Chapter 1
The Wetland, Its Catchment Settings and Socioeconomic Relevance: An Overview

S. Sánchez-Carrillo, D.G. Angeler, S. Cirujano, and M. Álvarez-Cobelas

Abstract Wetland loss is common worldwide. In Spain, around 90% of the surface covered by floodplain wetlands has disappeared during the last century, and only 32 km^2 remain as of today. Las Tablas de Daimiel National Park (20 km^2) is unique in Mediterranean Europe. It is the most representative Spanish floodplain wetland nowadays and depicts the core area of La Mancha Húmeda Biosphere Reserve (8,000 km^2), one of the main wetland district occurring in the semi-arid Mediterranean Europe. Despite the ecological richness supported by this wetland, a controversial history of desiccation, groundwater overexploitation and water quality deterioration threatens this wetland since the 1950s. This chapter describes the main features of the wetland as well as of its basin, revising all impacts received and their environmental consequences. Groundwater overexploitation by irrigation farming is discussed as the main cause of wetland degradation in the socioeconomic framework of the Upper Guadiana River Basin.

1.1 Introduction

Wetlands are a common feature of the Spanish landscape (≈1,200 km^2 or 0.2% of the total country surface; DGCN 1998), and elsewhere, with broad environmental and ecological settings and a wide size range – oligotrophic temporary mountain ponds, permanent karst lagoons, floodplain wetlands, coastal wetlands, ephemeral water bodies, endorheic hypersaline areas, temporary ponds, etc. (Casado and Montes 1995). Currently, out of the thousands of Spain's wetlands, only 63 (281,768 ha) are registered in the Ramsar list (http://195.143.117.139/profile/profiles_spain.htm) and a large proportion of the scientific, cultural and economic value of this natural patrimony still remains to be explored. One of most important

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S. Sánchez-Carrillo and D.G. Angeler (eds.), *Ecology of Threatened Semi-Arid Wetlands: Long-Term Research in Las Tablas de Daimiel*, DOI 10.1007/978-90-481-9181-9_1,

threats to Spanish wetlands is the lack of water due to the aridity effect in around three fourth of the Iberian Peninsula (Gao and Giorgi 2008). Other environmental pressures such as desiccation, eutrophication and pollution, organic matter accumulation, siltation, salinization and the invasion of exotic species enhanced the degradation processes affecting Spanish wetlands (Cirujano et al. 2009). Between 60% and 65% of the Spanish wetland surfaces have been lost since the nineteenth century (original wetland surface of 2,800 km^2) with most of this disappearance taking place between 1950 and 1990 (DGCN 1998). Whilst mountain ponds and karst lagoons remained quite preserved, floodplain wetlands suffered the largest areal reduction affecting the Spanish inland wetlands. In a very conservative approach DGCN (1998) suggested that 126 km^2 of floodplain wetlands have disappeared, with only 32 km^2 remaining nowadays; unfortunately, the ancient floodplain wetland surface covering Spain could be up to two–threefold of the one considered by that study. Floodplain wetland loss appears to be common worldwide (Finlayson and Spiers 1999). The reason why floodplain wetlands are more consistently reduced than other freshwater wetland types across the world can be found through the wetland landscape location and historical human–development–river relationships (draining for intensive agriculture, river regulation for irrigation and hydropower, etc.; Finlayson and Spiers 1999).

Floodplain wetlands can be found worldwide, where land areas adjacent to rivers or streams are subject to recurring inundation. While riparian wetlands (dominated by forest vegetation) are most frequent in worldwide landscapes, marshes (dominated by graminoids) are less usual throughout floodplains. Inundation of wide floodplain areas combining surface water (river) and groundwater is not very usual (Bradley 1997), and even less in semi-arid climates. Examples of this type of wetland have only been found in Ireland (The Callows at the Shannon river; Heery 1993), Germany (Spreewald at the Spree River; Köhler 1993), Nigeria (Macina or Niger inland delta; John 1986), Botswana (Okavango alluvial fan; Allanson et al. 1990), Irak (the wetland between the Tigris and Eufrates rivers; Richardson et al. 2005) and in South America (the várzea at the mid Amazonas, Junk 1983; the Orinoco floodplains, Hamilton and Lewis 1990; and the Paraná floodplain, Carignan and Neiff 1992). In the semi-arid South Europe it only appears at the Iberian Peninsula, in the area called La Mancha Húmeda Biosphere Reserve (MHBR hereafter; 39°16′N, 3°24′E; Fig. 1.1), a region located in central Spain and covering 8,000 km^2 in one of most arid areas of the Mediterranean basin, with the Las Tablas de Daimiel wetland as the core area (20 km^2). MHBR is an arid landscape featuring vast plains where groundwater surplus discharges on lowland areas, joined seasonally to river discharge, creating extended floodplain wetlands. Nowadays, Las Tablas de Daimiel is the only relict wetland left over from an extended floodplain wetland area covering 150–250 km^2 at the beginning of the twentieth century (Heras et al. 1971; Fig. 1.2). Since the 1950s, the extent of the wetland has been reduced and its ecological integrity strongly threatened. Impact was manifest in many forms, including a controversial history of desiccation in order to both eradicate malaria and to increase farming lands. Later, groundwater overexploitation for irrigation practices and water quality deterioration by wastewater

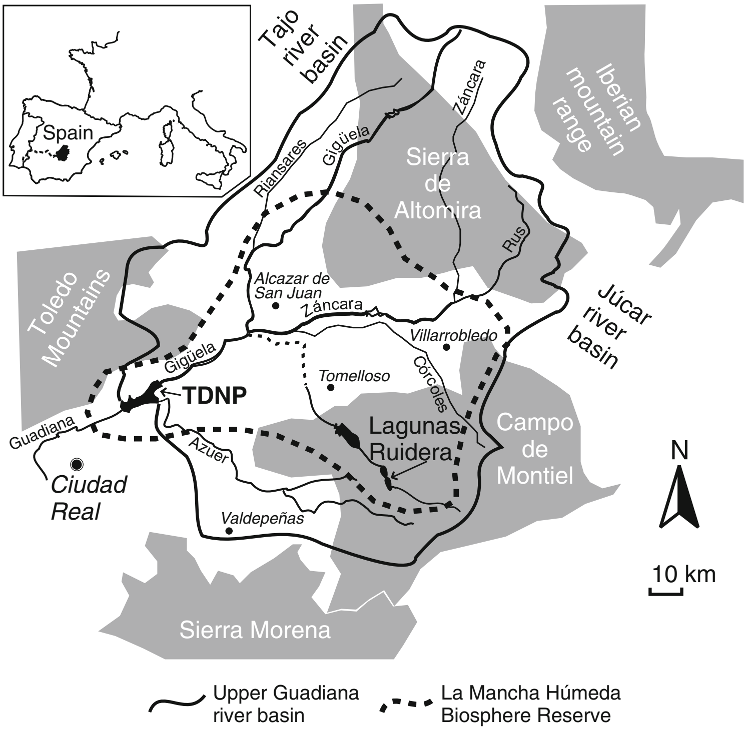

Fig. 1.1 Geographic location of Las Tablas de Daimiel at the Upper Guadiana river basin and La Mancha Húmeda Biosphere Reserve. Highlighted areas (*grey*) represent elevated zones. Only towns over 20,000 population are shown

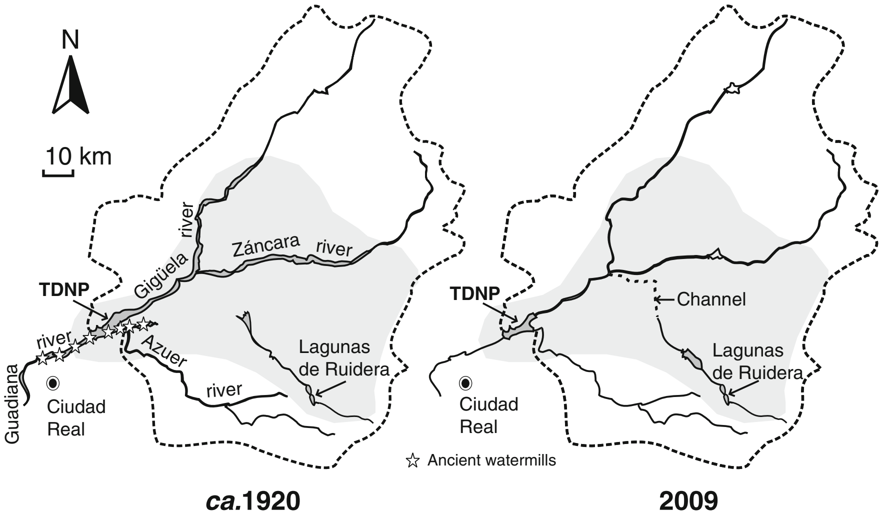

Fig. 1.2 Changes in the extent of floodplain wetlands at La Mancha Húmeda Biosfere Reserve during the twentieth century

discharges through the river, and agriculture runoff pollution aggravated the problem. Assorted hydrological remediation plans were implemented at the wetland scale from the mid-1970s; in spite of this, wetland degradation increased, given that the cumulative impacts on the wetland/watershed scale were never attended. Changes at Las Tablas de Daimiel have been recorded by means of significant long-term research efforts, which can then be used to assess the cumulative effects of global change on floodplain wetland performance and to develop sustainable management strategies, ensuring the survival of this unique wetland ecosystem.

1.2 The Wetland: Las Tablas de Daimiel National Park

Las Tablas de Daimiel National Park (TDNP hereafter) is located in Central Spain in the Castilla-La Mancha Autonomous Community (39°08′N, 3°43′W; Fig. 1.1) within the municipalities of Daimiel and Villarrubia de los Ojos. The wetland extends NE-SW parallel to the foothills of the Toledo Mountains, which represent the sole altitudinal reference in the geographical area (Fig. 1.1). Until the 1970s, wetland occurrence was due to natural flooding in the extended alluvial plain of both the Gigüela and the Guadiana Rivers, the latter flowing from the Ojos del Guadiana, a groundwater source area located around 10 km East of TDNP. The floodplain was also the natural groundwater discharge zone of the Llanura Manchega Occidental aquifer (23 Aquifer or 04.04 Hydrogeologic Unit according to the current official nomenclature of the Geological Survey of Spain–IGME) as the groundwater table was close to the surface. Therefore, TDNP inundation was supported by numerous groundwater surges along the wetland known as “Ojos” or “Ojillos” (‘eye’s or ‘little eyes’). Furthermore, the wetland’s flooded area was also maintained by human buildings, such as small water-mill dams which helped to retain water in TDNP. 15 water-mill dams have been identified along the Gigüela and Guadiana Rivers (Álvarez-Cobelas et al. 1996). Thus, the waterscape of TDNP appeared as the result of both natural flooding and human-induced inundation in an area where rainfall is scarce (Álvarez-Cobelas and Cirujano 1996). Until the 1950s, five water-mills artificially supported the inundation at TDNP: Zuacorta, Griñon, Molemocho, La Quebrá and Puente Navarro (Fig. 1.2). Nowadays, none of them are functional and only the Molemocho water-mill has been reconstructed for exhibition purposes.

At the present moment, the potentially flooded area of TDNP is 15.87 km^2. This area is divided by a central gabion dam named Presa Central or Presa del Morenillo which separates the wetland into two inundation areas of 11.82 km^2 and 4.05 km^2, located upstream and downstream, respectively (Fig. 1.3). At the end of TDNP – southwest area – the Puente Navarro dam, a domed concrete dam, controls the water storage in the wetland (Fig. 1.3). This zone is the deepest of the wetland (4.5 m; Álvarez-Cobelas et al. 1996).

The main morphometric features of TDNP are shown in Table 1.1. The number of islands is high (more than 30), the largest being Isla de Algeciras and Isla del

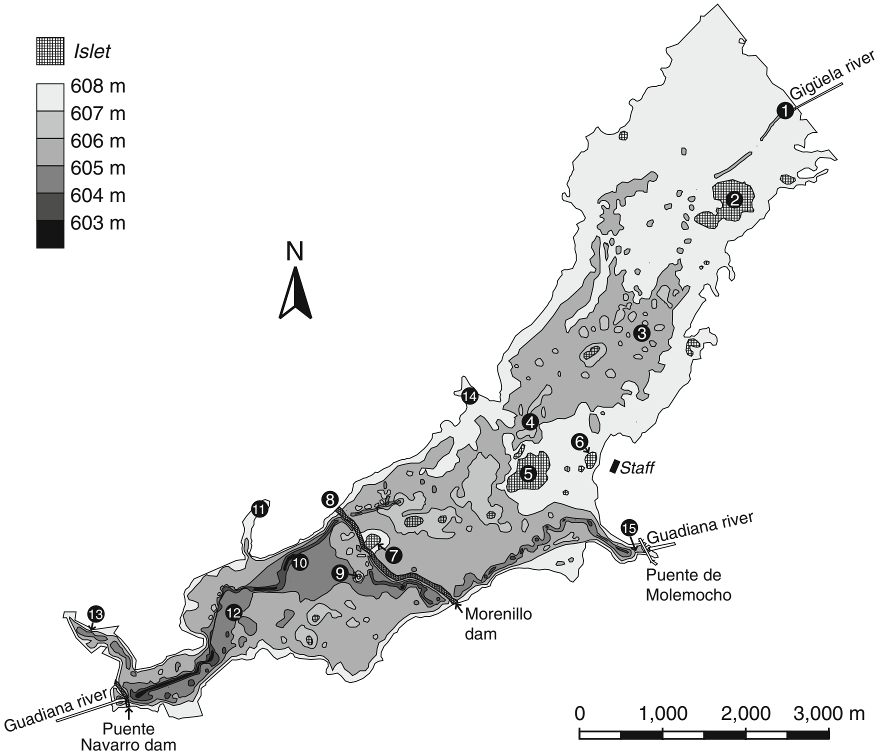

Fig. 1.3 Bathymetry of Las Tablas de Daimiel National Park at its highest inundation. Isolines shown are those of above mean sea level measured at the coast of the city of Alicante (Mediterranean Sea). Some main sites inside Las Tablas de Daimiel are shown by black circles: 1, Pata Gallina; 2, Algeciras island; 3, Tabla Larga – Long Water Table; 4, El Tablazo – Big Water Table; 5, Pan island; 6, Entradilla island; 7, Morenillo island; 8, Quinto de la Torre; 9, Las Cañas island; 10, Vado de los Toros; 11, Cañada del Gato – Cat Glen; 12, Almochinares; 13, Cachón de la Leona; 14, Cañada Lobosa – Lobosa Glen; 15, Molemocho

Table 1.1 Morphometric features of Las Tablas de Daimiel National Park (Álvarez-Cobelas et al. 1996)

Maximum length	10.58 km
Maximum width	2.75 km
Maximum depth	4–5 m
Average depth	0.91 m
Relative depth	0.2%
Surface area	1,928 ha
Volume	16.08 Mm^3
Shoreline length	39 km
Shore development	2.69
Island area	100 ha
Bottom roughness	9.05
Volume development	0.67

Pan, located in the northeastern area of the wetland. The effective wind exposition (fetch) can oscillate 1–2 km NW–SE in the Tablazo area (Fig. 1.3; Álvarez-Cobelas et al. 1996); however, recent emergent macrophyte changes, heterogeneity and macrophyte management practices make an accurate estimation difficult.

Wetland landscape uniqueness and richness are provided from two main hydrological and hydrochemical processes: TDNP provided an area where saline sulfate-rich surface waters flowing from the Gigüela River were mixed with freshwater coming from the groundwater sources (Coronado et al. 1974; see Chapter 6); besides, the distinctive seasonality of water sources increased wetland complexity. Therefore, aquatic emergent macrophytes appeared with European cut-sedge (*Cladium mariscus*) as the dominant population, accompanied by reed (*Phragmites australis*) and cattail (*Typha domingensis*) restricted to littoral areas (Cirujano 1996; see Chapter 8). TDNP represented the more important cut-sedge cover in Western Europe (Álvarez-Cobelas and Cirujano 1996) but, at present, this macrophyte is in regression due to wetland degradation (Álvarez-Cobelas et al. 2001). Wetland richness was also supplied by numerous vertebrate and invertebrate taxa, which regrettably disappeared or are undergoing a severe number reduction (Álvarez-Cobelas and Cirujano 1996).

International recognition of TDNP and its protected status appeared as a consequence of the habitat importance for waterfowl. In fact, the first written reference known about TDNP comes from "Libro de Caza" (*The hunting book*; 1325) by the Infante Don Juan Manuel (1282–1345) which described the area as "*a propitious place for every hunting activity*". Subsequently, following the "*Relaciones Topográficas"* by King Felipe II (a detailed statistical description of Spanish towns carried out during the sixteenth century), protection was ordered for the TDNP area, in order to protect its avifauna richness for hunting purposes (Sarria 1986). Thus, from the seventeenth to the twentieth century, the exceptional waterfowl richness of TDNP attracted important politicians and aristocrats devoted to hunting (Cobelas et al. 1996). Most representative and profuse waterfowl in TDNP are the mallard *(Anas platyrhynchos*), the common teal (*Anas crecca*) and the red-crested pochard (*Netta rufina*), the emblematic waterfowl in La Mancha Húmeda wetlands (see Chapter 8).

1.3 The Upper Guadiana Basin and the UNESCO's La Mancha Húmeda Biosphere Reserve

The Upper Guadiana basin comprises the TDNP's natural drainage area (Fig. 1.1) and extends over 15,000 km^2, covering the provinces of Ciudad Real (6,640 km^2), Cuenca (5,012 km^2), Toledo (2,460 km^2) and Albacete (1,898 km^2). The basin is located in the Submeseta Meridional Castellana (Castilian Southern Plateau) and limits to the West by the Toledo Mountains and the Tagus river basin, to the North by the Iberian mountain range, to the South by the Campo de Montiel region and the Sierra Morena and to the East by the Júcar river basin (Fig. 1.1). Ground elevations range from 550 to 1,200 m. The climate of the basin is semi-arid, with an average annual rainfall of 300–500 mm and an average annual temperature ranging 14–15°C (Pérez-González and Sanz-Donaire 1998). Annual potential evapotranspiration exceeds rainfall, reaching 800–900 mm. Spatial and temporal distribution of the rainfall is very heterogeneous at the basin scale (Pérez-González and Sanz-Donaire 1998). The fluvial net is ephemeral and closely linked to the aquifers. The main river at present is the Gigüela which flows NE–SW. Other minor rivers are Záncara, Córcoles, Azuer, Riánsares and Rus (Fig. 1.1). At the river basin scale, water is managed by the Guadiana Water Authority (Confederación Hidrográfica del Guadiana, http://www.chguadiana.es/), a public agency depending on the the Spanish government through the Ministry of the Environment. This basin management agency interacts with autonomous and local governments as well as with water user associations and, theoretically, has the last say in any water-related decisions at the basin scale.

Geology of the Upper Guadiana basin is basically composed of Jurassic, Cretaceous and Tertiary limestone underlain by a gneiss basement that crops out along the southern and eastern basin boundaries (Portero and Ramírez 1988). The most important geomorphologic landmarks are both those shaped by carbonate dissolution and collapse (sinkholes) and those related to floodplain wetland or small lagoon processes (alluvial fans, floodplain wetland, peatbogs and salts; Pérez-González 1996). Main soil types, according to FAO (1998), belong to the cambisol group, although regosol and, at the southeast, luvisol and podzol are found in the basin (Horra 1996).

Five aquifers are found along the Upper Guadiana basin (Fig. 1.4), two of them – 04.04 and 04.06 aquifer systems – being considered large groundwater reserves which feed lowland river areas and depressional landscapes that develop extended marshlands. The aquifer system 04.04 extends throughout 5,500 km^2 and includes most wetland ecosystems of the MHBR. This groundwater system is comprised by Miocene and Jurassic limestone and marls and can be subdivided into two aquifers, the upper one being a heterogeneous unconfined aquifer, while the lower one is confined. The Campo de Montiel aquifer or the 04.06 Hydrogeologic Unit is an unconfined Jurassic limestone system occupying an extension of 2,700 km^2. Aquifer geometry and hydrogeological parameters are yet to be accurately determined, although there seems to be little doubt about the mechanisms of groundwater flow (Cruces and Martínez-Cortina 2000). While thickness of each aquifer system oscillates between 30 and 300 m, transmissivity (the rate at which groundwater can flow through an aquifer section of unit width under a unit hydraulic gradient) and storage coefficient (the volume of water released from storage per unit surface area of aquifer per unit decline in hydraulic head) of the 04.04, is higher than those of 04.06 aquifer (transmissivity: 500–20,000 and 50–1,500 m^2 day^{-1}; storage coefficients: 5% and 2–5%, in the 04.04 and 04.06 aquifers, respectively) (Cruces et al. 1997). Therefore, the former controls the hydrogeology of the region and is considered as the most important aquifer of the Upper Guadiana basin. Both aquifers are ground connected but its complex hydraulic

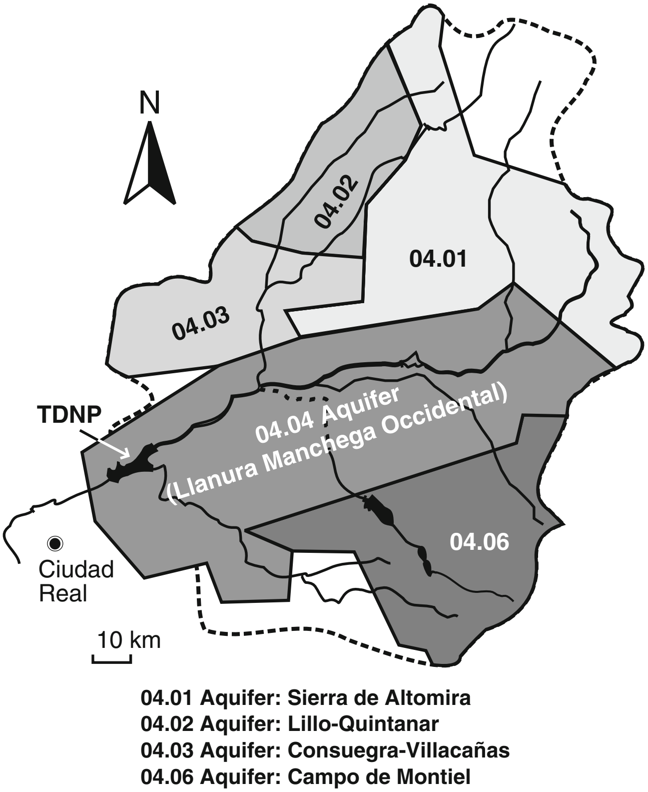

Fig. 1.4 Aquifers at the Upper Guadiana basin

transference is little known yet. There is evidence that 04.06 aquifer surplus discharges both through seepage and groundwater flow into the 04.04 the Aquifer area (around 50 Mm^3 year^{-1} according to some authors (Llamas and Martínez-Santos 2005); see Chapter 2). Under natural conditions, groundwater flow is observed to follow a westward trend, from the recharge areas (Campo de Montiel plateau) to the main discharge zone (Las Tablas de Daimiel National Park and surroundings; IGME 1989; Fig. 1.5 in 1974).

Wetland abundance along the Upper Guadiana Basin was so high that, in 1980, UNESCO recognized its environmental importance and value, designating La Mancha Húmeda region as a Biosphere Reserve (Man and the Biosphere Programme) in order to preserve its highly valued and strongly threatened wetlands. By this date, more than 50% of the wetlands covering MHBR were already lost. MHBR includes more than 100 wetlands (from freshwater to saline) constituting the most important wetland district in Spain. The inner area of MHBR is occupied by the “Llanura Manchega”. Wetland and lagoon occurrence and ecosystem functioning were intrinsically linked to the 04.04 Aquifer groundwater discharges. Nowadays, most wetlands

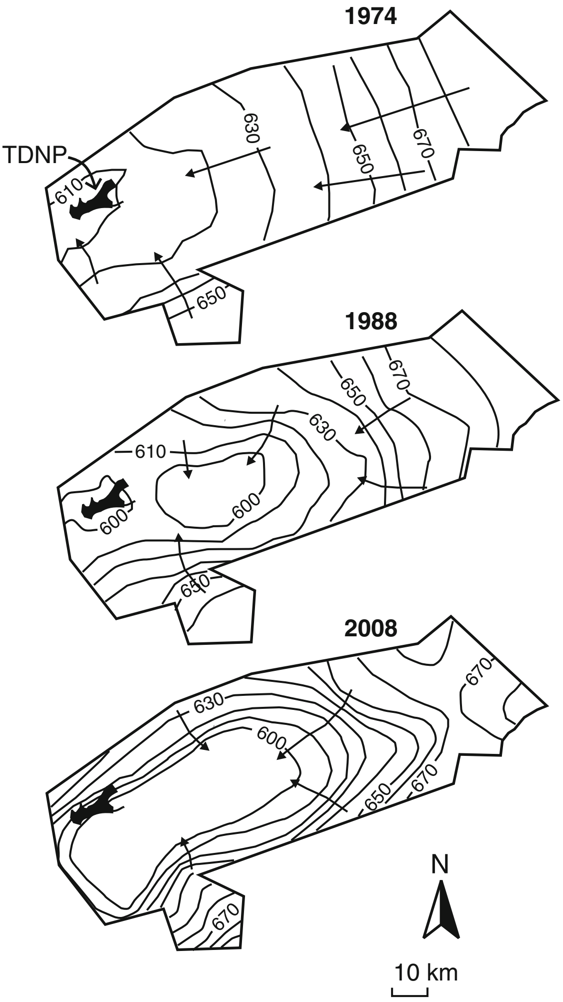

Fig. 1.5 Evolution of the 04.04 Aquifer (Llanura Manchega aquifer) piezometric levels from 1974 to the present day (Data source from SGDGOH 1989; IGME 2008)

at the MHBR are temporary and very fluctuating wetlands but before the 1950s most of them were permanent (Álvarez-Cobelas et al. 2001).

The designation of MHBR as a UNESCO Biosphere Reserve is only one among the many international acknowledgements of its wetlands. Five wetlands are listed in the Ramsar Convention and one of them, Las Tablas de Daimiel, also represents the only inland wetland of the Spanish Network of National Parks. MHBR contributes significantly to the European biodiversity (Florín and Montes 1999). Furthermore, these wetlands are also important at the community level, where habitats are considered to be of interest within the European Union (Directive 97/62/EC): inland salt meadows, Mediterranean halophilous bush formations (*Sacocornetea fruticosi*); Mediterranean salt steppes (*Limonietalia*), oligotrophic calcium-carbonate waters with a benthic vegetation of *Chara* spp., Mediterranean temporary ponds, and calcium-carbonate wetlands of *Cladium mariscus*. Other valuable communities not officially acknowledged include microbial mats of the cyanobacteria *Microcoleus chtonoplastes*, submerged macrophytes dominated by the Potamogetonaceae *Ruppia drepanensis*, crustacean communities of *Arctodiaptometum saline* and the communities of riparian carabids (Florín and Montes 1999).

1.4 Groundwater Overexploitation and the Wetland Complex

The importance of groundwater discharges to sustain wetland hydrology and ecology at the Upper Guadiana basin and, particularly, to TDNP until the 1970s has already been mentioned. Besides supporting most wetland occurrences at the Upper Guadiana basin, 04.04 Aquifer also sustains most human and economic activity in the region. Historically, the 04.04 Aquifer groundwater reservoir has been considered to store a volume of water up to 100 times its annual recharge (Sahuquillo-Herráiz et al. 1982). However, from the 1970s, groundwater pumping (mostly for irrigation practices) changed this situation dramatically. During the period between 1974 and 1989 the land devoted to irrigation increased by 324% and the groundwater extractions rose from 152 to 568 Mm^3 year^{-1} (IGME 2004; Fig. 1.6). In the 1970s groundwater reserve at the 04.04 Aquifer was deemed to be 11,000–12,000 Mm^3 (IGME 2004). Groundwater recharges measured in different areas of the aquifer have been estimated as ranging from 10 to 625 Mm^3 year^{-1} (Cruces et al. 1997), although numerous inconsistencies, including the location of the experimental plots and methodological procedures, can be found, preventing extrapolation to the entire aquifer. While frequency and extent of droughts in this region complicate the definition of an averaged hydrological year, most authors agree that the mean annual recharge oscillates between 150 and 350 Mm^3 year^{-1} (Cruces et al. 1997; Acreman et al. 2000; IGME 2004, 2008). At this exploitation regime, groundwater extraction exceeds

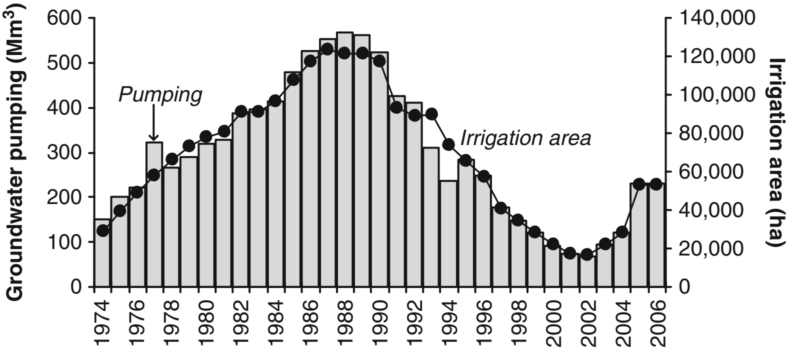

Fig. 1.6 Land devoted to irrigation and groundwater pumping at the Llanura Manchega aquifer (04.04 Aquifer) for the period 1974–2006

groundwater recharge and water reserve of the aquifer dropped severely until 1987 (from 5 to 30 m; Navarro et al. 1993), when the aquifer was declared temporarily overexploited (Box 1.1). Consequences of the piezometric level decline are that the aquifer was detached from wetlands in many areas, natural discharge areas disappeared, such as the Ojos del Guadiana spring (dry from 1983), flow dynamics changed so that groundwater does no longer flow westward, but rather towards the centre of the aquifer (where the main pumping cones are; Fig. 1.5). Furthermore, a dramatic drought was experienced from 1991 to 1995, perhaps the most significant ever in Spain during the twentieth century, exacerbating the situation all the more. In the period between 1980 and 1996, official data from the Guadiana River Water Authority assumed a groundwater loss of around 3,750 Mm^3 (IGME 2008), different to the 6,000 Mm^3 estimated by Cruces et al. (1997). The surface devoted to irrigation decreased in the aquifer area after pumping restrictions were imposed on farmers, followed as of 1992 by the application of the European Agro-Environmental Program on water demands for irrigation. This program also served as a vehicle to compensate farmers for income losses associated with voluntarily cutting down on water use (Viladomiu and Rossell 1997). These measures were not enough to recover the groundwater table to the 1970 levels and the aquifer was definitely declared

Box 1.1 Aquifer overexploitation

Groundwater overexploitation and aquifer overexploitation are terms that are common in water resources management. Hydrologists, managers and journalists use them when talking about stressed aquifers or groundwater conflict. Overexploitation may be defined as the situation in which, for some years, average aquifer abstraction rate is greater than, or close to the average recharge rate. Intensive exploitation of aquifers can give rise to overexploitation problems. Aquifer overexploitation depends on the balance between demand and renewable resources. In semi-arid regions, the absence of high rainfall and the existence of ephemeral rivers require an increased use of groundwater resources for maintaining specific socioeconomic activities (e.g. agriculture). This leads to overexploitation, which commonly arises from excessive abstraction for irrigation. The resulting increase in productivity and change in land use can establish a cycle of unsustainable socio-economic development within an irrigated region. Additional resources are exploited to satisfy the increased demand from the population and agriculture, exacerbating the already fragile environment by reducing groundwater levels and, in some circumstances, accelerating the desertification processes. Most cases, overexploitation is mainly a consequence of the fact that groundwater resources have historically provided a low-cost, high quality source for public water supply. Examples of aquifer overexploitation can be found in southeastern and southwestern USA, central and northern Mexico, in the arid Middle East and North African countries.

overexploited in 1994. From this date, the irrigation area at the watershed decreased until 2002, but it was not responsible for the slight aquifer recuperation registered between 1995 and 1999 (1,750 Mm^3), which was due to an uncommonly humid period registered in this region in 1997–1998 (Fig. 1.6). This aquifer recovery was used then by the farmers, to pressure policy makers for increased groundwater extractions for irrigation; once again, this meant an increase of groundwater pumping from 2002 and a descent of the aquifer groundwater reserve of around 800 Mm^3 from 1999 to 2004 (IGME 2008; Fig. 1.6). IGME (2004) stated that the 04.04 Aquifer water table levels dropped at an approximate average rate of 1–2 m $year^{-1}$ over the period 1999–2004. Again a slight aquifer recovery was computed by IGME (2008) for the humid period 2004–2005, estimated in a surplus of 300 Mm^3. From 2005, using the above mentioned lower annual recharge of 250 Mm^3 $year^{-1}$, groundwater extractions have been set at around 230 Mm^3 $year^{-1}$, although a continuous drought period evidenced that groundwater exploitation continues consuming the aquifer. Water table monitoring suggests that pumping still exceeds the aquifer renewable resources, dropping piezometric levels –3.32 m and consuming 500 Mm^3 for the period 2003–2008 (IGME 2008). The high number of illegal wells (58% of total wells) not taken into account, the inaccurate estimates of the remotely-based irrigation surface and the unrealistic water consumption per crop applied are significant uncertainties that obstruct management and restoration of the 04.04 Aquifer. After around 40 years of pumping irrigation being triggered in the Upper Guadiana basin, and after almost 25 years of different management strategies being implemented to reverse the overexploitation of the 04.04 Aquifer, the situation has not yet changed significantly, jeopardizing the recovery of TDNP.

1.5 Socioeconomic Aspects in the Upper Guadiana Basin

In 2005, about 570,000 people lived in the Upper Guadiana basin, with population growing at a rate close to 9% in the last 15 years (CHG 2009). However, 70% of Upper Guadiana basin municipalities, especially small villages, showed a negative demographic trend during this period. Average population density is 29 inhabitants km^{-2}, which is significantly below Spain's 87 inhabitants km^{-2}. The Upper Guadiana basin comprises 140 municipalities, four of which are home to 20,000–30,000 people, and seven to 10,000–20,000 (Fig. 1.1). Large urban agglomerations are absent in a region where most people live in towns with population density below 150 inhabitants km^{-2}. In view of these parameters, and according to OECD criteria, the Upper Guadiana basin can be classified as a rural area (OECD 1996; Viladomiu and Rossell 2002).

The Upper Guadiana basin presents a fairly young population, 21% of which is under the age of 16. This figure is comparable to the country's average, and slightly higher than Castilla-La Mancha's regional average. The number of people over 65 represents about 17% of the population (significantly lower than other rural areas of Spain). Population growth has been sustained in the last decades, although it slowed down in the 1980s and the first half of the 1990s (Martínez-Cortina 2002; Olmedo 2002).

The 04.04 Aquifer shelters about two thirds of the basin population (around 300,000 inhabitants; 35 inhabitants km^{-2}), and encompasses all of the more populated villages. This area is considered as one of the most dynamic areas of Castilla-La Mancha in terms of population and economy.

By 1997, per capita income in the Upper Guadiana basin was 85% of Spain's average, and 65% of the European Union (EU) average (Eurostat 1997). Thus, this region was considered as under objective one of the EU's structural funds (promoting the development of regions where per head Gross Domestic Product (GDP) is below 75% of the EU average) and has been until now in the receiving end of European subsidies.

In 1991, agriculture accounted for over 21% of employment in the basin, a rate similar to the industry and building sectors (Martínez-Cortina 2002). This percentage is significantly higher in the area of the 04.04 Aquifer where, in the year 2000, agriculture made up for approximately 38% of employment (Table 1.2) (up 60% in some municipalities as Las Labores, Arenas de San Juan, Santa María de los Llanos, Ossa de Montiel, Las Mesas, Carrizosa and Las Pedroñeras; Olmedo 2002). Agricultural employment has nevertheless been in constant decrease in recent times in the whole country, while employment has increased in the service sector (Table 1.2). Notwithstanding, manufacturing is limited in this region where most industry employment is found in building activities. Most manufacturing activities are linked to agricultural practices through food processing (wineries, meat and cheese; Martínez-Cortina 2002). Although the clothing industry and food manufacturing employment are the same in the basin, the latter activity creates more gross wealth (CHG 2009). Tourism industry still presents a low degree of development in this area, despite Don Quixote's excellent legacy.

Land uses in the Upper Guadiana basin are linked to agriculture. The useful farming surface in the basin accounts for 81% of the total area (Tarjuelo 1999). Around 73% of the basin surface is used for agricultural practices, with 65% of it devoted to herbaceous crops, 35% to vineyards and 5% to olives (Tarjuelo 1999). Forest areas represent less than 20% of the total basin surface and are restricted to the Toledo Mountains and to the east, in the Campo de Montiel. Most forests (68%) are privately owned, with a smaller surface belonging to community and public forests (6% and 7%, respectively). Forests are basically composed of Holm oaks which have been frequently replaced by the Stone pine (CHG 2008).

Table 1.2 Comparison of employment in the economic sectors between Spain, Castilla-La Mancha and the 04.04 Aquifer area. Data cover the period between 1991 and 2000 (Martínez-Cortina 2002; Olmedo 2002)

	Spain	Castilla-La Mancha	04.04 Aquifer
	1991/2000 (%)	1991/2000 (%)	1991/2000 (%)
Agriculture	10/7	16/10	44/38
Industry[a]	31/31	35/35	24/26
Services	59/62	49/55	32/36

[a] The building sector has been included within industry, accounting for 11%, 15% and 14% of the total employment respectively, in 2000. 1991 data were not available

Groundwater resources at the basin are also particularly important from the social point of view, catering to most of the urban water supply (serving 75% of the population; CHG 2008). For the whole basin, joint water demand for urban supply and industrial uses is of approximately 51 Mm^3 $year^{-1}$ (43 and 8, respectively; CHG 2008). Gascó et al. (2004) estimated that groundwater withdrawals for urban supply currently amount to only 2–4% of those for irrigation. Urban consumption showed a slow growth, with an annual rate of close to 1% (Martínez-Cortina 2002; see also Chapter 3).

1.6 A Chronological Summary of TDNP Impacts and Its Degradation

From 166 to 1400 BC there is archeological evidence of human influence in this wetland, through buildings named "motillas" (artificial hills constructed in a plain, used as settlements as, for instance, the archeological site "Motilla de las Cañas" inside TDNP). From then on, human presence has been constant in TDNP but its influence over the wetland has intensified in the last decades. Historical information compiled by Álvarez-Cobelas and Cirujano (1996) proved that this extended wetland territory, crossed and settled by numerous civilizations during thirty-six centuries, has been reduced to one third of its surface in a short period (1965–1985) due to desiccation, groundwater overexploitation and water pollution.

Natural wetland functioning was first altered in 1956, when the Law of July 17th on "*Saneamiento y Colonización de los Terrenos Pantanosos próximos a los márgenes de los ríos Guadiana, Gigüela y Záncara y afluentes de éstos últimos*" (Sanitation and Colonization of swampy areas close to the Guadiana, Gigüela and Záncara riversides and their tributaries). This Law was enacted based on the premise that recurrent flooding increased insalubrities, as well as to satisfy requirements to increase farming land to foster growth in this economically undeveloped area. Because uncultivated lands were considered rather as poor terrains, then the aim of this Law was to convert deep wetland areas to farmlands. River canalization and wetland draining increased quickly from 1967, adversely affecting wetland inundation patterns. In fact, the central southern area of the wetland (Las Cañas) was used for rice crops during some years, until the late 1970s. It stimulated an active social protest against the disappearance of Las Tablas, which forced the Government to stop desiccation works, after announcing that 1,000 ha of the wetland would be protected. In 1973, those 1,000 ha were declared as National Park by means of the Ordinance 1874/1973 (BOE 181 of June 30, 1973) in order "to conserve one of the most valuated ecosystems in Spain and the most representative wetland of "La Mancha Húmeda". The purpose of the conservation measures adopted was to avoid the increased wetland degradation by trying to maintain inundation patterns.

From 1974, this region experienced a huge agrarian transformation, when traditional agriculture with rain-fed lands (wheat, vineyard and olive) were replaced by herbaceous crops (maize, alfalfa, beet, melon, etc.) with more water requirements; this only could be obtained through an increase of groundwater pumping.

The Public Administration promoted and subsidized the change to this intensive agriculture, causing a quick raise of groundwater consumption, leading to aquifer overexploitation. Given that the adopted conservational measures were only applicable at the wetland scale, groundwater and river discharges declined and disappeared 10 years later, with the last known groundwater discharge occurring in 1986.

In the mid-1970s, TDNP degradation was already obvious, as warned by Sáez-Royuela (1977) who pointed out the need to increase water discharges into the wetland, controlling water quality and eutrophication. Thus, in 1980, the National Park was again legally classified (Law 25/1980, BOE 110 of May 7, 1980) providing a special legal regime devoted to protect the ecosystem, including conservation measurements of ground and surface waters as wetland supporters. Nowadays, the National Park area covers 1,928 ha, including the Las Cañas area as well, since it was also established as a buffer area (the protected zone includes 5,410 ha). Aiming to retain surface waters flowing by draining channels downstream of TDNP, a dam (Puente Navarro dam) was built at the end of the wetland. This measure should allow the restoration of the severely damaged area of Las Cañas. In 1986, a heavy intentional fire burnt some 185 ha of cut-sedge vegetation in the central area of the National Park (Alvarez-Cobelas et al. 2008).

Since 1986, due to the endless reduction of wetland inundation, the Public Administration established a Hydrologic Remediation Plan (HRP) at TDNP, in order to conserve its ecological values, in critical decline at that time. HRP estimated that, to preserve wetland ecological integrity, an inundation of 1,800 ha should be achieved after the humid season (Spring) and 600 ha after the dry season (Summer), through 18 Mm^3 $year^{-1}$ from external water sources (EPTISA 1986). The measures adopted by HRP included (i) groundwater pumping inside the wetland, (ii) water diversions from the Tagus basin, (iii) building an inner dam (Morenillo dam) in order to ensure inundation after the humid season in the shallowest part (NE) of the wetland, and (iv) recovering the 04.04 Aquifer groundwater level, declaring it as overexploited and limiting pumping, under the shelter of the European Agro-Environmental Program (UE 2078/92) by means of compensatory incomes for voluntarily cutting down on water use.

Nowadays, TDNP degradation continues, mainly due to water input deficit and water quality impairment. Wildlife and flora transformations have been significant during the last 40 years because wetland functioning changed severely since then. In 2008, a special Plan to restore aquatic ecosystems in the Upper Guadiana basin (known as the PEAG, Upper Guadiana Special Plan) was launched, intending to recover groundwater levels by 2027, thus enhancing the ecological performance of aquatic ecosystems which are mostly groundwater-dependent. As a part of this Plan, the Guadiana Water Authority promoted a smaller Plan to restore Las Tablas de Daimiel National Park and, as evidence that the PEAG is being useful, the National Park is now under restoring. The Plan for Las Tablas de Daimiel is called REGATA, which is the acronym for Gradual Restoration of Las Tablas. The REGATA Plan intends to act at two spatial levels, namely, that of the wetland and that of the Upper Guadiana catchment, both impinging on water quantity and the quality, to guarantee enough water of good quality for the wetland. Some actions within the Park have started in 2009, such as the disposal of sediment and decaying vegetation, but more actions should be implemented both in the wetland and in the catchment in the years to come if the wetland is to stay in good ecological health, as was the case with the measures pursued in the 1950s.

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