Integrative multi-scale analysis of the impact of the drainage of the La Janda lake (Cádiz Province, Spain) and a model for its sustainable regeneration.

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Abstract

The drainage of the lake of La Janda (Cádiz, Spain), Spain's largest lake, commenced at the beginning of the nineteenth century and the process was virtually complete by 1962. Its drainage signified the loss of one of the most important wetlands in the Palaearctic. There is currently a renewed interest in La Janda and the possibility of its regeneration is under study by the Consejería de Medio Ambiente of the Junta de Andalucía and the University of Córdoba. The purpose of this paper is to summarise the value of La Janda prior to its drainage through the results of a multidisciplinary study and to propose an integrative model for its regeneration which takes into account not only its geological and biological potential but also its historical and archaeological values. The study brings together data from historical and archaeological research with that gathered in the field by geologists and biologists. The model, which includes the physical and biotic processes operating across different spatial and temporal scales, considers this regeneration within the socio-economic use of La Janda.

1 Introduction

The drainage of the lake of La Janda (Cádiz, Spain), Spain's largest lake (4000 ha; Fig.1) commenced at the beginning of the nineteenth century and the process was virtually complete by the mid 1960s[1]. Its drainage signified the loss of one of the most important wetlands of the Palaearctic. This paper traces the history of the drainage of La Janda and proposes ways in which the ecological processes which were eradicated can be restored in a sustainable manner.

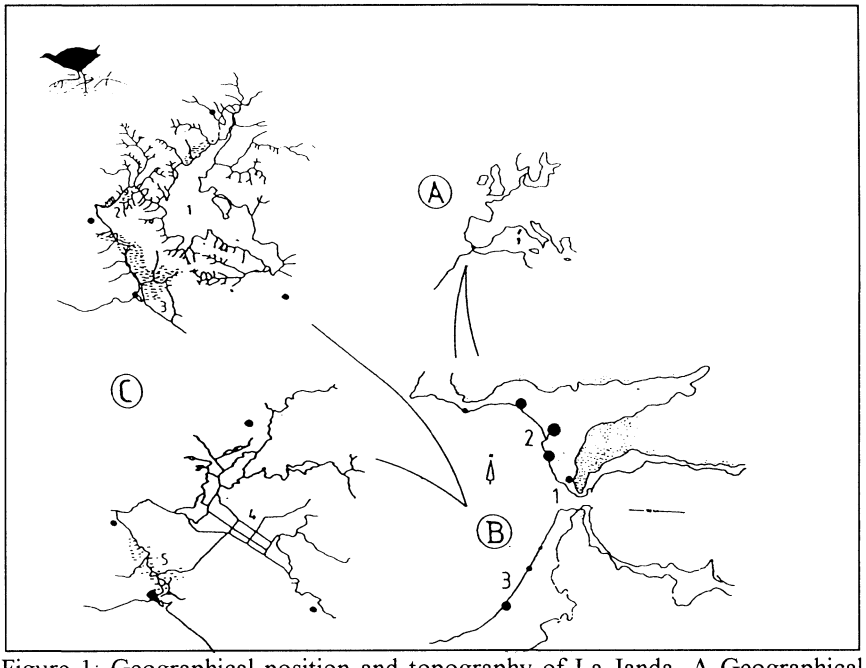

Figure 1: Geographical position and topography of La Janda. A Geographical position in relation to the Strait of Gibraltar, Europe and North Africa. B Position within the region of the Strait of Gibraltar. 1=La Janda (Spain); 2=Marismas del Guadalquivir (Spain); 3=Merja Zerga (Morocco). C Landscape of La Janda. Upper circa 1870; Lower 1996. 1=La Janda Lake; 2=Torero Lake; 3=Barbate Marsh and Estuary; 4=La Janda Lake Depression; 5=Barbate Marsh and Estuary. Solid points mark position of towns. After Finlayson[2]; Recio Espejo et al.[1]

2. The Physical Environment

The site of the former wetland of La Janda is located in a tectonic basin close to the coast at the western end of the Strait of Gibraltar, within the province of Cádiz (Spain) (Fig.1). This basin is surrounded by the harder Oligo-Miocene rocks of the Aljibe unit which rise in the form of hills to heights of up to 300 m. The basin deposits are derived from an Eocene clay formation interspersed with other materials, such as yellowish Upper Pliocene sands and rich red Plio-Quaternary kaolinite fluvial deposits. Its interior presents a sinuous relief with hills rising to 30 m above its floor and calcareous detritical-carbonated Lower Pliocene "mesas" which rise to between 60 and 100 m[1].

The origin of the tectonic basin can be traced to the Upper Pliocene and is associated with expansion phases in the western Betic Range[3] which caused the sedimentation of detritic carbonated material of a similar nature to those

deposited in shallow seas. The Plio-Quaternary deposits signal the beginning of the continentalization of the area and the appearance and growth of a lake from north to south, a process which eventually eroded the sea bed deposits. Subsidence in the area was accompanied by a further period of expansion which was characterised by certain fractures in the west and the formation of a second generation of rivers which flowed in the opposite direction and eroded former reliefs. New drainage patterns were established, the Jandilla-Vejer canyon evolved and a fertile valley was formed.

After the general geographical configuration of the area had evolved, the progressive sea-level rise during the Flandrian[4,5] marked the origin of the lake. The sea level rise probably generated an estuarine situation into which the main rivers (Barbate and Almodovar) flowed. The subsequent lowering of the sea level led to the formation of natural freshwater continental environments governed by great river floods.

The Almodovar flowed westwards into the same tectonic basin and, jointly with the Barbate, created the former lake (Fig.1c). Once the lake had filled, excess flow accummulated in the area of Jandilla and flowed from there towards the coastal marsh and the Atlantic Ocean. Numerous smaller streams flowed from the surrounding hills into the lake. The accummulated water mass covered an approximate surface area of 4000 ha and persisted from autumn to spring, depending on annual rainfall[6]. Although generally referred to as a lake La Janda constituted a highly integrated mosaic of small lakes and freshwater marshes, each with its own specific characteristics, which effectively produced a zone of high ecological diversity. Following periods of peak river volume and drainage by the main watercourse a series of small, independent, units fragmented from the main lake.

3.The early human occupation of La Janda

The presence of mid-Acheulian deposits of a primary form document the presence of pre-Neandertal populations which used the natural resources (fauna, wetland and prime lithic materials) available within the depression for their survival[7,8]. Cave art, representative of the populations of hunter-gatherers which lived in the area during the Upper Palaeolithic, were discovered during the 1980s in the sites known as *Tajo de las Figuras*[9] and *Cubeta de la Paja*[10].

The occupation of the unique archaeological complexes, composed of settlement, necropolis and stations with schematic rock art, of Los Charcones[11] and Los Algarbes[12,13] is at its height in the third and second millenia B.C. Elements of production gained a great importance in the area since the late Neolithic, giving rise to an eminently agricultural society. The cave of the *Tajo de las Figuras* is one of the most original of the post-palaeolithic sanctuaries of

sanctuaries of the Iberian Peninsula[14]. Its art reflects the interaction between human populations in recent prehistory and the natural environment of La Janda. Breeding, wintering and migratory birds, as well as mammals from the peripheral sierras, are represented in association with human figures. They create a conceptual and artistic description of the species which occupied the area 5000 years ago. The prehistoric settlement of Los Charcones[10] is situated in the Barbate basin, along the edge of La Janda, in a zone of fertile soils, well-suited for agriculture. At least twelve dolmens, some with associated megalithic art, have been described[15,16]. Among the most important Bronze Age sites is *Vejer de la Frontera* with a sequence of occupation commencing with the so-called orientalized Bronze Age (radio-carbon dated at 750-690 BC)[17] through to the Medieval periods. The fauna is already typically domestic, represented by ovicaprids, cattle, pigs and horses.

4. The Reclamation Process of La Janda

Throughout much of the Holocene humans exploited the resources of La Janda without severely affecting the nature of the ecosystem. It was in 1822 that the first attempt was made to drain and channel its waters. The construction of these first canals was not, however, entirely successful nor were other attempts which followed. In 1957 the Spanish Government's Council of Ministers authorised the company *Lagunas del Barbate S.A.* to undertake the reclamation of the lake. Various canals were initially constructed to release the water trapped within the basin. These canals proved inadequate to handle the great volume of water from the Barbate River and rapidly became sedimented. The construction of canals and irrigation ditches continued until 1962. The former river bed of the Barbate was converted into a canal and its natural course was virtually obliterated. The ecologically-rich Torero Lake (Fig.1c;) had disappeared by this time[1,6]. The different stages of reclamation were established during the 1960s and the occupation of the drained land was accorded a high priority. The complete reclamation of the lake commenced in 1962. A major network of canals was established and the entire network of small streams which flowed into the lake was controlled and channelled. The Almodovar River was re-channelled eastwards. Underground re-channelling of water also took place and the Barbate began to receive additional freshwater which caused profound biological changes[1]. The marshlands and the Janda Lake itself disappeared causing sudden and profound changes to the natural vegetation and to the fauna of the wetland, particularly its birds[2]. The process of drainage of La Janda reached its climax and the wetland lost its entire character[1].

5.Ecological conditions of the La Janda depression today

Even though La Janda has suffered a severe transformation, one which continues at present through the enhancement of the drainage works, it remains

a site of great ecological value. In this section we compare the present La Janda with that before its drainage, using birds as indicators of environmental health[18]. In the case of La Janda a unique and detailed record of the species which bred in the wetland is available[2].

The wetland of La Janda was part of a network of closely interlinked wetlands in south-western Europe and north-western Africa[19]. Its drainage and the progressive deterioration of other wetlands in the region created a fragmentation which has caused the significant decline and, in some cases extinction, of breeding bird species which only bred in these wetlands within the western Palaearctic[2]. The movements of bird species, operating at large spatial scales of thousands of kilometres, between the West African wetlands and these western Mediterranean ones fell within the dynamics of a single system. The system must have relied particularly heavily on the larger wetlands which acted as *source* zones for many species which fed the smaller *sink* wetlands, especially so after their partial disconnection from the African wetlands by the Saharan barrier 5000 years ago. La Janda and the Guadalquivir marshes (including Doñana) were central to the maintenance of the system (Fig.1b)[2].

Analysis of the data in the Cádiz Province Atlas of Breeding Birds[20] clearly identifies the zone of the Barbate drainage basin, including the La Janda depression, as one of the hot spots in terms of species richness (Fig.2a). A comparison of 25 sites in the south-western Iberian Peninsula which were censused using the same method between 1990 and 1997 revealed that La Janda today ranks only second to the Biological Reserve of the Coto Doñana in terms of breeding bird species richness. Inclusion of the former breeding community of La Janda ranks the site in first place. The data were analysed using a Principal Components Analysis and the sites could be ordinated on the first three axis which explained 43.5% of the total variance. The La Janda wetland and present-day Doñana in a wet season separated out from all other sites along the first axis which was dominated by aquatic birds. The La Janda wetland separated slightly from Doñana along the second component, having a greater representation of steppe and grassland species in keeping with the presence of such zones along its periphery. Present-day La Janda is absorbed in the volume which contains most of the remaining sites including Doñana in a drought year (Fig.2b). There is no doubt from the historical analysis of the wetland, its birds and vegetation, that La Janda was a mosaic of physical and biotic variables which formed a unique landscape. Such a mosaic promoted the ecological diversity within the wetland and was a key signal of its importance.The vegetation also exhibited a high spatial heterogeneity. Individual wetlands within the La Janda complex revealed their own peculiar characteristics and remnants of these remain, surprisingly, today. Even within the drained and heavily mechanised central depression it is possible to identify zones with natural or semi-natural characteristics such as the semi-natural grasslands, the olive dehesas and the matorrals and cork oak woodland of the surrounding hills. In the winter, areas

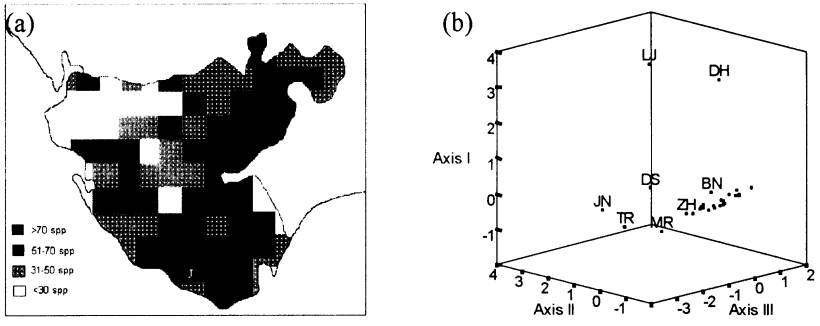

Figure 2: (a) Breeding bird species richness in Cádiz Province (Spain).La Janda falls within the square marked by a "J"; (b) Principal Components Analysis of breeding bird distribution data for southern Iberia: LJ=La Janda community 19th Century, JN=La Janda 1994, DH=Doñana wet season of 1996, DS=Doñana dry season of 1995. See text for further details.

of the central depression flood, in some instances the entire basin, as in the winter of 1996-97, but the water is removed too quickly to permit the establishment of permanent aquatic vegetation. The borders of drainage canals retain some aquatic vegetation although this is regularly cut to prevent their sedimentation[1].

6.Discussion

In presenting a model for the sustainable development and use of the La Janda area we have kept the spirit of the United Nations (1987) concept of sustainability, as adapted by Forman[21] central, viz "a sustainable environment is an area in which *ecological integrity* and *basic human needs* are concurrently maintained over generations." The data presented in this paper strongly indicate that the pre-1962 La Janda landscape mosaic complex satisfied the criteria of a sustainable environment. It exhibited a high degree of adaptability, in particular to frequent but irregular disturbances[22]. Such disturbances would have primarily taken the form of fluctuations in the intra- and inter-annual rainfall régime. At a higher spatial scale its resilience would have contributed towards the overall stability of the regional wetland network. The La Janda landscape mosaic operated since the genesis of the wetland until the 1960s as a highly integrated and sustainable environment which assimilated the exploitation of its resources by human groups. The ecological integrity of the system was maintained and basic human needs were sustained over many generations. Stability was maintained at the landscape and regional scales through the mosaic nature of the systems.

The transformations which took place before the 1960s were of an insufficiently large scale to compromise the ecological integrity of the system which showed sufficient resilience[23] to enable it to return to a position of equilibrium after disturbance[24]. Stability is expected if the amplitude of the fluctuations external to the system is small relative to the amount of an attribute in the system[25]. The drastic modifications which took place during and after the 1960s, as external inputs into the system, greatly exceeded in amplitude the capability of La Janda, compromising its ecological integrity beyond a level which would permit recovery. These changes not only affected the landscape of La Janda itself but also had far reaching consequences at higher levels of the spatial hierarchy especially as other similar landscapes were being stressed in a similar manner.

Forman[21] has focused on a small number of key components which capture the general meaning of ecological integrity. A system is considered to have ecological integrity when it has near-natural conditions for four broad characteristics: productivity, biodiversity, soil and water. As we have seen La Janda does not satisfy any of these conditions today. The human dimension requires the satisfaction of a basic level of human needs if sustainability is to be a reality. The six central needs are food, water, health, shelter (housing), energy and cultural cohesion. The high level of agricultural activity in La Janda today is based on short-cycle summer crops such as cotton, sunflower and vegetables. This is a relatively recent activity which dates to the time of the drainage. The traditional use has been livestock-based (Retinto cattle and fighting bulls) utilizing available pastureland. The recent changes significantly modified land tenure and today the largest farms are situated in the old lake floor. The traditional livestock farming has not disappeared totally, however, remaining in zones which have suffered least transformation. We argue here that the changes to La Janda have merely increased outputs from the system with only minor increased benefits to the human population within. Moreover it is unlikely that such benefits will be sustainable over a timescale of human generations.

Our model (Fig.3) proposes the examination of La Janda at multiple spatial scales. We argue that, in the time frame of human generations which is considered to be the optimal for sustainability[21], La Janda is not viable, ecologically or in meeting human requirements. Large inputs of nutrients, water and energy are required for the maintenance of agricultural productivity and the system is unlikely to have long-term stability and is geared towards maintaining maximum short-term market production. In attempting to restore the integrity of La Janda we are considering it as part of a wider picture of the restoration of a regional complex of wetlands which have suffered from massive perturbations for over a century with consequent significant loss of biodiversity. The data collected by the various teams working in La Janda together with the information gleaned from the literature and from existing documentation makes the reconstruction of La Janda possible. The investigation of the original

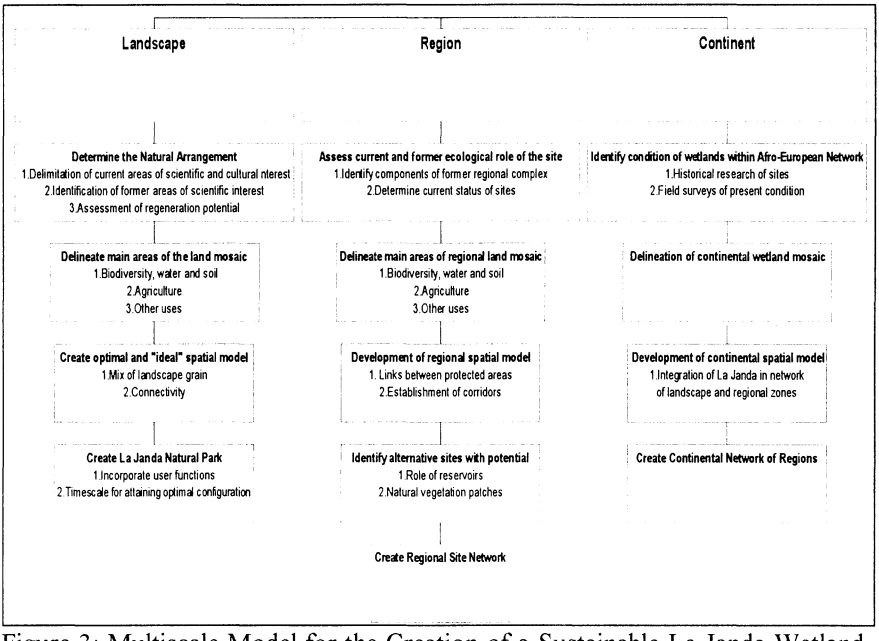

Figure 3: Multiscale Model for the Creation of a Sustainable La Janda Wetland Complex

conditions within the lake and its subsequent evolution is supported by a detailed study of the soil, of existing surface formations and of the modifications which have been made to the flow rate and to the surface run-off with the resulting disappearance of the characteristic soils of the area. We propose a model (Fig.3) which should serve as the basis for any action taken towards the regeneration of La Janda. It takes into account the dynamics of the wetland at different spatial and temporal scales and considers the eventual outcome to be one in which the various elements of the heritage (ecological, physical, cultural, economic) of the site are integrated under a single scheme.

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