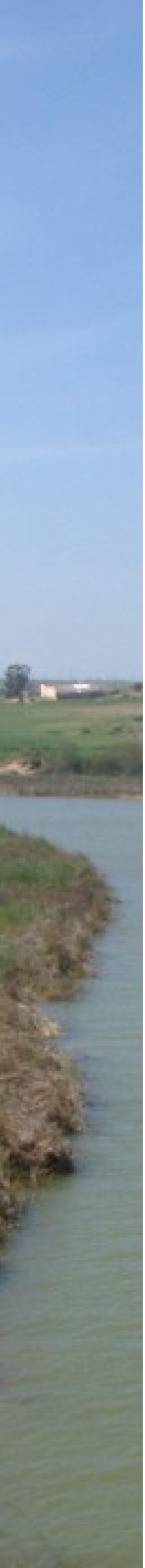

Assessment and Provision of Environmental Flows in Mediterranean Watercourses

- Basic Concepts, Methodologies and Emerging Practice

Mediterranean Case Study

RIVER FLOW REGULATION AND WETLAND CONSERVATION IN A DRY COUNTRY: ICHKEUL, TUNISIA

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The views expressed are those of the authors and do not necessarily reflect those of IUCN.

The Mediterranean case studies in this Resource Kit have been made possible by funding through the Water & Nature Initiative supported by the Government of the Netherlands and by the Government of United Kingdom and financial support of the Ministry of Foreign Affairs, Directorate General for Development Cooperation, Italy.

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River flow regulation and wetland conservation in a dry country: Ichkeul, Tunisia

1. Background

Study area: location and geography

While the surface area of Tunisia is modest, the steep decrease in annual rainfall from north to south leads to great divergences and diversities in ecological conditions. In the north, average annual rainfall may be as high as 1,200 mm per annum along the hills forming the border with Algeria, which are clothed with extensive oak forests, many of them deciduous. Annual rainfall declines sharply to around 500 mms in the densely populated coastal areas of central Tunisia, south of which there is a band of steppe lands with annual rainfall around the 300 mm mark. Much of the southern half of the country is classed as desert, with an average annual rainfall of less than 200 mms. In the centre and south, so-called "average" annual rainfall figures have little real meaning since cycles of dry years are often followed by one extremely wet year, giving over the years a median figure which bears little relation to actual rainfall in any given year. The northern part of the country has traditionally been an area of high and intensive agriculture production, notably of wheat (Carthage was the bread basket of the Romans) and olives.

In the half century since independence, the principal challenge has been to improve living standards for the whole country, not just the well-watered north, by developing economic opportunities, particularly in industry and tourism, by eliminating natural catastrophes such as flash floods and by building social infrastructure such as reliable water supplies for all. Tunisia has led the way in Africa and the Arab world in limiting birth rates (growth rate of 1.1% in 2001).

Lake Ichkeul ("Garaet Ichkeul" in Arabic, the word "Garaet" implying a freshwater basin) in northern Tunisia is a shallow natural lake covering some 8,900 hectares with a maximum depth of only two metres. Ichkeul originally received an average annual input of 405 million cubic metres (MCM) per annum; this was made up of 342 MCM of inflow from rivers ("oueds") flowing from higher up the catchment, almost entirely in winter from October to March, and 63 MCM of local precipitation. It acted as a flood storage basin; the winter inflows flood the surrounding marshes, and then in spring and summer the fresh water flows out to the much deeper and more saline Lake of Bizerta, which was a major naval base and arsenal during the French protectorate from 1881 to 1956. From the Lake of Bizerta, water flows on to the sea, via a channel deepened at the end of the 19th century to permit the entry of large military vessels; this now allows much greater backflow of saline water to the Lake of Bizerta and Ichkeul. In the 20th century therefore, conditions at Ichkeul changed from a naturally freshwater lake to a lake receiving varying amounts of saline inflow in summer, when salinity often rise to 30 grams per litre, this salt being flushed out by fresh water in the following winter.

Ichkeul has long been recognised as one of the four major wetland complexes of the Western Mediterranean (with the Camargue in France, the Guadalquivir estuary /Doñana National Park in southern Spain, and the El Kala wetlands of western Algeria). The conservation world has directed particular attention to these sites, mainly because of their importance for water birds; these included wintering ducks and geese which breed in central and northern Eurasia, passage migrants like waders or shorebirds en route from Eurasia to wintering areas often south of the Sahara, and breeding Mediterranean or Sarmatic species, some of them endangered.

The lake is a site of spectacular natural beauty, with a mountain rising dramatically from its centre; the mountain is dolomitic, with considerable botanical interest, and remains a geological enigma since it has little relation to other surrounding geological features. A number of villages are sited at the base of the mountain, and people living there have traditionally exploited grazing in the marshes, fished in the lake (notably for mullet which grow rapidly in this rich shallow lake with links to the sea, and for eels) and worked in the quarries on the mountainside, exploited since Roman times.

Water resource developments

The need to harvest and manage the nation's water resources - generous in the north, parsimonious in the south - was an obvious national development priority from independence in 1956 onwards. The object was to obtain control over surface water resources by construction of a series of dams on rivers, mainly in the well-watered north of the country. An equally important consideration was to be able to move water around the country to wherever it was needed; at the same time, therefore, a national water grid was planned, so that by a system of interlinked channels and pipelines, water could be moved around the country as required, taking water to drier areas in the south, or storing excess water from one dam in another which, because of local rainfall conditions, retained storage capacity. The top priority was always to provide drinking water for human populations and water for industry or tourist development. While agriculture and natural ecosystems may be able to adapt to occasional periods of water shortage or drought, human beings and industrial processes cannot survive without water.

It is important to emphasize the concept of *controlling* water resources; it was not merely a question of building dams, but of being able to move water to the places where it was required. In the initial planning process, requirements for ecological or environmental purposes were not given high priority, yet the construction of an integrated water control system always meant that the system could potentially be used in the future for environmental purposes. Similarly, if one day in the future desalinisation becomes an economically viable process, the network could be used to bring desalinated seawater produced from the south to thirsty areas of central or northern Tunisia.

While most attention was given in the first place to control of surface water resources, the importance of underground water resources was not overlooked. Clearly storage as groundwater is much more efficient in terms of avoiding evaporation. A detailed study of groundwater resources was therefore carried out, and some dams were constructed largely for recharge of groundwater; at present water is being injected into some 35 groundwater sites (mainly in the Kairouan area of central Tunisia); groundwater makes only a small contribution (15 MCM) to the waters of Ichkeul.

Another reason for developing the water control system was to reduce the impact of flash flooding. The rainfall regime, concentrated in winter with occasional torrential downpours in the western heights, often caused flash flooding in the plains downstream, leading to loss of human life and damage to roads, railways and other infrastructure. A particularly severe instance of such flooding occurred in early September 1969, when torrential rain in central Tunisia (over 300 mm, a year's "average" rainfall, fell in three days in one steppe area) caused massive run-off, extensive flooding, loss of some 600 lives (mainly in river valleys) and catastrophic damage to transport systems. (Recent meteorological events in neighbouring countries, such as the massive downpour in Algiers in late 2001, which caused high casualty figures in the Algerian capital, are a reminder that this is an ever-present risk, particularly in times of global climate change and the increased likelihood of extreme meteorological events). Hardly surprisingly, the reaction of Tunisia's leaders to the 1969 catastrophe was "never again". The 1969 floods thus gave added impetus to the development of an integrated

national water planning system, which would not only harness water resources, but would prevent further loss of life and infrastructure from extreme meteorological incidents.

The "Overall Plan for the Development of Water resources in the North", was finalized in 1975 and one of the main implementing bodies is the Ministry of Agriculture's General Directorate of Dams and Major Hydraulic Works (DGBGTH). It identified a series of major dam sites on oueds of northern Tunisia, six of them dams on rivers flowing into Garaet Ichkeul; two of these were of considerable size (a dam on the Oued Sejnane, with a capacity of 140 MCM and another on the Oued Joumine with a capacity of 100 MCM), and the other four rather smaller.

The current position is summarized in the Government's "State of the Environment" report for 2002: "The decade 1990-2000 has witnessed the implementation of an ambitious, integrated and comprehensive programme for the mobilisation of water resources, their control and their management, which has contributed in raising the rate of mobilisation of water resources from 56.7% in 1991 to 80% in 2000. …The ten-year complementary plan (2001-2010) aims to achieve a rate of 95%. ...The surface water resources reached 2,040 MCM in 2002, that is about 75.5% of the total water quantity, while it was hardly 47% in 1991. This considerable increase in mobilised surface water has been the result of the efforts made by the State in this regard, in particular the construction of 27 major dams, 182 hillside dams and 650 hillside lakes".

The need for an Environmental Flow assessment

At the time when the water strategy was being planned, the Ministry of Agriculture's General Directorate of Forests (DGF) was planning measures for biodiversity conservation at Ichkeul: Ichkeul became a National Park (covering 12,600 hectares and including lake, marshes and mountain) in 1980, and the quarries were closed in 1994; at international level Ichkeul was recognised by UNESCO as a Biosphere Reserve in 1977 and as a World Heritage site in 1979, and was designated as a wetland of international importance under the Ramsar Convention in November 1980. Few sites worldwide are recognised by three different international designations, so that the site gained particular international significance. Biosphere Reserve designation implies a balance between sustainable human exploitation, scientific research and conservation of biological diversity. Ramsar listing calls for the maintaining of ecological characteristics. World Heritage designation requires conservation of the features, for which the site was recognized.

The proposed dams were all outside the confines of the Ichkeul National Park, yet would obviously affect the flow of water to the wetland and its natural functioning. The Joumine Dam was completed in 1983, and the much smaller Ghezala Dam (capacity of 15 MCM) was built in 1984 on one of the smaller inflow rivers.

During the 1980s, a number of research projects were carried out at Ichkeul with a view to investigating the impact of the two dams and predicting the likely impact of the biggest of the six dams on the Oued Sejnane, whose building was planned in the early 1990s. These projects aimed to complement existing ornithological data with other information (especially on hydrology, botany and social issues), and were carried out under the auspices of the Ministry of Agriculture's Environmental Service and with financial support from the European Community. This research clearly demonstrated that environmental flows from the dams would be required if the main elements of the ecosystem were to be conserved.

As a practical measure, a water control structure ("sluice") was built at the outlet of Garaet Ichkeul to the Lake of Bizerta, which would make it possible to maintain fresh water in the lake or to prevent the flow of saline water into the lake in summer. The building began in 1986, and took some time to complete because of the difficult, very soft nature of the mud at

the bottom of the channel, but was finally ready for use in the early 1990s, though it was never actually closed to retain fresh water in Ichkeul until spring1996.

2. Environmental Flow Assessment Process and Approach

In 1989, at the invitation of the Tunisian Government, a mission from the World Bank prepared a review of environmental issues in Tunisia. The mission's report led to the adoption of a National Plan for the Environment and in December 1990 to a meeting of international funding bodies interested in providing funds for implementation, only the second of its kind at world level (after Madagascar). At institutional level, the World Bank report led to the establishment of the National Agency for the Protection of the Environment (ANPE), originally responsible to the Prime Minister's office and, since the setting up of the Ministry of the Environment and Land Use Planning in October 1991, to this Ministry.

One of the first tasks entrusted to ANPE was to investigate the inter-related issues of conservation and water resource use at Ichkeul, and it has continued to take the lead in this role until the present day, though responsibility for the management of Ichkeul and other National Parks remained, as it does today, with the DGF.

As a first step, ANPE decided to hold an international seminar on Ichkeul, with extremely broad participation from within Tunisia and from other interested and concerned parties outside the country, but in particular from around the Mediterranean basin. This seminar was held from 16-18 February 1990, and was one of the earliest and most thorough attempts in the region to reconcile socio-economic imperatives related to water management with biodiversity conservation. The seminar reaffirmed the necessity of the dams and the integrated water supply and management system, and decided that more detailed studies of the functioning of the Ichkeul ecosystem were required to define how the site could be protected and managed.

The detailed studies recommended by the international seminar were carried out over the period 1993-1995, and an exhaustive series of seven different reports on their findings was published in 1996 under the title "Study for the Safeguarding of the Ichkeul National Park". They devoted particular attention to the impact of the Sejnane Dam, the largest of the six, due to be completed by 1994 and filled from 1994 to 1997.

These reports noted that releases of water from the dams would be necessary if the principal ecosystems of the park were to be maintained. They suggested that if an annual amount of over 280 MCM from all sources (i.e. including not only environmental flows from the dams, but also inflow from undammed rivers, local precipitation and run-off), then the conservation of the ecosystem could be ensured; if total inflow was at a level between 230 and 280 MCM the pondweed *Potamogeton*/ waterbird link could be maintained, though some biological components of the ecosystem would be at risk; if the inflows went below 230 MCM then there would be great uncertainty since such a situation had never previously been met. The studies noted that there would be a need for political decisions on the amounts of water to be released, and on the precise origin of these environmental flows. The most difficult period would be 1995-2000 when the Sejnane dam was being filled, but that after 2000, by which time the Sidi Barrak Dam on another catchment should be operational, environmental flows from this new dam should be possible.

In addition to their recommendations on environmental flows, the reports addressed a number of other issues:

- ways of managing the sluice;
- socio-economic problems: the lack of employment opportunities for the 80 families living inside the Park on the mountain (particularly after the closing of the quarries)

and hence over exploitation of grazing on the mountain and marshes, and greater dependence on fishing in the lake;
- institutional problems in management of the park (essentially the lack of a central body with adequate authority to take wide-ranging decisions).

At international level the difficulty of resolving the needs of water supply and biodiversity conservation were recognised when Ichkeul was included (with the support of the Tunisian authorities) on Ramsar's Montreux Record ("of Ramsar sites where there is actual or potential change of ecological character") in 1990, and on the World Heritage in Danger list in 1996.

3. Management actions: Decisions taken and implications

Building and filling of the Sejnane and other dams: As predicted by the studies, commissioned by ANPE, the filling of the Sejnane Dam did indeed place considerable stress on the Ichkeul ecosystem. Filling of the dam began in winter 1994/95 and was completed by 1997/98 but, by a stroke of extreme bad luck, fell within a ten-year period of low rainfall and river flow (see below).

The Overall Water Resources Plan envisages the building by 2009 of three additional dams on smaller tributaries of the Ichkeul system, the Douimis, Tine and Melah. There have been calls for these dams to be cancelled because of the danger that they might cause further damage to the wetland ecosystem; it has been suggested that it might be appropriate to leave at least one of the inflow rivers in a natural state as a comparison with the dammed streams. It has however been confirmed that they will be built, on the basis that water supply is the priority and that, once the national water exchange network is fully operational, these dams may help to supply water to Ichkeul; furthermore, they will be considered as "ecological dams": on the one hand there will be no associated irrigation areas nearby (as is often the case with dams in Tunisia); on the other, their reservoirs will have a high storage capacity, so that water can be stocked in wet years for supply to the ecosystem in dry years.

The Sidi Barrak Dam: The Sidi Barrak Dam, much larger than either Sejnane or Joumine with a storage capacity of 265 MCM, has been built in northern Tunisia, just outside the Ichkeul catchment. This dam retains water from the area with the very highest rainfall, where shortfalls in precipitation are rare; indeed, from 2001, when filling was completed, it acted as the essential guarantor of Tunisian water supplies. It is now linked to the national water grid via the Sejnane Dam. The water planning authorities have always stated that environmental flows for Ichkeul would initially derive from Sidi Barrak, so that its completion and linking to the national water network was an essential precondition for such flows.

Drought and its impact on the ecosystem: Rainfall in the Ichkeul catchment has been characterized in the last ten years by a cycle of poor precipitation. At Ichkeul itself, in only two hydrological years between 1992/93 and 2001/02 did rainfall exceed the annual average; rainfall higher in the catchment was also correspondingly low, leading to greatly reduced flow in the oueds. These dry cycles were particularly severe between 1992/93 and 1994/95 (the years before the filling of the Sejnane dam), in 1996/97 and between 1998/99 and 2001/02. As a result, not only was there a reduced flow from upstream, but also an increased backflow from the sea via the Lake of Bizerta. The consequence was that the salinity of the lake in summer reached unprecedented levels (over 60 grams per litre in the summers of 1995 and 1997, even 80 grams in summer 2002), hence twice the salinity of sea water; in winter there was not enough inflow from the oueds for the normal lower winter levels of salinity to be restored. This increased salinity had a severe effect on the vegetation of the wetland: the belt of reeds *Phragmites australis* at the water's edge disappeared, the rushes *Scirpus maritimus* and *S. littoralis* growing in the marshes which were the main food of wintering geese disappeared, as did the floating pond weed *Potamogeton pectinatus*, one of the main foods of wintering ducks. The number of wintering water birds which had been around a quarter of a

million individuals crashed, the breeding birds no longer had any nesting cover in the vegetation. The salinity of the water became too high for many of the fish, so that catches of fish collapsed (in summer 2002 for the first time ever, no eel fishing took place); the ANPE reports indicate the value of the fish production varied between 320,000 and 1.5 million Tunisian dinars (240,000 to one million US dollars) per annum.

Implementation of the ANPE studies, with international support: The implementation of many of the measures identified for the safeguard of Ichkeul in the study was entrusted to ANPE. There was a clear policy aim, despite the increased salinity and loss of biological diversity in the National Park, to restore the site to a condition as near as possible to its original state.

To this end ANPE has co-operated closely with the international organizations concerned and in particular with the World Heritage Centre, the Ramsar Bureau and IUCN, reporting regularly to the World Heritage Committee. A World Heritage/Ramsar mission in 2000 made a number of recommendations on future actions, and the World Heritage Fund made an emergency grant to cover the organization in January 2003 of a workshop which produced recommendations on future management and in particular on parameters for monitoring.

Among the ANPE responsibilities are the operation and upkeep of the sluice at Tinja, and monitoring of the situation in the area:

- Operation of the sluice at Tinja: The sluice at the outlet to the Lake of Bizerta had been operational from the beginning of the 1990s; its provisional operating rules (laid down by the ANPE study for the critical period between 1995 and 2000, but requiring redefinition once the critical period was past) were calculated to ensure that fresh water was retained in the lake in summer. These rules indicated that a minimum salinity (19gms/litre) and water level (one metre above sea level) had to be reached before the sluice could be closed in spring; if the sluice gates were closed when salinity was too high or water levels too low, the lake behind the sluice would act as an evaporation basin in the high summer temperatures and push salinity even higher. As a result of the dry cycles, the operating conditions for closure were only met three times between 1992/93 and 2002/03 (in summers 1996, 1998 and 1999); the first closure of the sluice in 1996 represented a difficult decision and a major landmark in the restoration of Ichkeul; in other years, the sluice was left open, saline water from the sea and the Lake of Bizerta flowed back into Ichkeul; sea water was actually diluting the high salinity within the Ichkeul basin, which nevertheless reached concentrations of 60 and even 80 gms/litre.

- Upkeep of the sluice: The original sluice needed regular repair and upkeep; furthermore it was manually operated, and was therefore very difficult to raise and lower; it needed to be made automatic. These operations, of crucial importance for the management of water levels, should be complete by the end of winter 2003/04. In addition a fish pass has been installed to allow fish to enter the lake against the current even when the sluice gate is closed.

- Monitoring: ANPE has for some years been monitoring some abiotic and biotic features (water levels and flow, salinity, submerged vegetation), and has recently installed improved instruments for measurement. Since winter 2003/04 the monitoring has been extended to cover botanical and ornithological monitoring.

- Further studies: Bathymetric studies commissioned by ANPE will investigate sedimentation (to see whether the capacity of the lake basin has been reduced), and topographical studies will look into the restoration of the Oued Joumine, formerly a

meandering channel through marsh, but at present a rectilinear channel which evacuates water from neighbouring agricultural land.

New Management Plan: A three-year, five million dollar project, to improve management planning in Tunisian national parks, is being supported by the Global Environment Facility. A seminar was held at the Ichkeul Visitor Centre in January 2002 to present the outline of the funding request to all those interested; another workshop was held in Hammamet in December 2002 when the GEF authorities presented the plan as approved and explained the responsibilities of each of the actors. The project, which began in 2003, will develop new management plans for three Tunisian national parks, one in the southern desert area, one in the central steppes, and the third at Ichkeul. The lead in the management process is being taken by the DGF; the Ichkeul management plan will undoubtedly lay great stress on the need for environmental water flows, on socio-economic questions (with considerable input from local residents and stakeholders) and on institutional strengthening.

Inclusion of Ichkeul's water needs in the national water grid: Perhaps the most important decision of all for the safeguard and restoration of Ichkeul is its inclusion in water supply planning by the DGBGTH as a net consumer. The Directorate has been the major long-term actor in the development of the network, which allows water to be moved from one dam to another in times of water need, and to carry water throughout the whole country. The network is not yet entirely complete – some dams have still to be completed, and some links in the network are not yet built. When completed it will allow storage of water in times of excess and supply in times of need. Ichkeul is firmly recognized within this system as a net consumer of water. One of the most important recommendations of the January 2003 workshop was that environmental flows of the order of 80-120 MCM per annum should be guaranteed for the lake, over and above natural inflows and not including the proposal to build the last three dams. At the closing ceremony of the workshop the then Secretary of State for Water Resources confirmed that environmental releases of water for Ichkeul were included in his Department's planning, and mentioned a figure of 20 MCM.

A recent feasibility study (carried out for the Japanese Bank for International Cooperation in collaboration with the Tunisian Government) for additional pipelines to carry water from the North of Tunisia to the capital and Cape Bon gives information on the water requirements of Ichkeul and figures for proposed water releases. The report indicates that DGBGTH plans currently envisage releases of 20 MCM per annum from the Sidi Barrak Dam via the Sejnane Dam, and a further 50 to 70 MCM once the three remaining dams have been built.

Recommendations of the workshop in January 2003: The workshop held in January 2003 approved a number of recommendations and called for them to be taken into account in the implementation of the Management Plan currently being drawn up. In addition to the crucial issue of the amount of environmental flow, the recommendations refer to:

- other aspects of water management in the Ichkeul ecosystem;
- development of a monitoring programme;
- scientific research and the establishment of a Research Centre;
- setting up of a Scientific Committee;
- establishment of a management structure; and
- inclusion of Ichkeul as a force for sustainable development in its catchment area.

Good news! As regards rainfall, there has recently been good news: after the cycle of dry winters from 1992/93 to 2001/02, rainfall in the winters of both 2002/03 and 2003/04 has been well above average throughout the Ichkeul catchment. Winter 2002/03 proved to be the wettest for twenty years, and water had to be released from the dams, which were full to overflowing; these releases were in addition to inflow from as yet undammed rivers and local precipitation. In 2002/03 rainfall at Ichkeul itself was over 800 mm, while releases from the dams to the lake totalled some 429 MCM; more water reached Ichkeul in the winter of

2002/03 than in all the previous eight winters combined! As a result practically all the salt that had accumulated in the lake over the previous decade was leeched out to the sea; salinity levels in summer 2003 did not exceed 18 gms/litre. Winter 2003/04 has also seen above average quantities of water reaching the lake: by early February 2004, over 107 MCM had been released from the dams, a further 175 MCM reached the lake from natural sources and undammed rivers, and the salinity had dropped to as low as 6 gms/litre. These low salinity levels have allowed *Potamogeton* to reappear in the lake, while stands of *Scirpus* have begun to grow again on the marshes. Regeneration of the some elements of the much-damaged botany is thus clearly possible and indeed under way, though time (and more rain!) will be needed for further regeneration, particularly of *Phragmites*.

4. Key challenges and lessons learnt

It will be evident that approving environmental flows to Ichkeul has been a long slow process. The original thrust of actions around the Ichkeul catchment was to ensure water supplies for the national development effort, and this remains the highest priority. National and international measures were taken at an early stage to conserve the biological diversity of the site, yet dam building and water abstraction outside the park surface inevitably reduced water inflow and led to degradation of the original ecological conditions.

Now, there is general recognition of the need for environmental flows, but application of this recognition remains difficult. In theory, water might have been released in recent years from the Sedjenane or Joumine dams; in practice it was not possible. On the one hand, releases of small amounts would have had minimal effect, given the high levels of salinity in the lake, and in any case the system can adapt to occasional dry periods. On the other hand, there was a general shortage of water (the dams themselves were extremely low) and a need to use the meagre supplies for other purposes; psychologically speaking, it would have been difficult to explain to farmers who were deprived of water for their irrigated crops that water was required to maintain ecological conditions in the National Park – "for the ducks".

There is still much work to be done on Ichkeul on implementation of the emerging strategy for safeguard of the site. A major challenge – *the* major challenge – for the future will be to carry out the releases from the dams or the national water grid, given the highly variable meteorological and hydrological conditions. If the required amounts are to become available, it will be important for the National Park to become (and to be seen to become) a focus for regional development in the Bizerta area, through such activities as eco-tourism, use of an Ichkeul trademark for local produce and educational opportunities for schools and universities.

Another essential conclusion (of general relevance) that has emerged is the need to separate the research and management functions. Much data has been collected on Ichkeul, but it has not been critically validated nor stored for future reference and analysis in a central data-base; too often it has been collected by management staff who have neither the time nor the training to evaluate it properly because there are not sufficient scientists with expertise in the various disciplines. Yet these data are an essential foundation for policy making and monitoring. ANPE, in collaboration with the World Heritage Centre and IUCN, has defined the monitoring required, but it is important to train experts and establish permanent and ongoing databases. The idea of a scientific centre at Ichkeul is attractive, but will require much energy and support if it is to be realized.

Another lesson learnt is the need for closer collaboration between different arms of government, often between different divisions of the same ministry. At governmental level, a step in this direction has recently been taken with the amalgamation of the Ministries of Agriculture and Environment into a single Ministry of Agriculture, Environment and Water Resources. There is also an urgent need for better co-ordination at site level, and for

improving the institutional and decision-making process for management of the National Park.

The case of Ichkeul is clearly a model for North Africa, and for other countries with unpredictable rainfall (the example of Azraq in Jordan also springs to mind), where a balance is sought between the essential role of providing water for socio-economic development and the conservation of wetland biological diversity.

Acknowledgements

The author owes a great debt over many years to the many Tunisian government officials and scientists who have shared with him their views on Ichkeul, in particular staff of the General Directorate of Forests and the Association of the Friends of Birds. In preparing this paper he is particularly grateful to: Prof Mohamed Ennabli, to staff of the Ichkeul Unit in ANPE, and to staff of the General Directorate for Dams and Major Water Works. He is of course solely responsible for the views expressed in this paper.

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