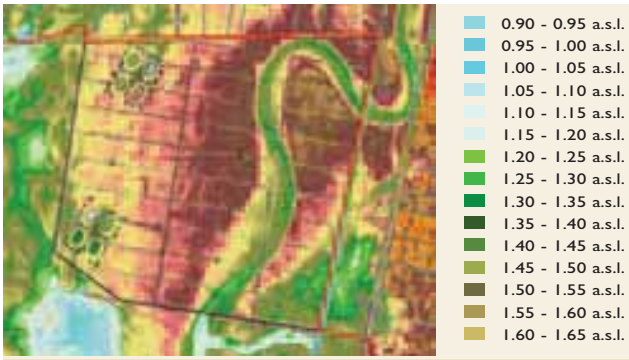
mise the ecological function and the biodiversity of the aquatic ecosystems, while at the same time minimising the need to further manipulate the hydrological function in the future. Moreover, to prevent a repetition of the mistakes made in the past, the underlying philosophy behind this restoration should be that the restoration *per se* is a challenge full of uncertainties. These uncertainties encompass how the water behaves in the marshes, the dynamics of the sediments and the new role that the different species will play in this restored area.



- *Vetas* (small sandy elevations)
- *Paciles* (pastures) with saltworts
- Areas between *quebradas* and *pacil*
- *Quebradas* (depressions)
- Bulrush formations
- *Lucios* (shallow ponds)
- Travieso channel outline
- Channels

Photogrammetric reconstruction of vegetation and topography in 1956 by ESPN/M.A. Bravo, based on the first American flight.

Source: Teledetection as a tool for restoration (Ricardo Díaz-Delgado, 2004).




Localisation of the new pools with different shapes and sizes. The image has been superimposed on the Digital Terrain Model of the marshes. The topographic variation along the transversal profile is of about 20 cm.

Source: Carlos Urdiales. Doñana National Park.

To strike this balance, both the design of the restoration and the posterior management of the restored area have to take into account the basic functional features that characterise marsh ecosystems. The aquatic ecosystems of the Doñana Marshes oscillate in an instable fashion between two alternative states of equilibrium: "turbid waters" (caused by sediment in suspension and the development of phytoplankton) and "clear waters", when there is sufficient submerged vegetation to prevent the suspension of sediments in the waters[9]. The water cycles modulate the relative dominance of each of these states in the different marsh wetlands, as both excessive depth and early desiccation will encourage the persistence of turbid water states. The spatial mosaic of wetlands, with varying depths and sizes, guarantees the large scale resilience of the system from this locally unpredictable factor by allowing some of the wetlands to remain in a clear water state at all times. Herbivorous waterfowl are another key element in the dynamics of these aquatic ecosystems because, by eating the water plants at the beginning of the spring cycle, they can destabilise the clear water state[10]; whereas, by dispersing plant propagules and aquatic invertebrates, they foster the re-colonisation of the wetlands when these are in a turbid water state[11,12]. For all these reasons, any attempt to identify an "optimal" flood cycle for these marshes in general is a mistake.

Current knowledge suggests that maintaining a highly diversified spatial structure and guaranteeing exchange and connection between the wetlands that make up the marshes is the best way to optimise the resilience, diversity and ecological function of the

Flooding as shown by a radar image from the RADARSAT satellite (December 1996). The blue shows the levels of flooding in the Caracoles farm in this exceptionally wet year, where the original bed of the Travieso channel is clearly visible. The average maximum flood levels are in green and the minimum levels in red.

Source: LAST/R.Díaz-Delgado and Aurensa.

aquatic ecosystems of the Doñana marshes.

Bearing in mind this available knowledge, the restoration faces uncertainties like deciding the best combination of sizes and depths of the restored wetlands, and the most appropriate spatial structure to foster the dispersal of propagules by different vectors (birds, water or wind). The range of uncertainties also includes dimensions that we do not know enough about and that we cannot control sufficiently, such as the possible effect of fish entering from the estuary, exotic species, herbivores (waterfowl, livestock, horses, deer, hares) and flamingos on the stability of clear water states. Work on a restoration design of this kind includes aspects that are in their first steps of development, such as determining ideal wetland profiles (size, depth, bank morphology) that will attract waterfowl in order to accentuate their dispersal function.

For all these reasons, the research team and scientific institutions responsible for the design of this project recognised the need to adopt an "adaptive management approach", avoiding identifying an optimum design *a priori* and then monitoring the result. Instead, they opted for a robust and flexible design that seeks to clarify present uncertainties experimentally and progressively optimise the restoration work. In practise, this approach translates into the need for a broad diversity of sizes and shapes of wetlands, distributed over the spatial gradient of the area being restored. During the restoration, apart from monitoring the ecosystem of the restored area, experiments will also be carried out (for example, manipulating the colonisation rates or excluding herbivores). These criteria are also applicable to the emerging vegetation and to the marshes, for instance by creating structures that make it easier for species to disperse and to settle, or by manipulating the residual drainage structures.

The hydrological analysis necessary for designing the restoration has been hard work, in which the images provided by remote satellite sensing over the last fifty years have played an essential part. To evaluate the flooding regime, a time series of Landsat satellite images was used (1973-2003) provided by the Doñana Biological Station Remote Sensing Laboratory, aerial photos from a 1956 American flight, images from a range of panchromatic cameras installed aboard the CORONA satellite (used by U.S.A. in the early seventies as a spy satellite, whose picture have recently been declassified) and all the different images and orthophotographs taken over the last ten years[13]. This material, together with a Digital Terrain Model constructed for Doñana with a horizontal spatial resolution of 2 m and a Numeric Hydrodynamic Model for the Marshes, has made it possible to develop a broad range of scenarios, providing a solid foundation for designing the restoration and experimental work.

What was initially an unjustifiable encroachment on the Marshes has become a vitally important laboratory for the future of Doñana and similar areas. It should not be forgotten that one of the objectives of the Caracoles project was to ensure that whatever actions were taken should provide systematic information on the ecology of both the natural and restored wetlands in the Doñana Marshes, i.e., to learn as much as possible as as to benefit many future restoration and management actions.

Before connecting the Caracoles area with the rest of the National Park, pools that will provide the foundation for much of its future diversity and will act as a laboratory to enhance our knowledge of the marshes have been built. At the same time, work began on the task of eliminating the effect of the drainage systems that were installed to prepare the land for farming..

Source: ESPN/Hector Garrido

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### the key to the Doñana 2005 Restoration Project


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