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The conservation status of Moroccan wetlands with particular reference to waterbirds and to changes since 1978

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Abstract

Morgan made detailed descriptions of 24 major Moroccan wetlands visited in 1978, with a total area of 4529 ha (Morgan, N.C., 1982a. An ecological survey of standing waters in North West Africa: III. Site descriptions for Morocco. Biological Conservation, 24, 161–182.). We revisited these sites, and found that 25% of the wetland area had been destroyed by 1999. This loss was concentrated in wetland types of low salinity (<5 g/l NaCl), with a 98% loss of seasonal mesohaline sites, 41% loss of mountain lakes and 33% loss of seasonal *Phragmites*/*Scirpus lacustris* marshes. Surviving mountain lakes showed increased conductivities, suggesting reduced inflow. No loss of area of other wetland types was recorded, although degradation has occurred at all sites due to hydrological impacts, overgrazing or excessive reed-cutting, sedimentation, urban development, pollution, introduction of exotic fish and other causes. Similar threats face another 23 major Moroccan wetlands reviewed in this study. Of the 47 wetlands studied in total, only 10 have some kind of protection status. We assess the importance of these wetlands for waterbirds and aquatic submerged or floating plants. The number of plant species recorded is strongly correlated with the number of threatened waterbird species (but not the total number of waterbird species). Natural, freshwater wetlands most affected by wetland loss hold more species of aquatic plants and invertebrates, and are of great value for threatened waterbirds such as marbled teal (*Marmaronetta angustrirostris*), ferruginous duck (*Aythya nyroca*), ruddy shelduck (*Tadorna ferruginea*) and especially the crested coot (*Fulica cristata*). Most surviving natural, fresh wetlands are unprotected, and measures to conserve them are urgently required. Human-made wetlands such as reservoirs have some value for threatened waterbirds (especially ruddy shelduck and marbled teal), but hold much lower densities of waterbirds than natural wetlands, and support fewer plant species. Thus, they do not compensate for the continuing loss of natural wetlands.

Keywords: Wetland loss; Mountain lakes; Threatened waterbirds; Species richness; Aquatic plants

1. Introduction

Across the Mediterranean region, natural wetlands are being destroyed and degraded at a rapid rate, with severe consequences for the status of aquatic fauna and flora (Finlayson et al., 1992; Pearce and Crivelli, 1994). However, quantification of the rates of wetland loss and their implications for biodiversity conservation has only been attempted in a few Mediterranean countries, and there is an urgent need for more studies of wetland loss, as well as prioritisation of remaining wetlands for conservation action (Jones and Hughes, 1993).

In Morocco, wetlands face threats similar to those in other Mediterranean countries (Finlayson et al., 1992), especially direct drainage, construction of upstream dams, extraction of groundwater, pollution, introduction of exotic fish species and intense grazing and reed cutting (Dakki and El Agbani, 1995; Dakki and El Hamzaoui, 1997; Chergui et al., 1999). For example, a total of 34 exotic fish species have been introduced into Moroccan wetlands since 1920, and 18 of them are now

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naturalised (Chergui et al., 1999). Dakki and El Hamzaoui (1997) estimated the current total area of Moroccan wetlands to be 200,000 ha (ca. 0.3% of the land surface area), including 80,000 ha of reservoirs. There are no previous, precise quantitative studies of wetland loss in Morocco, although Dakki and El Hamzaoui (1997) considered that most remaining sites have been at least partially degraded and that 34,000 ha of coastal wetlands have been directly drained.

In this journal, Morgan (1982a) made a detailed description of 24 major wetlands in Morocco based on visits in 1978. Morgan's paper remains a standard source for the description of these wetlands (e.g. Hughes and Hughes, 1992; Green, 1993). In this paper, we use Morgan's study as a reference to calculate rates of wetland loss and degradation in Morocco over the past 21 years. We assess the nature and causes of degradation on a site by site basis. We compare rates of loss and degradation between different wetland types, using the classification of Morgan and Boy (1982), and consider the implications for conservation of waterbirds and aquatic plants and invertebrates. We also document changes to the protected status of the wetlands over this period. We identify many important wetlands not studied by Morgan (1982a), and rank these and those studied by him in terms of priority for conservation action.

Morocco is of great importance for wintering, breeding and migrating waterbirds, with midwinter counts including up to 116,000 Anatidae and 250,000 waders (Rose, 1995; El Agbani et al., 1996; Scott and Rose, 1996; Delany et al., 1999; Qninba et al., 1999). In total, about half a million waterbirds are present in midwinter, whilst millions of individuals use Moroccan wetlands on passage (Dakki and El Hamzaoui, 1997). Morgan (1982a) paid particular attention to the value of the wetlands he studied for waterbirds, relying heavily on data from midwinter counts. The importance of these and other Moroccan wetlands for wintering ducks and waders has recently been assessed by El Agbani et al. (1996), and Qninba et al. (1999). We present data on their importance for waterbirds outside the wintering period. We assess the importance of each wetland for globally and regionally threatened waterbird species breeding in Morocco and assess the impact of the changes recorded to Moroccan wetlands over the past 21 years on these species.

2. Methods

The 24 Moroccan wetlands studied by Morgan (1982a) were selected because they were included in previous lists of wetlands considered to be of international conservation importance (especially for wintering Anatidae), or "on a geographical and physical basis" (see Morgan and Boy, 1982, p. 7). Each site was visited for a short period (usually <4 h) between 29 January and 12 February 1978, when water samples were taken at two points, invertebrate samples at three points and the waterbirds were counted. To assess the importance of each wetland for wintering waterbirds, Morgan (1982a) also used additional data collected between 1972 and 1975 by the International Waterfowl Research Bureau (now Wetlands International) and M. Thévenot.

We visited all but two of the 24 wetland areas studied by Morgan (1982a) from 2 to 27 October 1997 and from 7 May to 1 June 1999. The exceptions were Plan d'eau de Dwiyate and Aguelmam Azegza, visited on separate occasions. At the same time, we visited an additional 23 wetlands not included in Morgan's study. At the time of Morgan's (1982a) study, only limited information was available about the distribution of waterbirds in Morocco, and many other sites have subsequently been shown to be as important as those studied by him (e.g. midwinter censuses of waterbirds have now been carried out for 22 years, with a great increase in the number of sites covered since 1982, see http://www.wetlands.agro.nl/). We selected these additional wetlands especially on the basis of their known or suspected importance for four threatened waterbirds (see later), or their proximity to such sites. The locations of all 47 wetlands are mapped by El Agbani et al. (1996), and Qninba et al. (1999).

During each visit, we recorded land use, threats, habitat types and other details using a modified version of the datasheet presented by Morgan and Boy (1982). The wetland margins were carefully prospected to assess the number of species of aquatic macrophytes and charophytes present. The numbers of plant species identified represent minimum numbers, since we were unable to prospect the centre of the wetlands, and did not always distinguish closely related species. Conductivity and pH were measured with meters and turbidity with a secchi disk. Geographical co-ordinates were recorded using a GPS. Wetland area was calculated using a GPS and available maps. Morgan (1982a) described the vegetation, invertebrates and waterbirds observed at each site in considerable detail. In this paper we summarise the major changes and threats recorded at each wetland, as well as their importance for waterbirds. A more detailed description of the changes to each wetland and full details of our waterbird counts can be obtained from http://www.ebd.csic.es/~andy/ or by contacting the first author.

We counted waterbirds carefully on all accessible parts of the wetland, using a telescope with up to ×60 magnification. We paid special attention to four threatened waterbird species recorded during our surveys (marbled teal *Marmaronetta angustirostris*, ferruginous duck *Aythya nyroca*, ruddy shelduck *Tadorna ferruginea* and the crested coot *Fulica cristata*). The marbled teal is globally threatened (Vulnerable) and the ferruginous duck Near Threatened (BirdLife International, 2000), whereas ruddy shelduck and crested coot both have small, isolated, declining populations of <10,000 individuals in the West Mediterranean (Tucker and Heath, 1994; Rose and Scott, 1997). Whilst neither species are globally threatened, their West Mediterranean populations can be considered to be threatened with extinction (IUCN 1994). We paid great attention to the identification of coots (see García et al., 1990; Forsman, 1991; Keijl et al., 1993 for details of field identification of the common coot *F. atra* and the crested coot), identifying as many individuals as possible in each flock to species, then applying the observed ratios to unidentified members of the flocks to estimate total numbers of each species.

For the description of changes to each wetland and analyses of wetland loss according to type, we retain the classification of wetland types made by Morgan and Boy (1982). Although newer methods of detailed wetland classification exist (Costa et al., 1996; Farinha et al., 1996), they have not yet been applied to all the wetlands under study (Dakki, 1995). Furthermore, it is hard to reclassify all wetlands visited by Morgan (1982a) to a detailed level, since several of them no longer exist. Hence, to classify wetlands studied by us but not by Morgan in broad terms, we use the Ramsar

Table 1
Moroccan wetlands studied by Morgan (1982a), showing their coordinates, changes in their area (ha) and conductivity/salinity by 1999, grade (conservation importance) assigned by Morgan (1982a) and this study (1999) and major threats responsible for wetland degradation

Wetland	Latitude (N)	Longitude (W)	Area 1978	Area 1999	Sal/Con 78–79[a]	Condy 97–99[b]	Grade 1982[c]	Grade 1999[c]	Threats[d]
Vegetated sebkhet									
Salines de Sidi M'Barek	32°58′	08°46′	100	100	27		1	3	HU
Marais d'El Hotba-Wlad Salem	32°55′30″	08°48′32″	40	40	10	21–23	1	1	DHOPU
Saline d'El Merja	32°50′	08°54′	40	40	42		1	3	DHU
Sebkha Zima	32°04′38″	08°38′56″	400	400	21	92	3	3	D
Seasonal mesohaline sites									
Merja Dawra	34°38′	06°24′	75	10	6		3	4	D
Merja Sidi Mohammed Ben Mansour	34°31′	06°27′	400	0	1.6		3	4	D
Mountain lakes									
Dayet Agoulmane	33°43′	04°51′	141	0			1	4	D
Lac d'Isly	32°13′11″	05°32′58″	221	221		2.5	1	2	S
Dayet Hachlaf	33°32′48″	05°00′01″	202	0	0.55	0.83	1	4	DS
Lac Tislie	32°11′42″	05°38′22″	83	83		1.4	2	2	OS
Aguelmam Azegza	32°58′	05°27′	60	60	0.37		2	2	OST
Dayet Ifrah	33°33′45″	04°55′45″	191	100	0.56	0.74–0.96	2	3	OS
Aguelmams Sidi Ali-Ta'nzoult	33°04′34″	05°00′13″	250	150	0.79	1.1–1.6	2	2	DHOS
Aguelmam N'Tifounassine	33°09′15″	05°05′30″	35	35		1.2–1.4	2	1	OS
Aguelmam Afourgagh	33°37′	04°53′	24	5	0.75	1.6	3	4	DOS
Dayet 'Awa	33°39′20″	05°02″	140	140	0.38	0.42–0.50	3	1	DHOT
Seasonal Phragmites/Scirpus lacustris marshes									
Marais du bas Loukkos	35°09′15″	06°06′30″	200	200	0.2	1.1–1.9	2	1	HU
Marais de l'wad Malwiya	35°07′	02°30′	100	0	12			4	D
Individual wetlands									
Merja Zerga	34°50′	06°20′	1500	1500	5-31	19–35	1	1	DFOPU
Merja de Sidi Bou Ghaba	34°14′18″	06°40′23″	157	157	9	13–20	2	1	ST
Oxbow at Embouchure de l'wad Malwiya	35°07′	02°20′	5	5	11	26		3	U
Plan d'eau de Dwiyate	34°03′	05°07′	85	85	3.2-60		1	1	
Pond by Sebkha Zima	32°05′	08°40′	3	? [e]					
Salines at Sebkha Bou Areg	35°06′49″	02°44′36″	80	80	97	23–167		3	P

[a] Salinities (g/l NaCl) listed by Morgan (1982a) for 1978, or (for the mountain lakes) conductivities (mS/cm) in September 1979 (R. Flower pers. comm.).

[b] Range of conductivities (ms/cm) recorded in 1997–1999.

[c] 1, international importance; 2, national importance; 3, local importance; 4, site of former importance that has since been lost.

[d] D, drainage, water-extraction or other hydrological changes; F, disturbance or by-catch from net fishing; H, hunting and egg-collecting; O, overgrazing or reed-cutting; P, pollution; S, siltation; T, disturbance from tourism; U, urban or road development. See http://www.ebd.csic.es/~andy/anex1.html for full details. Another important threat, introduction of exotic fish species, is a universal problem (see text).

[e] A site whose continued existence is not clear.

classification of wetland types (http://www.ramsar.org). The former and current conservation importance of Morgan's sites, as well as the current importance of additional sites were graded using the subjective criteria (based on effectiveness as a conservation unit, representativeness, richness, naturalness, rarity, potential value, research use and educational/tourist potential) presented by Morgan (1982b, pp. 84–85).

The spelling of names for Moroccan wetlands varies considerably in the literature and between different maps, owing to the subjectivity of transcribing Arabic names with the roman alphabet. We use names consistent with the inventories of El Agbani et al. (1996), and Qninba et al. (1999) used in the International Waterbird Census (Delany et al., 1999).

3. Results

3.1. Current status of wetlands studied by Morgan

Changes in the area and conservation status of wetlands studied by Morgan (1982a) are summarised in Table 1. Major threats affecting each site, and comparative data on salinities and conductivities from the two periods are also shown in Table 1. The current importance of each site for waterbirds (especially threatened species) is summarised in Table 4.

Overall, 25% of the wetland area studied by Morgan in 1978 had been lost by 1999 (Table 2). This is equivalent to an annual loss of 1.2%. This loss has not been evenly spread between wetland types, but instead has been restricted to seasonal mesohaline sites (98% loss), mountain lakes (41% loss) and seasonal *Phragmites*/*Scirpus lacustris* marshes (33% loss). This loss has been highly concentrated in wetland types of relatively low salinity (Table 2). Loss for the 1947 ha of wetlands of below 5 g/l NaCl(fresh or oligosaline) has been 48.9%, compared to only 6.4% of the 2582 ha of wetlands of higher salinity.

In total, drainage or other hydrological impacts have affected 52% of the sites (Table 1). Other major threats are apparent at those sites which have not been destroyed (Table 1), the most widespread being overgrazing or excessive reed-cutting (apparent at 47% of remaining sites), sedimentation (42%), urban development or road construction (32%) and hunting (32%). Furthermore, all the mountain lakes in the Middle and High Atlas and most other Moroccan wetlands have been affected by repeated introductions of exotic fish species which started in the 1920s and are still continuing (Chergui et al., 1999). Numerous cyprinids, salmonids and predators have been introduced into these lakes, many of which were previously fishless.

Although our measurements were taken at different times of the year, those mountain lakes that have not been destroyed appear to have undergone a consistent increase in their conductivities since the late 1970s (Table 1), suggesting a change in their water balance due to reduced inflow via increased water extraction in the catchment, or other factors. Morgan described all the mountain lakes he studied as "fresh", yet most lakes now have conductivities exceeding 0.8 mS (Table 1), making them oligosaline (Cowardin et al., 1979; Farinha et al., 1996). For wetlands other than mountain lakes, Morgan measured salinity in grams per litre NaCl (Table 1). These data are difficult to compare with our conductivity measurements, owing to variation in salt composition in inland wetlands (Moss, 1998).

Of the 24 wetlands studied by Morgan (1982a), only four were protected at the time. These four still retain the same protected status: Merja Zerga and Merja de Sidi Bou Ghaba as biological reserves, Plan d'eau de Dwiyate as a royal reserve and Aguelmam Azegza as a "site et monument historique". Of the remaining 20 wetlands, two (Lac Iseli and Lac Tislit) have now been included within a national park, and the other 18 remain unprotected (four of them have now been destroyed, Table 1). Merja Zerga and Merja de Sidi Bou Ghaba were two of four Ramsar sites declared in 1980 when Morocco signed the Convention on Wetlands, the others being Aguelmam Afennourir (Table 3) and Lagune de Khnifiss.

3.2. Status of other Moroccan wetlands

Details of other Moroccan wetlands included in our study are summarised in Table 3. They include many

Table 2
Wetland loss in different categories of Moroccan wetlands studied by Morgan (1982a) in relation to their salinity

Wetland type	Area in 1978 (ha)	LowSal[a] (%)	Loss by 1999[b] (%)
Vegetated sebkhet	580	0	0
Seasonal mesohaline sites	475	84.2	97.9
Mountain lakes	1347	100	41.1
Seasonal *Phragmites*/*Scirpus lacustris* marshes	300	66.7	33.3
Other types	1827	0	0
All combined	4529	43.0	24.7

[a] % Total area of this wetland type that had a low salinity <5 g/l NaCl according to Morgan's (1982a) data (<0.5 g/l is roughly equivalent to fresh, 0.5–5 g/l is roughly equivalent to oligosaline, Cowardin et al., 1979; Farinha et al., 1996).

[b] % Surface area lost by 1999.

wetlands of different types to those studied by Morgan, including reservoirs and other artificial wetlands which now represent an important part of the wetlands in Morocco. These additional sites are similar in their conservation importance to those studied by Morgan (Tables 1 and 3). Major threats are apparent at most of these sites (Table 3), the most widespread being overgrazing or excessive reed-cutting (apparent at 57% of sites), sedimentation (48%) and urban development or road construction (35%).

Of the additional 23 wetlands described in Table 3, only four are protected (Afennourir as a Ramsar site and Reserve, Plan d'eau de Zerrouqa as a Reserve, and the two wad Massa wetlands within the Souss-Massa National Park). The current importance of each site for waterbirds (especially threatened species) is summarised in Table 4.

3.3. Impact of wetland loss on aquatic biodiversity

Freshwater, natural wetlands in Morocco are facing the greatest rates of wetland loss (Table 2). Fresher sites hold a higher diversity of submerged or floating plant taxa (Fig. 1: Spearman's rank correlation between number of plant taxa and conductivity, $n=34$, $r_s=-0.420$, $P<0.015$). This is confirmed by Morgan's

Table 3
Wetlands covered during the current study but not by Morgan (1982a), classified according to the Ramsar system, showing their coordinates, area (ha) in 1999, grading for conservation value and major current threats responsible for wetland degradation

Wetland	Latitude (N)	Longitude (W)	Area	Grade[a]	Threats[b]
Mountain lakes[O]					
Aguelmam N'Tghalwine	33°23′18″	05°05′36″	5	2	OS
Dayet Iffer	33°36′	04°55′	5	3	
Aguelmam Afennourir	33°16′50″	05°15′	60	1	OS
Aguelmam Abekhane	32°40′	05°32′	30	2	OS
Fresh lowland lakes[O]					
Merja des Wlad Skher	35°03′10″	06°12′32″	89	2	OPSU
Merja Bargha	35°01′18″	06°12′58″	260	2	FHOPSU
Merja Al Halloufa	34°57′53″	06°14′53″	570	3	DFHOPS
Brackish/saline lakes[Q]					
Dayet Roureg	34°49′18″	06°18′06″	20	3	OSU
Lake to south of El Hotba	32°55′02″	08°49′01″	15	1	DOU
Oxbow II at Malwiya Delta	35°07′12″	02°19′45″	1	2	U
Permanent rivers[M]					
Lower Wad Massa	29°55′38″	09°39′37″	30	1	DU
Estuarine waters[F]					
Embouchure de l'wad Massa	30°03′22″	09°39′18″	100	1	F
Reservoirs[6]					
Barrage Mechra' Hommadi	34°44′17″	24°09′40″	1500	2	
Barrage Mohammed V	34°37′35″	02°56′07″	5000	1	OS
Barrage Al Massira	32°29′12″	07°34′24″	7500	1	FHOSU
Barrage Taghdout	30°37′24″	07°18′05″	250	3	O
Barrage Youssef Ben Tachafine	29°46′26″	09°28′29″	5000	3	OS
Barrage Al Mansour Ad-Dahbi	30°57′46″	06°45′26″	7000	2	HOSU
Small upland dams[2]					
Plan d'eau de Zerrouqa	33°32′39″	05°05′38″	5	2	
Plan d'eau de Sidi Mimoun	33°39′04″	04°58′05	2	3	
Artificial ponds[2]					
Pond at Sidi Moussa	32°59′49″	08°43′45″	2	3	
Pond near M. Bargha	34°59′07″	06°14′13″	3	2	PU
Salines[5]					
Salines de Lixus	35°12′	06°07′	150	2	

Ramsar codes for wetland types are given in superscript (Capital letters indicate natural wetlands, numbers human-made ones).
[a] 1 international importance; 2 national importance; 3 local importance.
[b] D drainage or water-extraction; F disturbance or by-catch from net fishing; H hunting and egg-collecting; O overgrazing or reed-cutting; P pollution; S siltation; U urban or road development. Another important threat, introduction of exotic fish species, is a universal problem (see text).

(1982a) data, as there is a significant negative correlation between the number of submerged or floating plant taxa described and his salinity data (substituting our conductivity data translated into approximate salinities for those sites described simply as "fresh" by Morgan, Spearman's rank correlation, $n=19$, $r_s=-0.675$, $P<0.002$). His data also show that fresher wetlands tend to support more zooplankton taxa ($n=19$, $r_s=-0.411$, $P=0.08$). In contrast, there was no significant relationship between conductivity and number of waterbird species recorded by us in 1997 ($n=22$, $r_s=0.267$, $P>0.2$) or 1999 ($n=27$, $r_s=0.179$, $P>0.3$). Owing to a greater presence of migratory species, at most sites more waterbird species were recorded in October 1997 than in May 1999 (Table 4). Neither was there a significant relationship between conductivity and number of threatened waterbird species (i.e. range of 0–4) recorded in 1997 ($r_s=-0.237$, $P>0.2$) or 1999 ($r_s=-0.340$, $P>0.08$).

Likewise, there was no significant relationship between the number of submerged or floating plant taxa and number of waterbird species recorded at each wetland in 1997 (Fig. 2a: $n=24$, $r_s=0.285$, $P>0.1$) or 1999 ($n=28$, $r_s=0.304$, $P>0.1$). However, there were significant relationships between the number of plant taxa and number of threatened waterbird species recorded in both years (Fig. 2b: 1997, $r_s=0.648$, $P<0.001$; 1999, $r_s=0.559$, $P<0.01$).

Although the relationship between conductivity and plant diversity holds true for both natural and artificial wetlands in Morocco, in general the natural wetlands support more plant species than the artificial ones (Fig. 1). This is despite the fact that the reservoirs are much larger in area than the natural wetlands (Tables 1 and 3).

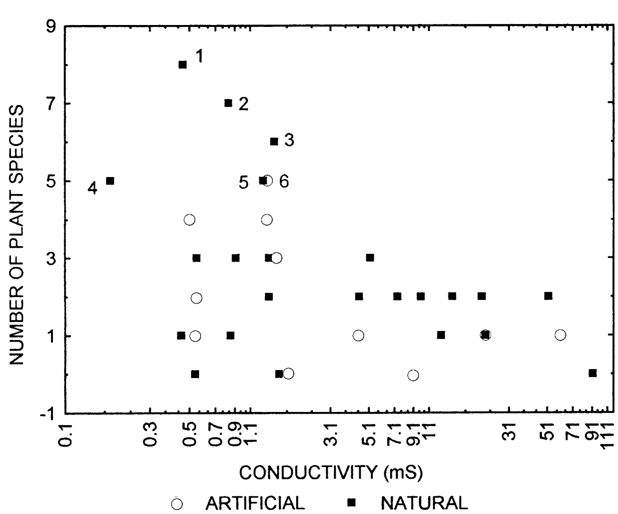

Fig. 1. Relationship between mean conductivity (logarithmic scale) and number of species of aquatic plants (charophytes and submerged or floating macrophytes) identified in natural or artificial wetlands in Morocco during visits in 1997 and 1999. The wetlands identified are: 1 Dayet 'Awa, 2 Dayet Hachlaf, 3 Marais du bas Loukkos, 4 Aguelmam Afennourir, 5 Aguelmam N'Tifounassine, 6 Barrage Mechra' Hommadi.

The observed trends for wetland loss in Morocco are having a particularly strong impact on the crested coot, which is highly dependent on mountain lakes and other natural wetlands of low salinity (Table 4). Peak numbers recorded of crested coot during our surveys in 1997 and 1999 showed a strong negative correlation with mean conductivity (Spearman's rank correlation, $n=36$, $r_s=-0.493$, $P<0.0023$). In contrast, there were no significant relationships between numbers and conductivity for marbled teal ($r_s=0.122$, $P>0.4$), ruddy shelduck ($r_s=-0.260$, $P>0.1$) or ferruginous duck (only recorded by us on three wetlands). Whilst natural wetlands are also of great importance to the marbled teal and ruddy shelduck, both species make major use of artificial reservoirs which are replacing natural wetlands but which are of little value to crested coot (Table 4). Numbers of ferruginous duck in Morocco are relatively small, and in recent years breeding has only been recorded in Merja de Sidi Bou Ghaba and Marais du bas Loukkos (Table 4), two sites providing denser cover of emergent vegetation than other remaining wetlands.

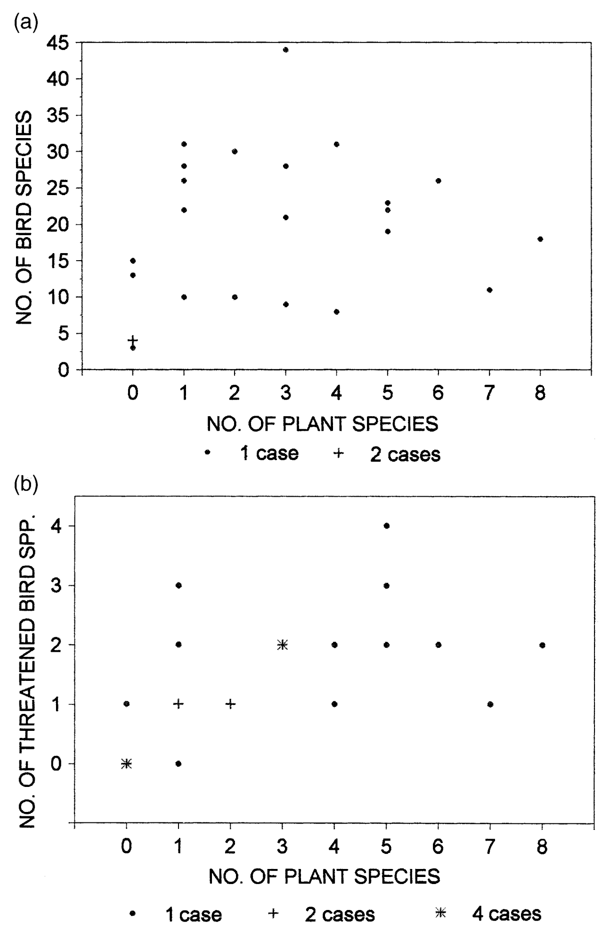

Fig. 2. Relationship between the number of species of aquatic plants (charophytes and submerged or floating macrophytes) identified in Moroccan wetlands and (a) total number of waterbird species recorded ($n=24$, $r_s=0.285$, $P>0.1$), (b) number of threatened waterbird species recorded ($r_s=0.648$, $P<0.001$) during visits in October 1997. Similar results were obtained for 1999 (see text).

Table 4
Counts of waterbirds at Moroccan wetlands included in the current study (total numbers, plus number of species recorded) and their importance for threatened waterbird species (maximum counts in the 1990s for each species) in relation to wetland type (classified according to the Ramsar system) and conductivity

Wetland[a]	Cond[d]	Total 1997	Species 1997	Total 1999	Species 1999	Ruddy shelduck	Marbled teal	Ferruginous duck	Crested coot
Mountain lakes[O]									
Aguelmam Afourgagh	1.6	35	4			0	0	0	1
Dayet 'Awa	0.42	2740	18	3056	13	3	1200	1	878[b]
Dayet Hachlaf	0.83	660	11			0	0	0	188[c]
Dayet Ifrah	0.74	458	10	202	6	70	0	0	40
Lac Tislie	1.4			142	7	2	0	0	1
Lac d'Isly	2.5			42	3	0	0	0	0
Aguelmam Azegza						61	0	0	0
Aguelmam N'Tifounassine	1.2	1224	19	1079	10	302[c]	4	0	195[b]
Aguelmams Sidi Ali-Ta'nzoult	1.1	1069	9	249	7	378[b]	0	0	> 100
Aguelmam Tghalouine				13	1	33	0	0	0
Aguelmam Afennourir	0.17	2807	22	3535	12	650[b]	1	1	1113[b]
Aguelmam Baghane	4.5	489	10			10	0	0	12
Dayet Iffer	0.91	0	0			0	0	0	0
Fresh lowland lakes[O]									
Merja des Wlad Skher	0.45			4506	24	0	2	2	197
Merja Bargha	0.54	3375	28	3240	24	0	15[b]	12	396
Merja Al Halloufa	1.04	880	15	171	6	0	3	1	200
Permanent brackish/saline lakes[Q]									
Marais d'El Hotba-Wlad Salem	10	7512	44	5232	37	123	1420[b]	0	70
Merja de Sidi Bou Ghaba	13	3736	31	394	21	1	835[b]	13[b]	557[b]
Plan d'eau de Dwiyate						1	519[b]	2	625[b]
Dayet Roureg	15			290	16	0	0	0	23
Permanent rivers[M]									
Lower wad Massa	5.2			199	13	0	14	2	0
Permanent fresh marsh[Tp]									
Marais du bas Loukkos	1.1	2113	26	2522	32	0	75[b]	100[b]	3000[b]
Estuarine waters[F]									
Embouchure de l'wad Malwiya	2.5	767	30	515	30	0	90[b]	3	0
Embouchure de l'wad Massa	7.4			2733	19	47	350[b]	14	0
Seasonal brackish/saline lakes[R]									
Sebkha Zima	92	892	13	210		250	56	0	0
Merja Dawra						0	0	0	2
Coastal lagoon[J]									
Merja Zerga	19			> 10,000		1	25[b]	0	67
Reservoirs[6]									
Barrage Mechra' Hommadi	1.04	496	23	172	11	62[b]	62	44	0
Barrage Mohammed V	1.55	6506	21	9094	26	383[c]	455[c]	13	0
Barrage Al Massira	1.33	2805	31	3535	32	427[c]	1973[c]	0	12
Barrage Taghdoute	1.8	28	3	10	4	31	4	0	0
Barrage Youssef Ben Tachafine	0.6			26	7	2	700	0	0
Barrage Al Mansour Ad-Dahbi	1.27	1682	22	528	16	500[b]	255	0	0
Artificial ponds[2]									
Pond at Sidi Moussa	4	90	3	45	2	0	0	0	0
Pond near M. Bargha	0.54			363	13	0	0	0	11
Small upland dams[2]									
Plan d'eau de Zerrouqa	0.47	102	8	95	8	0	0	0	64[b]
Plan d'eau de Sidi Mimoun	0.55			16	3	0	0	0	10

(*continued on next page*)

Table 4 (*continued*)

Wetland[a]	Condy[d]	Total 1997	Species 1997	Total 1999	Species 1999	Ruddy shelduck	Marbled teal	Ferruginous duck	Crested coot
Salines[5]									
Salines at Sebkha Sidi Bou Areg	23	726	26	381	11	0	4	0	0
Salines de Lixus	51	1753	28	701	24	0	63	0	0

Total waterbirds and number of species given for counts made from 2 to 27 October 1997 and 7 May to 1 June 1999 (left blank when wetland was not surveyed, or different species could not be adequately identified). See Rose (1992), Rose and Taylor (1993) for counts of wintering waterbirds at each site. Census data for threatened species from current study, Green (1993, 2000), the International Waterbird Census, and the chronique ornithologique published annually in the journal Porphyrio.

[a] Ramsar codes for wetland types given in superscript (Capital letters indicate natural wetlands, numbers human-made ones).

[b] Sites where breeding has been confirmed during the 1990s (nests or broods seen).

[c] Sites where breeding was probable during the 1990s.

[d] Minimum conductivity (mS/cm) recorded in 1997–1999.

4. Discussion

4.1. Wetland loss in a Mediterranean context

In Morocco, we have recorded a relatively high annual rate of wetland loss (1.2%) compared with previous studies in the Mediterranean region. Calculations of total wetland loss to date in Mediterranean countries include >60% in Spain by 1990 (Bifani et al., 1992) and about 70% in the western Algarve region of Portugal by the mid-1980s (Jones and Hughes, 1993). In Italy, 75% of wetlands were lost between 1865 and 1972 (Hollis, 1992). In Israel, 97% of wetlands have been lost since 1880 (Kroll, 2000). In Greece, at least 61% of wetlands were lost between 1910 and 1990 (Handrinos, 1992; Psilovikos, 1992). In North Africa, the only previous quantitative study is from Tunisia, where 28% of wetlands had been destroyed in the 100 years prior to 1988 (Maamouri and Hughes, 1992), a relatively low rate of loss.

In all these previous studies, the annual loss rate is <1% of wetland area, although these rates are not strictly comparable with each other since the periods covered within each study are different. No previous studies specify wetland loss between the 1978–1999 period covered by us. Amongst other studies, our overall rate of loss of 1.2% a year has only been exceeded in specific regions within other Mediterranean countries. Thus, in Macedonia, Greece, 94% of marshes (and over a third of lakes) were lost between 1930 and the mid-1980s (Jones and Hughes, 1993). In Cadiz province, southern Spain, 95% of the area of natural lagoons were destroyed between 1948 and 1991 (Granados, 1991). However, most of this loss was due to the drainage of one wetland, Laguna de la Janda, which represented 85% of the total area of lagoons in 1948.

Loss of natural wetlands in the whole Mediterranean region to date is probably well over 50% (Hollis, 1992), and greater wetland loss in recent years may explain why many more waterbird species have declined since 1974 in this region than in other parts of Europe (Delany et al., 1999). The particularly high rate of loss recorded by us may be because we have only considered the past 21 years when wetland loss may have been particularly high. Wetland loss in Morocco has accelerated over the past two decades owing to rapid economic development and human population increase (Dakki and El Hamzaoui, 1997), a pattern also occurring in other North African countries. Unfortunately, the wetland loss rate may increase even further in the near future. Moroccan wetlands are being rapidly degraded by a process of accelerated development in which their values are taken little into account and in which conservation interests have little weight compared with those of other sectors (Dakki and El Hamzaoui, 1997). Furthermore, most Moroccan wetlands of importance for conservation are still completely unprotected. Of the 47 wetlands considered in this study, only 10 have some kind of protection status.

It is conceivable that climate change may have some role in the current loss of Moroccan wetlands. Franchimont et al. (1994) considered that a prolonged drought period since the early 1980s is partly responsible for the disappearance of lakes in the Middle Atlas region. Variation in precipitation clearly influences the water levels in these lakes (Flower and Foster, 1992), and the periods 1980–1986 and 1991–1995 were unusually dry in northwest Morocco. From 1973 to 1998 inclusive, 21 of 26 years had below long-term average precipitation in Kénitra (Ramdani and Elkhiati, 2000).

4.2. History of wetland loss in Morocco

Wetland loss rates may have been even greater in Morocco during some earlier parts of the 20th century. While wetland destruction in the Middle Atlas and other upland areas as well as in arid eastern and southern parts of Morocco occurred mostly over the past two decades, most wetland loss in the fertile coastal plains in north-west Morocco took place much earlier (Smith, 1965; Morgan, 1982a; Dakki and El Agbani, 1995). The draining of the large Merjas of the Gharb plain associated with the wad Sebou and its tributaries began in

1920 (during the French colonial period) in order to combat malaria and to provide agricultural lands for European settlers. At this time, most of the area between Kénitra (in the southwest), Moulay Bousselham (in the northwest); Souk El Arba (in the northeast) and Sidi Slimane (in the southeast) was marshy, with large permanent swamps and even larger transient wetlands flooded in autumn and winter. The first marshes to be drained were those surrounding Kénitra (e.g. Merja du Fouarat, Merja Bir Rami) and other cities. They were followed by coastal marshes such as Merja Dawra which was almost completely drained between 1929 and 1934, but which continued to refill during wet winters up to the late 1960s. Similarly, from the 1920s to the 1950s, extensive drainage was carried out further north in the former protectorate of Spanish Morocco in the marshes of the Loukkos valley and in the coastal plains of eastern Morocco (e.g. the Triffa plain, Brosset, 1956). The loss of the inland Lac Iriki of 8000 ha in the 1970s following the damming of the wad Draa was also notable (Robin, 1968; Scott, 1980).

Detectable impacts on freshwater wetlands from deforestation, drainage and other human activities date back centuries, even in the remotest mountain lakes in the Middle Atlas (Flower et al., 1989, 1992) but increased markedly in the 20th century with entirely new threats such as exotic fish introductions (Dakki, 1997; Chergui et al., 1999). Deliberate fish introductions by government agencies for sport and other purposes are still widespread (Chergui et al., 1999), despite their often profound impact on native fish species and other aquatic biodiversity (Reinthal and Stiassny, 1991; Maitland and Crivelli, 1996). Similar policies were adopted in developed countries in previous decades (Pister, 1994).

4.3. Impact of wetland loss and degradation on biodiversity

Current wetland destruction in Morocco is being concentrated in the fresher natural wetlands which are of most importance for plant and invertebrate biodiversity (Dakki, 1997), as well as for threatened waterbirds such as the crested coot (itself a good "umbrella species" for such wetlands, i.e. a species whose conservation automatically saves many other species, see Lambeck, 1997; Simberloff, 1998) and ferruginous duck and for the regionally rare red-crested pochard (*Netta rufina*; El Agbani, 1997). Species richness in both aquatic macrophytes and aquatic invertebrates generally increases in wetlands as salinity decreases (Hammer and Heseltine, 1988; Wollheim and Lovvorn, 1995), as found in this study. However, these patterns are reversed amongst wetlands with low conductivities below 0.4 mS (Johnson and Leopold, 1994; Wilkinson and Slater, 1995). The greater loss of freshwater wetlands is a widespread phenomenon in Mediterranean countries, reflecting the high demand for freshwater sources for irrigation and other uses. Thus, in Tunisia the wetland type of which the greatest area has been lost is freshwater, inland marshes (Maamouri and Hughes, 1992). However, saline wetlands with a low species richness can also be important for the conservation of rare species. For example, oxbow II in the Malwiya delta (Table 3) had a conductivity of 52 mS and only two submerged plant species on 1 June 1999, yet one of them was the threatened *Althenia orientalis* (García Murillo, 2000).

Most Moroccan wetlands known to be of major importance for threatened waterbird species are included in Table 4. The most notable exceptions are Daya Tamezguidat (also known as Dayet Srij or Dayet Merzouga), a temporary brackish lake which held up to 1000 marbled teal and 660 ruddy shelduck in 1996 (Green, 2000), and the wetlands of wad (oued) Al Mellah at Mohammedia, where 220 marbled teal and at least 16 broods were recorded in 1999 (A. Miquet pers. comm.). However, this latter site was largely destroyed in 2000 (M. Thévenot pers. comm.). Table 4 plus these two wetlands cover all sites known to be currently important for breeding marbled teal, ferruginous duck and crested coot in Morocco. Other known, important breeding sites for ruddy shelduck are Daya La'wina, Lagune de Khnifiss, Embouchure de l'wad Al Wa'er, Embouchure de l'wad Chbeyka, Wad As-Saqia Al Hamra à La'youn and Barrage Tleta Bou Beker (Green, 2000; M. Thévenot personal communication).

Overgrazing and intense reed-cutting is an almost universal problem in Moroccan wetlands related to the increase in the rural human population, and has practically eliminated emergent vegetation from the margins of most wetlands except in strictly protected sites such as Plan d'eau de Dwiyate and Sidi Bou Ghaba (Franchimont et al., 1994; Dakki and El Hamzaoui, 1997). The shortage of wetlands with an extensive fringe of emergent vegetation has a serious impact on many ducks and other waterbirds that need such a fringe for nesting. This may explain why the recent recovery and expansion of the globally threatened white-headed duck (*Oxyura leucocephala*) in Spain (Ayala et al., 1994; Torres and Moreno-Arroyo, 2000) has not led to a notable expansion southwards into Morocco. The white-headed duck was probably formerly a widespread breeding species in Morocco (Green and Anstey, 1992), but requires extensive reedbeds to breed. The only records of white-headed duck from Morocco in recent years are two observations of a male at Merja Bargha in 1997 (Torres, 2000) and recent observations at Plan d'eau de Dwiyate, where 35 birds were seen in January 2001 and breeding was confirmed in 2000. The ability of crested coot to nest on platforms made of submerged vegetation in the centre of wetlands, and that of ruddy shelduck to nest in cavities well away from the water are undoubtedly key to their survival as a breeding species in many wetlands lacking extensive emergent vegetation (Table 4). Poaching and egg collecting are also serious problems for waterbirds, although they benefit from the relatively low number of active hunters in Morocco (25,000 licensed hunters in 1992, Franchimont et al., 1994).

Like more recent wetland loss, the historic destruction of freshwater marshes in the coastal plains had a severe effect on threatened waterbird species. For example, the original Merja Dawra and other wetlands of the Gharb that no longer exist held large numbers of crested coot, ferruginous duck, ruddy shelduck (all three as breeding species) and marbled teal, and also held the white-headed duck (Heim de Balsac and Mayaud, 1962).

The emphasis placed by Morgan (1982a), ourselves and the wider conservation community (the Ramsar Convention, Important Bird Area programmes, etc) on waterbirds to identify wetlands that are priorities for conservation action risks overlooking sites of no importance for birds but of great importance for other aquatic taxa. Thus, we have found no significant correlations between the number of waterbird and aquatic plant species found at each wetland. "Hotspots" identified for different taxonomic groups often have little relationship between each other (Prendergast and Eversham, 1997; Pearson and Carroll, 1998; Wilkinson et al., 1999). However, we found that the importance of Moroccan wetlands for threatened waterbird species is strongly correlated with the diversity of aquatic plants found at each site. This suggests that focussing conservation action on sites important for these declining waterbird species will bring benefits for other taxonomic groups that are also affected by the same processes of wetland loss and degradation.

Whilst reservoirs and other human-made wetlands have value for conservation, particularly for many waterbird species (Pandey, 1993), our results illustrate how they do not compensate for the loss of natural wetlands which, despite their smaller size, support a higher diversity of plant species than human-made wetlands of a similar conductivity. Natural sites hold much higher densities of waterbirds than reservoirs (compare Table 4 with areas from Tables 1 and 3), which typically have large areas of very deep, unproductive waters. Reservoirs do not offer appropriate conditions for important bird species (e.g. crested coot) and many more plant and invertebrate species. Similarly, artificial wetlands are not suitable for all amphibian species (Baker and Halliday, 1999).

It is noteworthy that the reservoir holding the greatest diversity of submerged or floating plants (Mechra' Hommadi, Fig. 1) is the only one with stable water levels, which are maintained via the larger barrage Mohammed V upstream. In natural wetlands, intermediate fluctuations in water levels tend to increase diversity of plant species (Pollock et al., 1998). Most Moroccan reservoirs undergo extreme depth fluctuations of many metres that prevent the establishment of many plant species. However, Mechra' Hommadi is also one of the oldest reservoirs studied (created in 1955, SECA-BCEOM, 1992), thus there has been more time for different plant species to colonise the site.

5. Conclusions for conservation policy

Morocco is undergoing rapid wetland loss concentrated in those wetlands of greatest importance for biodiversity conservation, and most remaining sites of importance are completely unprotected. Measures to improve the conservation status of the remaining natural Moroccan wetlands are urgently required.

There has recently been a special emphasis on the conservation of coastal wetlands in Morocco, with particular attention being paid to Merja Zerga and Sidi Bou Ghaba where a series of conservation projects have been focussed (Bayed et al., 1998; Dakki et al., 1998; El Agbani et al., 1998; Hajib and Marraha, 1998). This is largely due to the tendency to focus attention on sites holding large numbers of waterbirds, yet this is not a reliable way to identify the sites of most ecological or conservation importance (Herrera, 1988). The wetland types identified as those under most threat in our study have been largely ignored by conservationists and their importance overlooked. For example, Dakki and El Agbani (1995) considered the Atlas lakes to be of "low value" for waterbirds. In terms of total numbers of wintering birds this may be the case when compared to coastal wetlands (Franchimont et al., 1994; El Agbani et al., 1996). However, these lakes are of great importance for threatened species of waterbirds (Table 4), as well as being particularly diverse for other aquatic species (Fig. 1). Combined with their rapid loss, this makes the protection and conservation of remaining Atlas lakes and freshwater marshes a very high priority. Particular attention is required to assure the conservation of the unprotected wetlands with grade 1 in Tables 1 and 2, especially the most diverse of the remaining Atlas lakes (e.g. Dayet 'Awa or Aguelmam N'Tifounassine) and the Marais du bas Loukkos.

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