The conservation status of freshwater species and habitats in Key Biodiversity Areas at the Sebou river basin

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An introductory and interactive web story of this report is available at:

EN – https://digital.iucn.org/water/sebou-river

FR – https://digital.iucn.org/water/la-riviere-sebou

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Sebou river. © Ronaldo Sousa

Executive summary

This report presents the results of a broad assessment of the freshwater diversity in four Key Biodiversity Areas (KBAs)[1] and some key additional sites in the Sebou river basin in Morocco. The Sebou river basin houses a large proportion of the Moroccan human population that depends on the river for their livelihood. The basin has important ecosystems for threatened species that are currently being recognized as Ramsar sites or national parks. Additionally, four sites have been identified as Key Biodiversity Areas (KBAs) for the persistence of freshwater biodiversity.

Assessments were made on the effectiveness of the existing Key Biodiversity Areas (KBAs) in containing important populations of trigger species. During the summers of 2018 and 2019, biodiversity surveys of the taxaused to identify freshwater KBAs (fishes, molluscs, dragonflies and damselflies, crabs and aquatic plants) were undertaken by a team of experts in 39 sampling points, of which 29 were located in KBAs, and the remaining 10 were located in surrounding areas. A total of 192 species was recorded: 17 fish, 6 bivalve, 17 gastropod, 44 dragonfly and damselfly, 2 crayfish/crab species and 106 aquatic plant species. Twenty-one of these species are classified as threatened with extinction in the IUCN Red List of Threatened Species™ (7 aquatic plant species, 2 fish species, 1 damselfly species, 1 crayfish species, 4 bivalve species, and 6 gastropod species).

The highest native freshwater biodiversity was recorded in the South and East of KBA Oued Imouzzer Kandar. Also, in the central-east of KBA Oued Tizguite & Oued Ouaslane a high number of native species were found, especially aquatic plants. On the other hand, the number of threatened species was especially high in the KBA Oued Bouhlou and the KBA Oued Tigrigra. KBA Oued Bouhlou and its surroundings hosted a high number of threatened fish and a total of 7 threatened molluscs, including the Critically Endangered *Pseudunio marocanus* (assessed as *Margaritifera marocana* in the IUCN Red List) and *Unio foucauldianus*. Many threatened molluscs species were also found in the surroundings of the KBA Oued Tigrigra, as well as the Endangered damselfly species *Calopteryx exul* and several threatened aquatic plants.

[1] Sites that contribute significantly to the global persistence of biodiversity: https://www.keybiodiversityareas.org/

For the surrounding areas, high freshwater biodiversity was found in the main channel of Oued Sebou, especially a high number of fish and dragonfly species.

A major threat to the survival of the freshwater biodiversity is the introduction of non-native species that might outcompete the native species. A total of 11 non-native fish species were found in this study. High numbers of non-native fish were found in KBA Oued Tizguite & Oued Ouaslane and KBA Oued Tigrigra, as well as in the lakes' region (Dayat Iffer/ Dayat Yfrah/ Dayat Afourgah) and the sites in Aguelmam n'Tifounassine and Sidi Ali. Habitat Quality Assessments (HQA) produced high values for KBAs and surrounding areas, but the Habitat Modification scores (HMS) were neither clearly negative nor positive. The region around the KBA Oued Tizguite & Oued Ouaslane is especially affected by human activity, and management plans have to be implemented to properly protect the biodiversity in the area.

Other important threats are the construction of dams that are hindering the environmental flow required by many threatened species, soil erosion and siltation of river substrate and wastewater/solid waste disposal in the rivers. The Sebou basin has a high socio-economic importance for the Moroccan population, and is extensively used both for agriculture and industry. The effluents from agricultural or industrial activities have caused high contamination levels, that are harmful to humans, their livestock and the biodiversity. Another issue is the water shortage due to the water extraction for agricultural and urban uses, causing extreme droughts in some sites, especially in KBA Imouzzer Kandar. This intensive water extraction causes soil saline extrusion and increased water conductivity, as has been witnessed in the sites Aguelmam n'Tifounassine & Sidi Ali. Lastly, many of the springs and lakes are becoming unsustainable tourism destinations and have been completely altered and polluted, with the risk of a complete destruction of the freshwater biodiversity in the near future.

The inclusion of freshwater biodiversity into the management plan for the Sebou basin, with the involvement of local authorities and communities, is necessary in order to preserve these high valued freshwater ecosystems. In the river Bouhlou crossing the Tazekka natural park, one of the best recruiting populations of the freshwater mussel *Pseudunio marocanus* (assessed as *Margaritifera marocana* in the IUCN Red List), one of the world's 100 most threatened species, was detected. In order to protect this precious freshwater biodiversity, several measures should be taken to adjust the agricultural and industrial sector: inclusion of freshwater biodiversity into the water management plans and the increase of riparian buffers, wastewater treatment plans, the prevention of cattle overgrazing and bank destruction by trampling near the river banks. Campaigns on the correct management of the channels and the control of recreational activities by local authorities, could aid to manage the environmental flow necessary for many native species. For the rivers/lakes suffering from droughts, it will be necessary to setup an aquifer management plan covering the catchment of the aquifer on which the rivers/lakes depend, and develop artificial reservoirs to enable the reduction of exploitation of ground water. Finally, measures should be taken to stop the active re-stocking of fish in order to avoid non-native species outcompeting the native species.

Further studies should be conducted to have a better understanding on the freshwater biodiversity in the Sebou basin. It is necessary to re-evaluate some of the KBAs to assess the presence of their trigger species and other threatened species. Finally, many of the additional sites that were studied here could be included as extension of the KBA, or a new KBA should be created to help focusing conservation efforts and promoting management actions that allow the persistance of the biodiversity elements present in there.

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List of acronyms

CBMA	Centro de Biologia Molecular e Ambiental (*Centre of Molecular and Environmental Biology*)
CIBIO	Centro de Investigação em Biodiversidade e Recursos Genéticos (*Research Centre in Biodiversity and Genetic Resources*)
CIMO	Centro de Investigação de Montanha (*Mountain Research Centre*)
CITAB	Centro de Investigação e Tecnologias Agroambientais e Biológicas (*Centre for Research & Technology of Agro-Environmental & Biological Sciences*)
CNR	Consiglio Nazionale delle Ricerche (*National Research Council*)
HMS	Habitat Modification Score
HQA	Habitat Quality Assessment
InBIO	Research Network in Biodiversity and Evolutionary Biology
INBO	Instituut voor Natuur- en Bosonderzoek (*Research Institute for Nature and Forest*)
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
UCA	Université Cadi Ayyad (*Cadi Ayyad University*)

1 Introduction

The Sebou river is located in the northeast of Morocco, flowing from its source in the Middle Atlas mountains to the Atlantic Ocean in the town of Mehdya, near Kenitra. Besides being the largest North African river by volume, it is also one of the main industrial and agricultural drivers of the Moroccan economy. The Sebou basin covers an area of 39,021 km^2 (Amine & El Kettani, 2017) and encompasses 4 regions and 17 provinces in Morocco. It is of vital socio-economic importance to the country, being home to nearly 20% of the Moroccan population and 30% of the agricultural land. The basin also hosts many important industries, including sugar refineries, paper and oil mills and tanneries.

The course of the Sebou river and its tributaries are irregular in space and time, with some tributaries present with perennial flow (water present all year round) and others presenting intermittent flow with the occurrence of massive temporary floods (Minoia & Brusarosco, 2006). More than 30 dams have been built to regulate the water flow, generate hydroelectric power, and allow navigation through locks. One of these dams, the Al Wahda is the second largest dam on the entire African continent and plays an important role when it comes to the irrigation of the most fertile region of Morocco, the Gharb plain (Haida et al., 2004). Large-scale irrigation schemes have been developed in this important agricultural region, where cereals, vegetables, olive, sugar beet, citrus and grapes are being cultivated.

However, many of these developments in the Sebou basin have negatively affected the remarkable ecosystems and biodiversity of the region. To protect these fragile ecosystems and the high diversity of endemic animal and plant species, several protected areas have been designated: 39 important wetlands including 6 areas classified as Ramsar sites (wetlands designated of international importance under the Ramsar Convention), 3 national parks and 17 sites of biological and ecological interest. Besides this, 14 Key Biodiversity Areas (KBAs) have been identified in the basin, of which four shelter key freshwater biodiversity. These sites are the natural habitat of many endemic animal and plant species that are threatened with extinction (Figures 1 and 2).

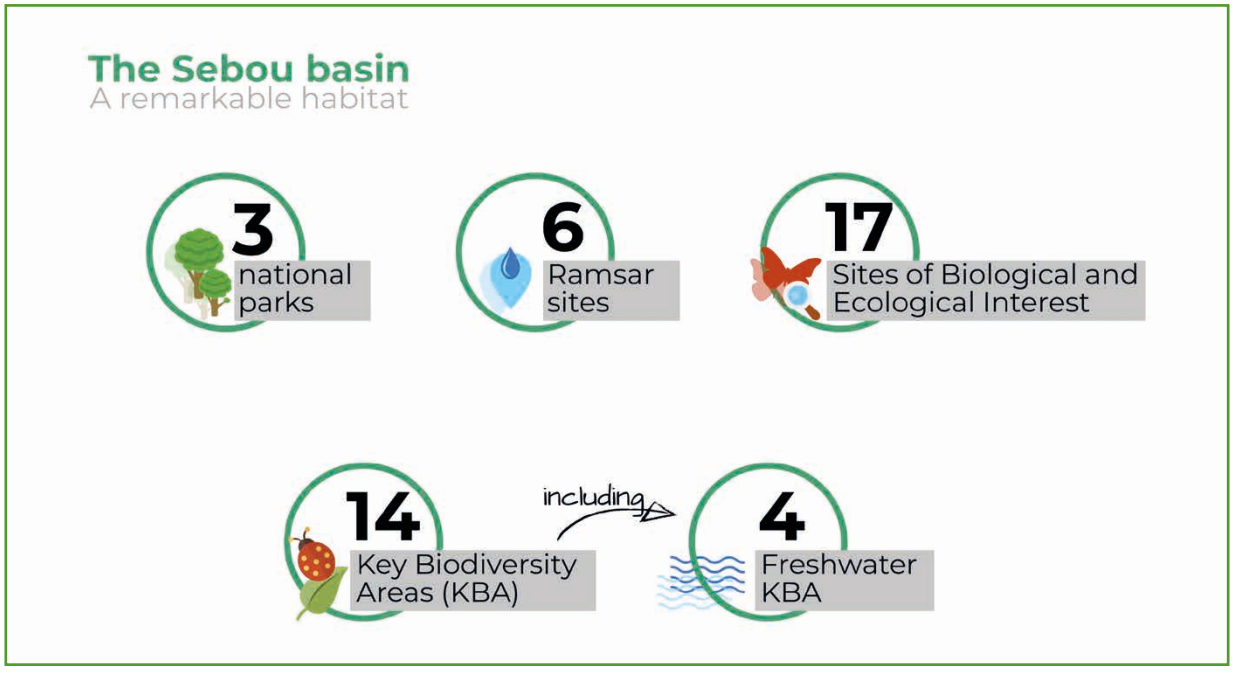


Figure 1. Protected areas and other important areas for conserving biodiversity in the Sebou basin. Source: Protected Planet, World Database of Key Biodiversity Areas and Ramsar Sites Information Service (2021)

During the summer of 2018 and 2019, a team of experts surveyed several sites in the south-eastern part of the Sebou basin to assess the status of the freshwater biodiversity in the four freshwater KBAs and the surrounding areas of interest. The aim was to collect reasonably comprehensive data on the presence of the trigger species for the KBAs and on the occurrence of species of fish, odonates, bivalves, crabs and aquatic plants (Table 1).

Table 1. Overview of the freshwater trigger species surveyed in four KBAs in the Sebou river basin (IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

Name	Area type	Sampling sites	Trigger species	
			Taxa	Global IUCN Red List Category
Oued Bouhlou	KBA	6	Fish	*Cobitis maroccana* (**VU**)
			Bivalves and Gastropods	*Heideella knidirii* (**EN**) *Horatia* sp. nov. *'haasei'* (**EN**)
			Odonates	*Calopteryx exul* (**EN**) *Cordulegaster princeps* (**LC**)
			Aquatic plants	*Plantago lacustris* (**VU**)
Oued Imouzzer Kandar	KBA	7	Fish	*Cobitis maroccana* (**VU**)
			Bivalves and Gastropods	*Horatia* sp. nov. *'haasei'* (**EN**) *Melanopsis scalaris* (**EN**) *Theodoxus marteli* (**VU**) *Theodoxus numidicus* (**VU**)
			Odonates	*Calopteryx exul* (**EN**) *Cordulegaster princeps* (**NE**)
			Aquatic plants	*Plantago lacustris* (**VU**)
Oued Tizguite and Oued Ouaslane	KBA	8	Fish	*Cobitis maroccana* (**VU**)
			Bivalves and Gastropods	*Giustia midarensis* (**EN**) *Heideella knidirii* (**EN**) *Horatia* sp. nov. *'aghbalensis'* (**EN**)
			Odonates	*Calopteryx exul* (**EN**)
Oued Tigrigra	KBA	8	Fish	*Cobitis maroccana* (**VU**)
			Bivalves and Gastropods	*Horatia* sp. nov. *'haasei'* (**EN**) *Melanopsis scalaris* (**EN**) *Theodoxus numidicus* (**VU**) *Melanopsis arbalensis* (**DD**) *Unio durieui* (**EN**)
			Odonates	*Calopteryx exul* (**EN**) *Cordulegaster princeps* (**LC**)
			Aquatic Plants	*Lepidium violaceum* (**VU**)

Source: Darwall et al., 2014; World Database of KBA.

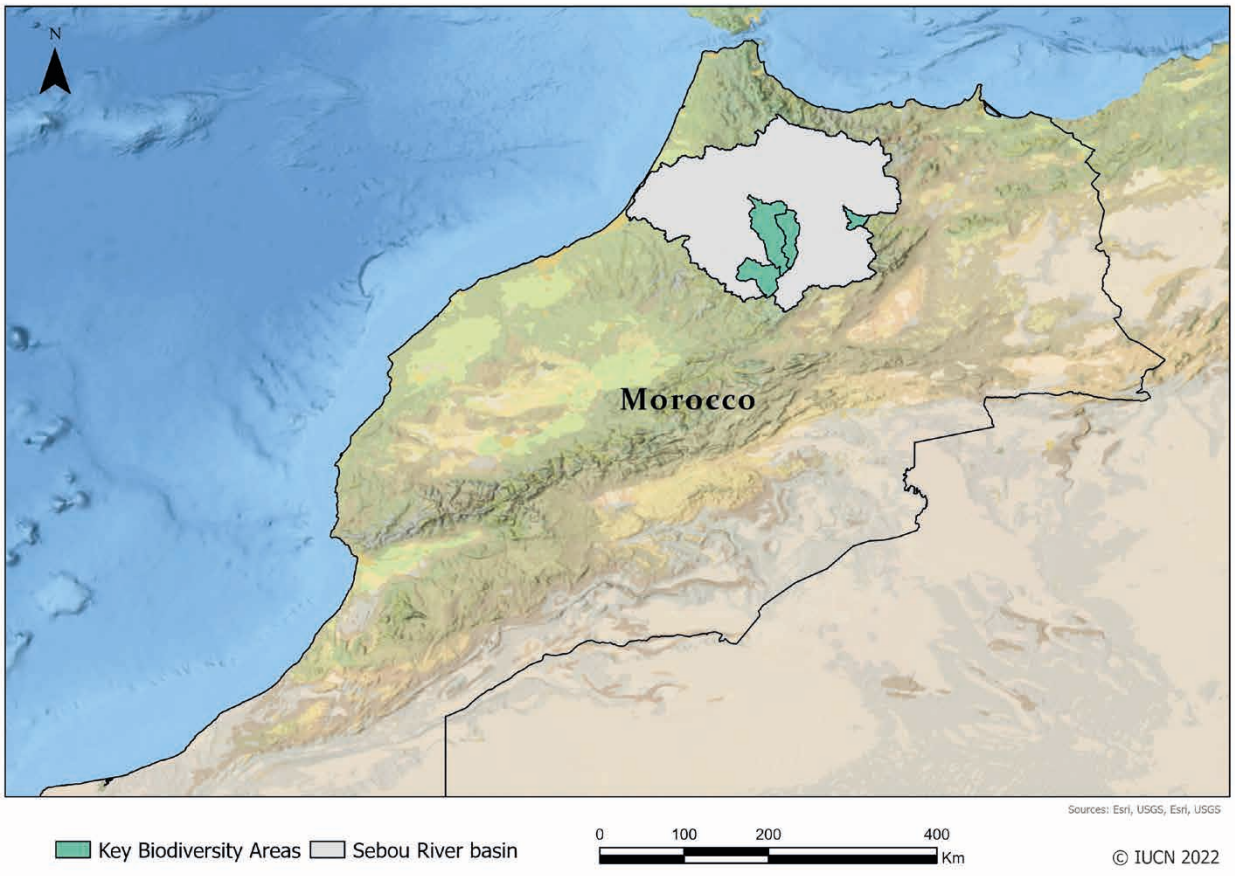


Figure 2. Map of Morocco with the Sebou river basin represented in light grey and the freshwater KBAs in green. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013) and World Database of KBA.

2 Methodology

SITE SELECTION

A total of 39 sites were selected by the team members based on local knowledge, the available bibliography, and satellite imagery to try to encompass the whole range of freshwater habitats and taxa. Priority was given to sites where the species have been previously recorded or that were within the focal area of the designated KBAs (Figure 3). The fieldwork was accomplished through two distinct campaigns: The first campaign happened from 14 till 21 August 2018, and the second from 7 till 14 June 2019.

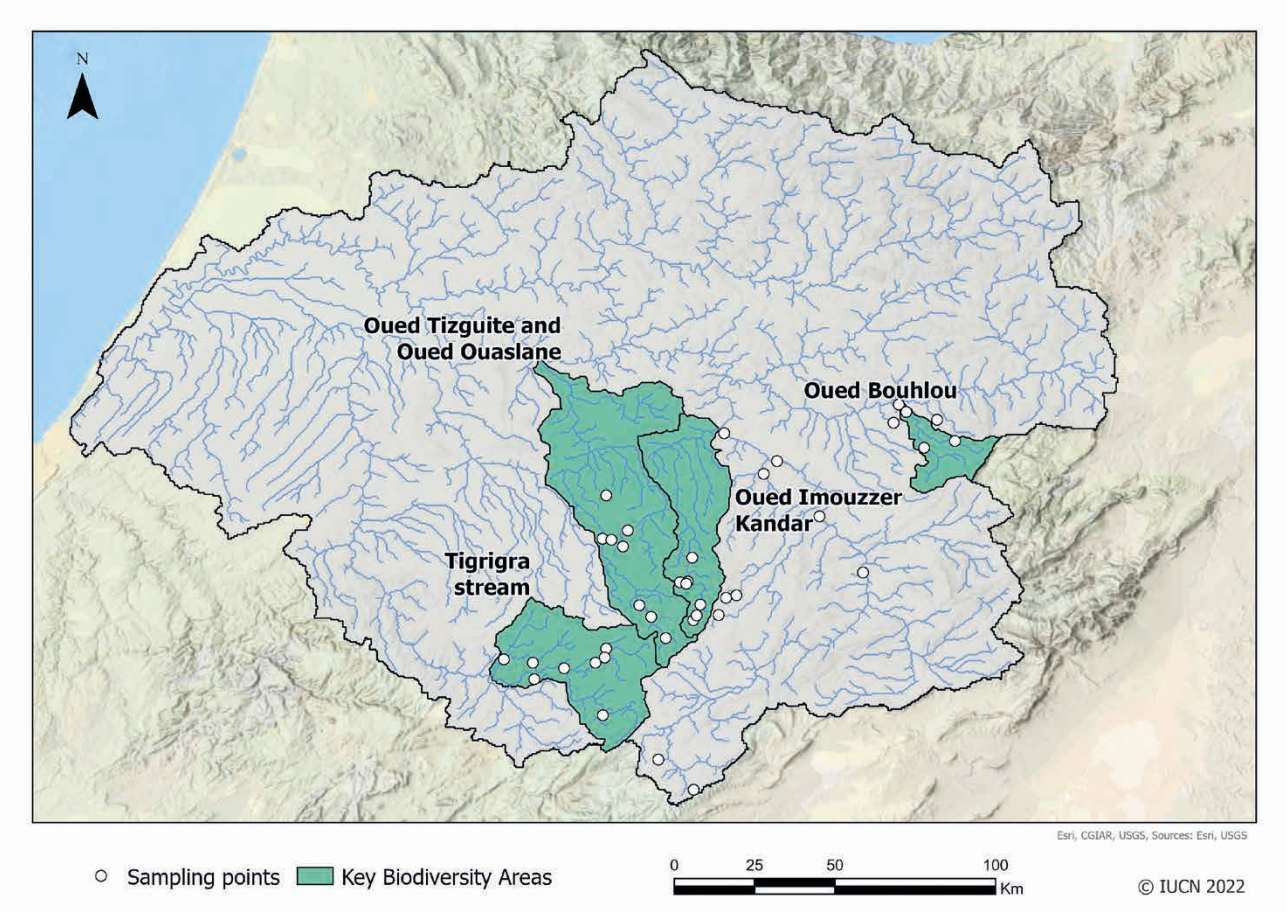


Figure 3. Map of the Sebou basin in light grey, with the four KBAs in green and all sampled sites represented by white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.

SURVEYS

All selected sites were visited for survey potential on aquatic plants, fish, and all macroinvertebrates including special surveys for crabs, crayfish, gastropods, molluscs, and odonates (Annex 1). Not all taxa were surveyed on all 39 sites, but only those that could potentially be present in the specific freshwater habitats (Annex 1). Furthermore, seven of the selected sites in the focal areas were completely or partially dry and only suitable for very few taxonomic groups (Annex 1). The surveys were complemented with River Habitat Surveys, and standard water physical-chemical features to evaluate

ecological integrity and anthropogenic modification of each site. Two water samples were also collected on a selected site per KBA for eDNA metabarcoding to verify if the methodologies used were capturing the whole diversity of each target taxa.

DATA COLLECTION

- Fish were assessed using electrofishing following INAG (2008).
- Freshwater molluscs were assessed using a Rapid Bioassessment for freshwater molluscs following Cummings et al. (2016) and complemented with the macroinvertebrate assessment.
- Crayfish and crabs were assessed by the combined effort of macroinvertebrate sampling plus electrofishing for fish.
- Adult odonates were assessed by using the protocol for site count and complemented by the macroinvertebrate assessment for the larval stages. All dragonflies present at the time of the assessment are counted during 1 hour. Not only dragonflies next to and above the water but also the adjacent vegetation was checked. Special attention was paid to microhabitats which were sun-exposed and that give some protection against the wind. Special attention was given to exuviae, empty larval skins left behind after emergence on the vegetation or stones.




Elements of the sampling field work. © Ronaldo Sousa

- Aquatic plants were assessed by walking surveys of selected river reaches and selected parts of the margins and water column of standing water bodies. The numbers employed indicate the percentage cover.
- Macroinvertebrates were collected following INAG (2008).
- Fish and bivalves presence was assessed with the method of metabarcoding using water eDNA, following Valentini et al. (2016) and Prié et al. (2021).
- Habitat Survey was accomplished using the River Habitat Survey Methodology (Raven et al., 1997; 1998).
- Water temperature, dissolved oxygen, conductivity and pH were measured at each site with a YSI EXO 2 multi-parameter probe.

3 Freshwater biodiversity in the KBAs

3.1 KBA: Oued Bouhlou

BACKGROUND

This KBA is composed of the area surrounding Oued Bouhlou, one of the few permanent rivers in the middle Atlas. Its upper part is located inside the Tazzeka National Park and has a big dam on its main tributary, the river/Oued Bousbâa, impacting most of the river basin (Figure 4). The Oued Bouhlou KBA does not have a focal area and was triggered by six species (Table 2) encompassing the Bouhlou river network and scattered springs.

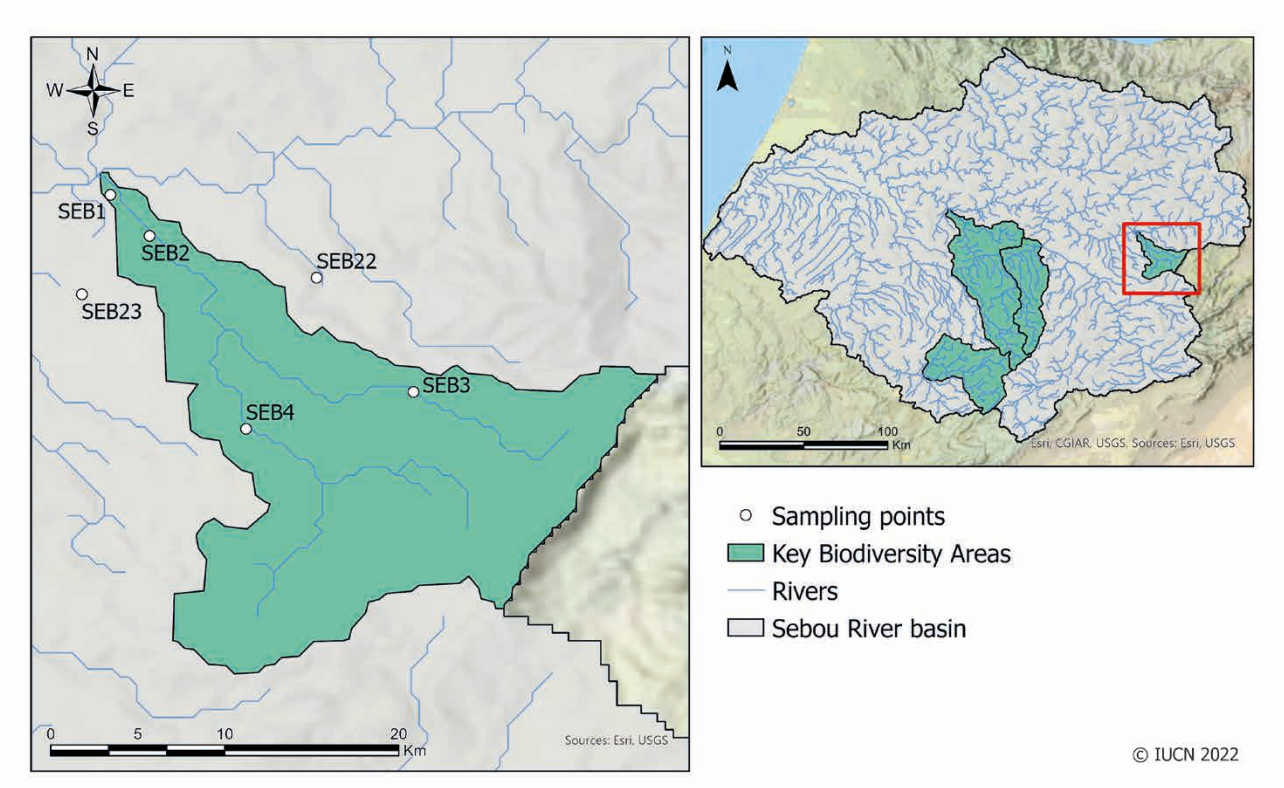


Figure 4. Map of the Oued Bouhlou KBA in green with the sampled sites as white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.

SURVEY

We sampled four sites within the KBA, below the dam and two spring sites just outside the KBA. Immediately below the dam reservoir, the main Bouhlou river dries completely during the dry season, being unable to maintain most freshwater taxa. The river starts to have more water around 20 km from its mouth where we surveyed two sites one in the Bouhlou main channel and another in its main tributary, Oued Bousbâa (SEB04). Below the junction of both rivers, the river has permanent flowing water and we surveyed two sites at these lower stretches (SEB01 and SEB02). We also surveyed two springs, Aïn Sahla and Aïn Fendel, just outside the KBA to try to find the trigger gastropod species.

The reservoir of Oued Bouhlou Dam inside Tazzeka National Park. © Ronaldo Sousa

Left: middle sections of the Bouhlou river. Right: middle sections of the Bousbâa river. © Manuel Lopes-Lima

Left: Oued Bouhlou (SEB01). Right: Oued Bouhlou (SEB02). © Ronaldo Sousa

DIVERSITY

In Table 3, we present the total species richness and threatened species richness at each site. The river Bouhlou has a good ecological condition in its lower stretches and hosts diverse freshwater groups in high abundances. Diversity is generally higher in the lower sites, possibly due to the hydrological instability of the upper reaches (Table 2). The two springs are highly modified by humans and exploited for water consumption and disturbed by human activities. There were still healthy gastropod communities living in both sources, but we detected the presence of the non-native North American mosquito-fish *Gambusia holbrooki* in Aïn Sahla (SEB22). We failed to detect most of the trigger species, with a single trigger odonate species being collected in SEB3 and the trigger aquatic plant species in the downstream sections. However, we found seven additional threatened species: three bivalve, two gastropod, one odonate and one fish species (Table 2).

Fish

We detected a stable fish community in the river stretches mainly composed of native cyprinids (*Carasobarbus fritschii* and *Luciobarbus labiosa*) (Table 3). We failed to detect the presence of the trigger species *Cobitis maroccana* in any of the sampled sites (Table 3). However, we detected the presence of another threatened species (*Salaria atlantica* Doadrio, Perea & Yahyaoui, 2011) listed as VU B1ab(iii) (Williams et al., 2014) that had only been previously recorded in another disjunct Sebou tributary.

Molluscs

Bivalves: we confirmed the presence of a stable and recruiting small population of *Pseudunio marocanus* (assessed as *Margaritifera marocana* in the IUCN Red List). This is one of the two single recruiting populations of this species, turning this site extremely important for conservation.

Table 2. Species richness and threatened species richness in the Oued Bouhlou KBA. Green corresponds to native and red to non-native species (× no species found, — not sampled).

	Species richness					
Taxa	**SEB1**	**SEB2**	**SEB3**	**SEB4**	**SEB22**	**SEB23**
Fish	1	3	1	1	× (1)	×
Molluscs	5	5	3	1	1	5
Bivalves	3	3	×	×	×	1
Gastropods	2	2	3	1	1	4
Odonates	6	11	3	6	—	—
Crabs & Crayfish	1	1	×	×	×	×
Aq. plants	9	8	—	9	—	—
TOTAL	27	33	10	18	2 (1)	10
Macroinvertebrates						
Families	14	13	18	7	—	—
Shannon-Wiener diversity	0.77	1.83	2.02	0.68	—	—
	Threatened species richness					
Taxa	**SEB1**	**SEB2**	**SEB3**	**SEB4**	**SEB22**	**SEB23**
Fish	×	1	×	×	×	×
Molluscs	3	3	×	×	×	2
Bivalves	3	3	×	×	×	×
Gastropods	×	×	×	×	×	2
Odonates	×	1	1	×	—	—
Crabs & Crayfish	×	×	×	×	×	×
Aq. plants	1	1	—	×	—	—
TOTAL	6	6	1	0	0	2

Source: data collected by the authors.

Gastropods: We did not find any of the two trigger hydrobiid gastropod species. At the Bouhlou river, we mainly found good communities of four common species *Physella acuta* (assessed as *Haitia acuta* in the IUCN Red List), *Ancylus fluviatilis, Melanopsis praemorsa* and *Melanopsis cariosa* (Table 3). The native range of *Physella acuta* is contentious, and potentially includes the Western Mediterranean region (Vinarski, 2017). Until further research clarifies this, it is considered as native in Morocco. We found two additional records for threatened species at Aïn Fendel, the Vulnerable *Theodoxus numidicus* and the Endangered *Horatia* sp. nov. *'aghbalensis'*.

Odonates

The diversity of odonates was high, but no trigger species were detected in any of the sites, although the habitat conditions in SEB02 seem favourable for *Calopteryx exul*. In the past, this trigger species was found in SEB01. *Calopteryx virgo meridionalis* and *Pseudagrion sublacteum*, two Critically Endangered species for North Africa were present in SEB01. The Bouhlou river still has a good flowing section at SEB02 surrounded by a rather narrow band of gallery forest. Here we found *Onychogomphus costae*, an endemic species of Iberia and the Maghreb which is globally assessed as Near Threatened. *Gomphus simmilimus*, another dragonfly species typical from lentic water habitats with a semi-volatile life cycle, is still present, indicating a constant water flow of the river.

Aquatic plants

The sites surveyed within this KBA were all located along river channels and grade from a largely natural, fairly narrow, cobble-bed channel with no instream vegetation but with margins heavily dominated by *Nerium oleander*;

Table 3. Target and detected species presence and abundance with the IUCN Red List Category in the Oued Bouhlou KBA (× no species found, — not sampled, IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

TRIGGER SPECIES		IUCN Red List Category	ABUNDANCE					
			SEB1	SEB2	SEB3	SEB4	SEB22	SEB23
Fish	*Cobitis maroccana*	VU	×	✓*	×	×	×	×
Molluscs								
Gastropods	*Heideella knidirii*	EN	×	×	×	×	×	×
	Horatia sp. nov. *'haasei'*	EN	×	×	×	×	×	×
Odonates	*Calopteryx exul*	EN	×	×	1	×	—	—
	Cordulegaster princeps	LC	×	×	—	×	—	—
Aq. plants	*Plantago lacustris*	VU	500	10	—	×	—	—
NEWLY DETECTED SPECIES								
Fish			SEB1	SEB2	SEB3	SEB4	SEB22	SEB23
	Salaria atlantica	VU	×	1*	×	×	×	×
	Carasobarbus fritschii	LC	×	12*	×	×	×	×
	Gambusia holbrooki	LC	×	×	×	×	200	×
	Lepomis gibbosus	LC	×	✓*	×	×	×	×
	Luciobarbus labiosa	LC	40	45*	222	78	×	×
Molluscs			SEB1	SEB2	SEB3	SEB4	SEB22	SEB23
Bivalves	*Pseudunio marocanus*	CR	26	28*	×	×	×	×
	Unio foucauldianus	CR	4	8*	1	×	×	×
	Potomida littoralis	EN	36	32*	×	×	×	×
	Pisidium sp.		×	×	×	×	×	2
Gastropods	*Horatia* sp. nov. *'aghbalensis'*	EN	×	×	×	×	×	5
	Theodoxus numidicus	VU	×	×	×	×	×	38
	Ancylus fluviatilis	LC[4]	×	1	29	×	×	×
	Melanopsis praemorsa	LC	38	×	5	×	24	18
	Peregriana peregra[6]	LC	×	×	×	1	×	×
	Physella acuta[7]	LC	×	×	2	×	×	×
	Melanopsis cariosa	DD	65	118	×	×	×	×

Odonates			SEB1	SEB2	SEB3	SEB4	SEB22	SEB23
	Onychogomphus costae	NT	×	6	×	×	–	–
	Orthetrum nitidinerve	NT[3]	×	3	×	×	–	–
	Anax imperator	LC	×	1	×	×	–	–
	Brachythemis impartita	LC	×	×	4	×	–	–
	Calopteryx haemorrhoidalis	LC	30	22	×	20	–	–
	Calopteryx virgo	LC[1]	1	×	×	×	–	–
	Erythromma lindenii	LC	×	×	×	6	–	–
	Gomphus simillimus	LC[2]	×	1	4	1	–	–
	Onychogomphus forcipatus	LC	×	1	×	×	–	–
	Onychogomphus uncatus	LC	6	×	4	×	–	–
	Orthetrum chrysostigma	LC	×	1	×	1	–	–
	Orthetrum coerulescens	LC	4	2	×	×	–	–
	Paragomphus genei	LC	×	1	×	×	–	–
	Platycnemis subdilatata	LC	2	21	×	44	–	–
	Pseudagrion sublacteum	LC	2	×	×	×	–	–
	Trithemis annulata	LC	3	4	×	7	–	–
	Trithemis kirbyi	LC	×	3	×	4	–	–
Crabs & Crayfish			**SEB1**	**SEB2**	**SEB3**	**SEB4**	**SEB22**	**SEB23**
	Potamon algeriense	LC	4	2	×	×	×	×
Aq. plants			**SEB1**	**SEB2**	**SEB3**	**SEB4**	**SEB22**	**SEB23**
	Arundo donax	LC	40	3-5	–	45	–	–
	Cyperus longus	LC	×	≤1	–	1-3	–	–
	Equisetum ramosissimum	LC	×	×	–	≤1	–	–
	Juncus acutus	LC	×	×	–	≤1	–	–
	Nerium oleander	LC	×	1-3	–	20	–	–
	Plantago major intermedia	LC[5]	≤1	×	–	×	–	–
	Potamogeton nodosus	LC	×	✓[n]	–	1-3	–	–
	Typha domingensis	LC	×	1-3	–	1-3	–	–
	Populus nigra	DD	30	×	–	×	–	–
	Salix sp.		10	×	–	20	–	–
	Tamarix sp.		×	≤1	–	1-3	–	–

[1] CR in North Africa; [2] NT in North Africa; [3] LC in North Africa; [4] DD in North Africa; [5] assessed as *Plantago major*; [6] assessed as *Radix balthica* in the IUCN Red List; [7] assessed as *Haitia acuta* in the IUCN Red List; [n] not in sampled quadrat but detected in the area. * detected by the eDNA sampling.
Source: data compiled by the authors with categories from IUCN Red List.

through a medium-sized, heavily modified channel with a narrow floodplain and developing marginal vegetation; to a broad turbid channel flowing through a broad, fertile floodplain. The main plant species of conservation concern recorded was *Plantago lacustris* which was very abundant in and around irrigated fields at the downstream site and occasional at the mid-stream site. Apart from this species, no other notable plants species were recorded and the vegetation on the margins was generally highly modified and not worthy of note.

Plantago lacustris is listed as a trigger species in the KBA designation. Its continued presence was confirmed and a large population (potentially exceeding 500 individuals) found in irrigated fields at the downstream site surveyed. An additional smaller population was found in a seasonally inundated area of a field adjacent to the channel at the mid-stream site.

Macroinvertebrates

The sampled sites revealed diverse and healthy communities of macroinvertebrates, especially SEB2 and SEB3.

HABITAT

The river sites have been fairly modified by humans, mainly by the construction of weirs, channel networks in both margins, culverts and bridges. Nevertheless,

Table 4. Habitat parameters measured per site within the Oued Bouhlou KBA (— not sampled, values coloured red indicate negative results (high modification, low quality, low biodiversity, etc.), orange and yellow indicate average results, while green and blue indicates positive results (low modification, high quality, high biodiversity, etc.)).

	SCORES					
PARAMETERS	SEB1	SEB2	SEB3	SEB4	SEB22	SEB23
River Habitat Survey (RHS)						
Habitat Quality Assessment (HQA)	60	65	69	66	—	—
Habitat Modification Score (HMS)	590	20	1155	910	—	—
Macroinvertebrates						
Biotic index (IBMWP)	60	66	91	38	—	—
% of Individuals - EPT	4.97	21.31	41.12	9.52	—	—
Physical-Chemical						
Dissolved Oxygen	6.1	6.3	5.9	5.9	—	—
pH	10.47	10.77	10.4	5.98	—	—
Conductivity	526	426	239	382	—	—
Temperature	23.6	23.6	23.0	27.8	—	—

Source: data collected by the authors.

the river still has a good habitat quality, as revealed by the HQA index and macroinvertebrate biotic index (Table 4). Both springs are now heavily affected by human exploitation and should be protected from further modification. Physical-chemical parameters are within the normal range although the rivers seem to have distinct pH ranges.

THREATS

The river is heavily modified throughout, although the upstream section appears reasonably intact. It is affected by uncontrolled vehicle crossing when water levels are low. Elsewhere, there is evidence of flow diversion, dams, wastewater and solid waste disposal into the channel, as well as casual use for a variety of reasons. The river is therefore polluted and degraded throughout much of its length. The adjacent floodplain was characterized by irrigated fields which appeared to be in fairly good condition. Although heavily degraded, the river still has conservation value. It is threatened by uncontrolled pollution, hydrological modification and casual access of the sort which causes habitat degradation. Water extraction for agriculture is the main threat to river species and habitats. For the springs, an additional threat is the continuous modification for water extraction.

CONSERVATION GUIDANCE

It is crucial to maintain the environmental flow for the threatened species living in the lower sections of the river Bouhlou. The threatened bivalves occur in less than 20 cm of water during the summer and will be extirpated if water levels continue to decrease. These bivalves and fish were also found living in the adjacent irrigation channels that are not cleaned periodically. Therefore, campaigns to the local authorities and populations should instruct on how to manage the channels to avoid the destruction of threatened species habitat. All collected animals during the cleaning activities should be returned to the main channel. The high value of the lower section of the river should justify the extension of Tazekka natural park along the river down to its mouth. This river holds one of the best-recruiting populations of the freshwater mussel *Pseudunio marocanus* (assessed as *Margaritifera marocana* in the IUCN Red List) listed among the world's 100 most threatened species. For the springs, habitat restoration and protection should be the primary actions. Also, since it's a confined place, the eradication of the non-native mosquito-fish should be attempted. Most of the other factors causing degradation of the river are low-level and casual in occurrence, occurring more or less throughout the length of the river. It is difficult to see what action could be taken to control or reverse the impacts without a large-scale catchment management programme.

To increase our knowledge about the detected threatened species, measures should be put in place to:

1. Survey the full extent of the populations on the river.
2. Identify priority areas for its conservation.
3. Ensure continuation of the management which currently enables it to survive.

3.2 KBA: Oued Imouzzer Kandar

BACKGROUND

The Oued Imouzzer Kandar was mainly composed by an intermittent river network with many small wetlands and lakes (Figure 5). The KBA has a focal area in Dayat Aoua and Dayat Hachlaf. Except for a small section of the dam reservoir downstream of Dayat Hachlaf, both lakes are now dry.

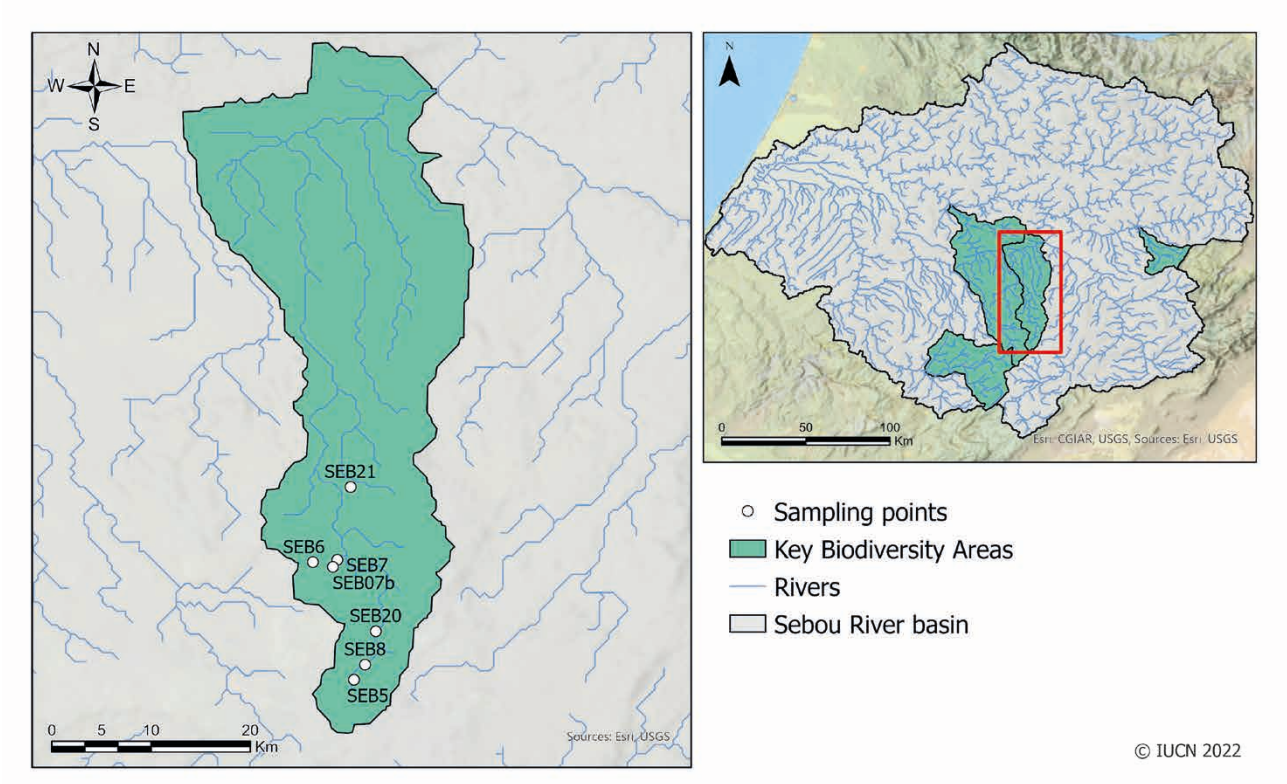


Figure 5. Map of the Oued Imouzzer Kandar KBA in green with the sampled sites as white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.

Dayat Aoua. © Ronaldo Sousa

Dayat Aoua. © Ronaldo Sousa

Dam with remnant water downstream of Lake Hachlaf. © Manuel Lopes-Lima

Local people reported that the water level in both lakes has decreased during the last decade and both lakes are completely dry at least since 2015. This may be attributed to the increased water extraction activities in the area, mainly for agriculture purposes.

SURVEY

We sampled the remnants of the two lakes and the surrounding wetlands for the taxa non-dependent on permanent waters, for the others we sampled a small outlet of a dam reservoir at the edge of Lake Hachlaf (Table 5).

DIVERSITY

None of the trigger and no threatened species were found in this KBA. The dam reservoir presented very poor biodiversity, with no fish. The reservoir outlet was channelized and hosted only a couple of fish species (one native and another non-native) and an improved macroinvertebrate community (compared to the reservoir). Only species that are not dependent on permanent water, such as plants, were considerably diverse. We also visited a spring (Aïn Sultan) within the KBA, that is all concreted, highly modified, and impacted by recreational activities. The diversity was very low, and no trigger species were detected.

Aïn Sultan. © Ronaldo Sousa

Table 5. Species richness and threatened species richness in the Oued Imouzzer Kandar KBA. Green corresponds to native and red to non-native species (× no species found, — not sampled).

	Species richness					
TAXA	**SEB5**	**SEB6**	**SEB7**	**SEB8**	**SEB20**	**SEB21**
Fish	×	×	×	×	1 (1)	×
Molluscs						
Bivalves	×	×	×	×	1	×
Gastropods	×	1	2	×	1	×
Odonates	×	1	3	—	3	×
Crabs & Crayfish	×	×	×	×	×	×
Aq. plants	18	10	21	—	—	—
Macroinvertebrates						
Families	×	×	×	×	19	×
Shannon-Wiener diversity	×	×	×	×	1.71	×
TOTAL	18	12	26	0	6	0
	Threatened species richness					
TAXA	**SEB5**	**SEB6**	**SEB7**	**SEB8**	**SEB20**	**SEB21**
Fish	×	×	×	×	×	×
Molluscs	×	×	×	×	×	×
Bivalves	×	×	×	×	×	×
Gastropods	×	×	×	×	×	×
Odonates	×	×	×	×	×	×
Crabs & Crayfish	×	×	×	×	×	×
Aq. plants	×	×	1*	×	×	×
TOTAL	0	0	0	0	0	0

* Near Threatened. **Source**: data collected by the authors.

Fish

We could only sample two sites with permanent water, i.e. SEB21 in the dam reservoir and the outlet. No fish were detected in the reservoir by both the traditional and the eDNA survey. We only detected two species in the small flowing channel outflowing from the dam, one common native species (*Luciobarbus labiosa*) and the non-native mosquito-fish (*Gambusia holbrooki*) (Table 6).

Molluscs

Almost no molluscs were found in the sampled sites. In the reservoir (SEB21) only a single common resilient species, *Physella acuta* (assessed as *Haitia acuta* in the IUCN Red List), was found in high densities and two other common species in remnant pools or channels surrounding the dry lakes (Table 6).

Odonates

Only two sites were sampled for adults within this KBA. Dayat Aoua (SEB06) was dry and thus with poor environmental conditions for dragonflies. Only a vagrant individual of *Sympetrum fonscolombii* was observed. At SEB07 some dragonflies could be seen, and at SEB20 three larvae were collected during the macroinvertebrate assessment. Altogether the diversity of odonates was low in this KBA (Table 6).

Aquatic plants

Two sites within this KBA were surveyed, both lakes which were dry except for small sumps or low- lying areas which remained wet. A side stream flowing into one of the lakes held fairly deep water where water backed up, upstream of a minor road crossing, to form a fairly extensive marsh. The vegetation of the main lakes was generally fairly sparse and heavily influenced by the length of time for which the lake had been dry. Thus, Dayat Hachlaf supported a mainly grassy sward with extensive bare ground and a combination of ruderals with plants more typical of seasonal wetlands. In contrast, Dayat Aoua had more recently held water and consequently, although some ruderals were beginning to germinate at the time of the survey, the drying mud was covered by a mat of drying charophytes, with abundant *Ranunculus peltatus*. The

Table 6. Target and detected species presence and abundance with the IUCN Red List Category in the Oued Imouzzer Kandar KBA (× no species found, — not sampled, IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

TRIGGER SPECIES		IUCN Red List Category	ABUNDANCE					
			SEB5	SEB6	SEB7	SEB8	SEB20	SEB21
Fish	*Cobitis maroccana*	VU	×	×	×	×	×	×
Molluscs								
Gastropods	*Horatia* sp. nov. *'haasei'*	EN	×	×	×	×	×	×
	Melanopsis scalaris	EN	×	×	×	×	×	×
	Theodoxus marteli	VU	×	×	×	×	×	×
	Theodoxus numidicus	VU	×	×	×	×	×	×
Odonates	*Calopteryx exul*	EN	×	×	×	×	×	×
	Cordulegaster princeps	LC	×	×	×	×	×	×
Aq. plants	*Plantago lacustris*	VU	×	×	×	×	×	×
NEWLY DETECTED SPECIES								
Fish			SEB5	SEB6	SEB7	SEB8	SEB20	SEB21
	Gambusia holbrooki	LC	×	×	×	×	5	×
	Luciobarbus labiosa	LC	×	×	×	×	22	×
Molluscs			SEB5	SEB6	SEB7	SEB8	SEB20	SEB21
Bivalves	*Pisidium casertanum*	LC	×	×	×	×	1	×
Gastropods	*Ancylus fluviatilis*	LC	×	1	29	×	×	×
	Physella acuta[4]	LC	×	×	2	×	134	×

Odonates		SEB5	SEB6	SEB7	SEB8	SEB20	SEB21
Coenagrion scitulum	LC[3]	×	×	1	–	×	×
Ischnura pumilio	LC	×	×	2	–	17	×
Orthetrum coerulescens	LC	×	×	×	–	11	×
Pyrrhosoma nymphula	LC[3]	×	×	×	–	2	×
Sympetrum fonscolombii	LC	×	1	1	–	×	×
Aq. plants		**SEB5**	**SEB6**	**SEB7**	**SEB8**	**SEB20**	**SEB21**
Juncus heterophyllus	NT	×	×	1-3	–	–	×
Agrostis stolonifera	LC	3-5	3-5	1-3	–	–	×
Botrydium granulatum	LC	×	✓	×	–	–	×
Chenopodium album	LC	1-3	×	×	–	–	×
Cyperus fuscus	LC	1-3	5	×	–	–	×
Eleocharis palustris	LC	×	3-5	×	–	–	×
Groenlandia densa	LC	×	×	1-3	–	–	×
Juncus articulatus	LC	3-5	✓	≤1	–	–	×
Juncus bufonius	LC	1	×	≤1	–	–	×
Lemna gibba	LC	✓	×	×	–	–	×
Lythrum junceum	LC	×	×	3-5	–	–	×
Mentha pulegium	LC	×	≤1	≤1	–	–	×
Mentha suaveolens	LC	×	×	1-3	–	–	×
Nasturtium microphyllum	LC	×	×	1-3	–	–	×
Nasturtium officinale	LC	≤1	×	×	–	–	×
Plantago major intermedia	LC[2]	×	≤1	×	–	–	×
Plantago major major	LC[2]	×	×	✓	–	–	×
Plantago maritima	LC	×	×	≤1	–	–	×
Poa annua	LC	40	×	×	–	–	×
Polygonum aviculare	LC	1-3	×	×	–	–	×
Polypogon monspeliensis	LC	×	×	1-3	–	–	×
Polypogon viridis	LC	×	×	✓	–	–	×
Ranunculus peltatus	LC	3-5	70	3-5	–	–	×
Ranunculus sceleratus	LC	≤1	×	×	–	–	×
Schoenoplectus litoralis	LC	×	×	✓	–	–	×
Sparganium erectum	LC	×	×	✓	–	–	×
Veronica catenata	LC	✓	×	3-5	–	–	×
Zannichellia palustris	LC	✓	✓	×	–	–	×
Apium repens	NE[1]	20	×	3-5	–	–	×
Chara aspera	NE	×	✓	×	–	–	×
Chara vulgaris	NE	×	×	75	–	–	×
Herniaria hirsuta	NE	≤1	×	×	–	–	×
Hypericum tomentosum	NE	×	×	≤1	–	–	×
Matricaria aurea	NE	≤1	×	×	–	–	×
Chara sp.		✓	×	×	–	–	×
Persicaria sp.		×	×	✓	–	–	×
Schoenoplectus sp.		✓	×	×	–	–	×

[1] VU in the Mediterranean; [2] assessed as *Plantago major*; [3] NT in North Africa; [4] assessed as *Haitia acuta* in the IUCN Red List. **Source**: data compiled by the authors with categories from IUCN Red List.

small water body off the Dayat Aoua showed a stark contrast to the two main lakes with almost 100% cover of wetland-dependent plant species, including a few notable taxa.

Plantago lacustris is listed as a trigger species in the KBA designation. This species was not found during surveys, but this cannot be taken to mean that it has been lost from the KBA. *Apium repens, Juncus heterophyllus* and *Nasturtium africanum* subsp. *mesatlanticum* were all found in the small water body off Dayat Aoua. Populations of all three species appeared healthy and serve as an indication of the potential species richness and diversity of the main lakes if the hydrology can be restored.

Macroinvertebrates

The sampled sites within and below the reservoir are completely distinct. Above the dam almost no species were present, but we detected diverse and healthy communities of macroinvertebrates in the stream outflowing from the reservoir.

HABITAT

Most of the riverine and lacustrine habitats have disappeared and only temporary wetland habitats remain during the wet season. Therefore, strict freshwater species have almost no available habitat.

The only remaining strip of permanent freshwater is the outflow of the reservoir dam which although it has been highly artificialized (Table 7), still presents considerable biodiversity of aquatic taxa.

THREATS

The two large lakes and associated wetlands are suffering from extreme drought, probably due to over-abstraction of water in the surrounding area. It is possible that if water levels were restored, many of the animal species may recolonize and plant species which formerly occurred would recover from the seed or spore-bank. However, the longer these sites suffer from low or no water, the less likely it becomes that they will be able to recover fully, and some species may already have been lost.

CONSERVATION GUIDANCE

An aquifer management plan needs to be developed and implemented to cover the catchment of the aquifer on which these lakes depend. This needs to be linked to an assessment of methods for the development of alternative water supplies, almost certainly including artificial reservoirs to enable a reduction of exploitation of groundwater. On a lower scale, the environmental flow from the outlet of the dam should be maintained, given that is the single refuge for many taxa in this region.

Table 7. Habitat parameters measured per site within the Oued Imouzzer Kandar KBA (— not sampled, values coloured red indicate negative results (high modification, low quality, low biodiversity, etc.), orange and yellow indicate average results, while green and blue indicates positive results (low modification, high quality, high biodiversity, etc.)).

	SCORES					
PARAMETERS	SEB5	SEB6	SEB7	SEB8	SEB20	SEB21
River Habitat Survey (RHS)						
Habitat Quality Assessment (HQA)	—	—	—	**50**	**47**	—
Habitat Modification Score (HMS)	—	—	—	**1130**	**1130**	—
Macroinvertebrates						
Biotic index (IBMWP)	—	—	—	—	**76**	—
% of Individuals - EPT	—	—	—	—	25.6	—
Physical-Chemical						
Dissolved Oxygen (mg/L)	—	—	—	9	9	—
pH	—	—	—	11.32	11.48	—
Conductivity (µS)	—	—	—	180	190	—
Temperature (°C)	—	—	—	23.0	23.4	—

Source: data collected by the authors.

3.3 KBA: Oued Tizguite and Oued Ouaslane

BACKGROUND

This KBA was designed mainly for river systems with a focal area in the upper reaches of two rivers Oued Tizguite and Oued Ouaslane (Figure 6).

SURVEY

Eight sites were surveyed for aquatic taxa on this KBA ranging from streams to associated wetlands.

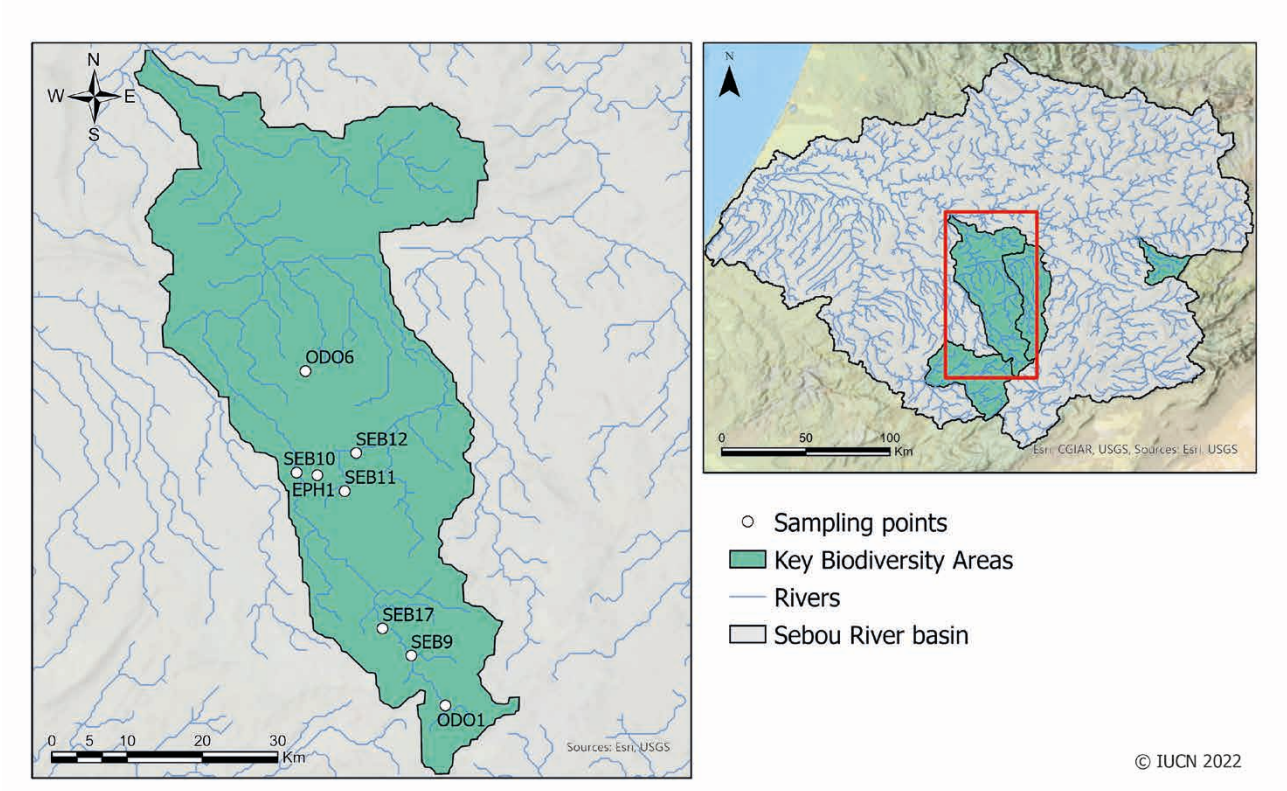


Figure 6. Map of the Oued Tizguite and Oued Ouaslane KBA in green with the sampled sites as white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.

Left: Oued Tizguite. Right: Oued Ouaslane. © Manuel Lopes-Lima and Ronaldo Sousa

One of the drinking sites (SEB12). © Ronaldo Sousa

Oued Ouaslane (SEB11). © Manuel Lopes-Lima

DIVERSITY

The fish and molluscs diversity were low throughout the area (Table 8). None of the trigger species was detected with only a single threatened species of plant being recorded (Table 8).

Fish

A fish community was detected that was poor in diversity and composed mainly of non-native species, including *Gobio gobio*, a species reported for the first time for North Africa. The common rudd *Scardinius erythrophthalmus*, a native barbel species, was also detected (Table 9).

Table 8. Species richness and threatened species richness in the Oued Tizguite and Oued Ouaslane KBA. Green corresponds to native and red to non-native species (× no species found, — not sampled).

	Species richness							
TAXA	**SEB9**	**SEB10**	**SEB11**	**SEB12**	**SEB17**	**ODO1**	**ODO6**	**EPH1**
Fish	(2)	×	1 (1)	×	×	×	×	×
Molluscs								
Bivalves	1	×	×	×	1	×	×	×
Gastropods	1	×	3	2	1	×	×	×
Odonates	×	3	4	7	1	7	9	5
Crabs & Crayfish	(1)	×	×	×	×	×	×	×
Aq. plants	—	—	11	9	—	—	15	12
Macroinvertebrates								
Families	10	—	19	19	19	—	—	—
Shannon-Wiener diversity	0.84	×	1.34	1.45	1.73	×	—	—
TOTAL	2 (3)	3	18 (1)	18	3	7	2423	17
	Threatened species richness							
TAXA	**SEB9**	**SEB10**	**SEB11**	**SEB12**	**SEB17**	**ODO1**	**ODO6**	**EPH1**
Fish	(1)	×	×	×	×	×	×	×
Molluscs	×	×	×	×	×	×	×	×
Bivalves	×	×	×	×	×	×	×	×
Gastropods	×	×	×	×	×	×	×	×
Odonates	×	×	×	×	×	×	×	×
Crabs & Crayfish	×	×	×	×	×	×	×	×
Aq. plants	×	×	×	1	×	×	1	1
TOTAL	(1)	0	0	1	0	0	1	1

Source: data collected by the authors.

Molluscs

No molluscan trigger species were detected. Very low mollusc diversity throughout the sites with common bivalves and gastropods being detected in high abundance in Dayat Aguemguem and Oued Tizguit (Table 9).

Odonates

One lentic and five lotic sites were surveyed for dragonflies. No trigger species were detected. The temporary pool (EPH001) was colonised with *Ischnura pumilio*, *Lestes barbarus*, *Sympecma fusca* and *Sympetrum meridionale*, the typical species associated with such shallow pools. It is possible that a survey earlier in the season might reveal the presence of *Lestes dryas*, assessed as Vulnerable for North Africa. The other sites were all flowing rivers. The species assemblage of dragonflies is here dominated by species able to tolerate a wide range of environments (eurytopic) and species typical for lentic waters. Only the more common riverine species such as *Calopteryx haemorrhoidalis* and *Platycnmeis subdilatata* were present (Table 9).

Aquatic plants

A wide range of sites was visited within this KBA. These ranged from a spring which although modified still held some aquatic and wetland plants flowing in, to a medium-sized stream almost devoid of vegetation due to over-watering and trampling by stock, to a small stream flowing through arable fields and orchards, to a large shallow depression dominated by *Bolboschoenus* sp. and other monocots but also supporting large populations of plants typical of seasonal wetlands, including *Damasonium bourgaei, D. polyspermum* and *Elatine macropoda*.

Table 9. Target and detected species presence and abundance with the IUCN Red List Category in the Oued Tizguite and Oued Ouaslane KBA (× no species found, — not sampled, IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

TRIGGER SPECIES		IUCN Red List Category	ABUNDANCE							
			SEB9	SEB10	SEB11	SEB12	SEB17	ODO1	ODO6	EPH1
Fish	*Cobitis maroccana*	VU	×	×	×	×	×	—	×	×
Molluscs										
Gastropods	*Giustia midarensis*	EN	×	×	×	×	×	—	×	×
	Heideella knidirii	EN	×	×	×	×	×	—	×	×
	Horatia sp. nov. *'aghbalensis'*	EN	×	×	×	×	×	—	×	×
Odonates	*Calopteryx exul*	EN	×	×	×	×	×	×	×	×
NEWLY DETECTED SPECIES										
Fish			SEB9	SEB10	SEB11	SEB12	SEB17	ODO1	ODO6	EPH1
	Gobio gobio[A]	LC	20	×	×	×	×	—	×	×
	Luciobarbus labiosa	LC	×	×	100	×	×	—	×	×
	Scardinius erythrophthalmus[A]	LC	5	×	×	×	×	—	×	×
	Oncorhynchus mykiss[A]	NE	×	×	3	×	×	—	×	×
Molluscs			SEB9	SEB10	SEB11	SEB12	SEB17	ODO1	ODO6	EPH1
Bivalves	*Pisidium casertanum*	LC	1	×	×	×	52	×	×	×
Gastropods	*Ancylus fluviatilis*	LC	×	×	20	×	×	×	×	×
	Peregriana peregra[4]	LC	×	×	4	7	×	×	×	×
	Physella acuta[5]	LC	×	×	309	×	845	×	×	×
	Theodoxus maresi	DD	×	×	×	42	×	×	×	×
	Bythiniidae sp.		5	×	×	×	×	×	×	×
Odonates			SEB9	SEB10	SEB11	SEB12	SEB17	ODO1	ODO6	EPH1
	Orthetrum nitidinerve	NT[1]	×	×	2	×	×	3	2	×
	Anax imperator	LC	×	×	1	×	×	3	×	×
	Calopteryx haemorrhoidalis	LC	×	×	×	8	×	1	1	×
	Coenagrion caerulescens	LC	×	×	×	×	×	1	×	×
	Coenagrion scitulum	LC[3]	×	×	×	×	×	×	2	×
	Crocothemis erythraea	LC	×	1	5	3	×	×	1	×
	Erythromma lindenii	LC	×	×	3	3	×	2	1	×
	Ischnura graellsii	LC	×	1	×	×	×	×	1	×
	Ischnura pumilio	LC	×	×	×	×	6	×	1	+1000
	Lestes barbarous	LC	×	1	×	×	×	×	×	1
	Orthetrum chrysostigma	LC	×	×	×	×	×	×	3	×
	Orthetrum coerulescens	LC	×	×	×	1	×	6	2	×
	Platycnemis subdilatata	LC	×	×	×	7	×	×	×	×
	Pyrrhosoma nymphula	LC[3]	×	×	×	×	×	×	2	×
	Sympecma fusca	LC	×	×	×	×	×	×	×	11
	Sympetrum fonscolombii	LC	×	×	×	×	×	1	×	×
	Sympetrum meridionale	LC	×	×	×	×	×	×	×	101
	Sympetrum striolatum	LC	×	×	×	×	×	×	×	2
	Trithemis annulata	LC	×	×	×	11	×	×	×	×
	Trithemis kirbyi	LC	×	×	×	5	×	×	×	×

Crabs & Crayfish			SEB9	SEB10	SEB11	SEB12	SEB17	ODO1	ODO6	EPH1
	Astacus astacus[A]	VU	17	×	×	×	×	–	×	×
Aq. Plants			**SEB9**	**SEB10**	**SEB11**	**SEB12**	**SEB17**	**ODO1**	**ODO6**	**EPH1**
	Scrophularia eriocalyx	EN	–	–	×	1-3	–	–	5	×
	Damasonium polyspermum	VU	–	–	×	×	–	–	×	3-5
	Agrostis stolonifera	LC	–	–	1-3	×	–	–	1-3	×
	Alisma plantago-aquatica	LC	–	–	×	×	–	–	×	✓
	Alopecurus aequalis	LC	–	–	×	×	–	–	×	≤1
	Apium nodiflorum	LC	–	–	≤1	×	–	–	×	×
	Arundo donax	LC	–	–	×	×	–	–	×	×
	Cyperus fuscus	LC	–	–	×	3-5	–	–	×	×
	Cyperus longus	LC	–	–	×	×	–	–	15	×
	Damasonium bourgaei	LC	–	–	×	×	–	–	×	3-5
	Elatine macropoda	LC	–	–	×	×	–	–	×	1-3
	Eleocharis palustris	LC	–	–	×	×	–	–	×	50
	Juncus acutus	LC	–	–	×	≤1	–	–	×	×
	Juncus bufonius	LC	–	–	×	×	–	–	1-3	×
	Lemna gibba	LC	–	–	30	×	–	–	×	×
	Lythrum junceum	LC	–	–	×	×	–	–	5	×
	Mentha pulegium	LC	–	–	×	×	–	–	×	✓
	Mentha suaveolens	LC	–	–	×	≤1	–	–	10	×
	Nasturtium officinale	LC	–	–	1-3	×	–	–	×	×
	Nerium oleander	LC	–	–	×	≤1	–	–	×	×
	Plantago major	LC	–	–	×	×	–	–	≤1	×
	Polypogon monspeliensis	LC	–	–	×	×	–	–	1-3	10
	Polypogon viridis	LC	–	–	×	×	–	–	3-5	×
	Pulicaria arabica	LC	–	–	×	×	–	–	1-3	×
	Ranunculus penicillatus pseudofluitans	LC[2]	–	–	3-5	×	–	–	×	×
	Schoenoplectus lacustris	LC	–	–	×	×	–	–	×	✓
	Trifolium resupinatum	LC	–	–	×	×	–	–	×	3-5
	Veronica catenata	LC	–	–	≤1	×	–	–	≤1	×
	Zannichellia palustris	LC	–	–	1-3	×	–	–	×	×
	Glyceria spicata	DD	–	–	×	×	–	–	×	≤1
	Bolboschoenus planiculmis	NE	–	–	×	×	–	–	×	1-3
	Cladophora glomerata	NE	–	–	20	×	–	–	×	×
	Dorycnium rectum	NE	–	–	×	≤1	–	–	×	×
	Hildenbrandia rivularis	NE	–	–	×	1-3	–	–	×	×
	Holoschoenus vulgaris	NE	–	–	×	1-3	–	–	15	×
	Hypericum tomentosum	NE	–	–	×	≤1	–	–	×	×
	Sium latifoium	NE	–	–	×	×	–	–	3-5	×
	Bacillariophyceae sp.		–	–	40	×	–	–	×	×
	Cinclidotus sp.		–	–	1-3	×	–	–	×	×
	Glyceria sp.		–	–	≤1	×	–	–	×	×
	Juncus sp.		–	–	×	×	–	–	25	×
	Poa sp.		–	–	×	×	–	–	≤1	×

[A] Non-native species; [1]LC in North Africa; [2]as *Ranunculus penicillatus*; [3]NT in North Africa; [4]assessed as *Radix balthica* in the IUCN Red List; [5]assessed as *Haitia acuta* in the IUCN Red List. **Source**: data compiled by the authors with categories from IUCN Red List.

Large populations of *Damasonium polyspermum* and *Elatine macropoda* occurred throughout much of the large depression. It is possible that a survey of this water body at different stages of inundation would reveal more notable plant species (Table 9).

Macroinvertebrates

Macroinvertebrate communities were more diverse in Dayat Aguemguem and lower sections of the Oued Tizguit (Table 10).

HABITAT

The KBA is composed of networks of streams and rivers, and associated springs and wetlands around the city of Ifrane. Most of the river network is heavily modified and impacted by humans, as reflected in the human modification scores (HMS) of the River habitat surveys (Table 10).

THREATS

The region is highly impacted by increasing water shortage due to the increase of water demanding agriculture practices. This KBA occurs in a touristic area and many streams are highly disturbed by recreational activities and non-native species. The red swamp crayfish *Procambarus clarkii* and the noble crayfish *Astacus astacus* have been actively introduced by the authorities and are very abundant, mainly in Oued Tizguite. These species may threaten the native aquatic fauna and flora since they are omnivorous and opportunistic. Fish communities are also mainly composed of non-native species, like *Gobio gobio* and *Scardinius erythrophthalmus*.

Most of the sites surveyed within this KBA were higly degraded, some situated in an arable context were subject to nutrient inputs and over-exploitation of surface-water. The spring and associated river were not only disturbed by cattle trampling, but the spring itself had been extensively modified to facilitate access to people. In contrast, even though it was clearly heavily grazed, the large seasonal wetland appeared to largely retain its hydrological function, there was no evidence of pollution and grazing levels appeared to be appropriate for the habitat.

CONSERVATION GUIDANCE

The spring system near Ifrane needs a more effective protection. Recreation activities should be reduced and a strong control of the activities within the area is necessary. The control of non-native species and stopping the re-stocking of crayfish species are also measures that should be implemented to conserve the native diversity.

The rivers and streams are not the most important parts of the KBA for plant conservation. The low-lying basin merits action to ensure that its hydrological function is not compromised and that aspects such as grazing and other uses are not allowed to damage the site.

Table 10. Macroinvertebrate diversity metrics and habitat parameters measured per site in the Oued Tizguite and Oued Ouaslane KBA (— not sampled, values coloured red indicate negative results (high modification, low quality, low biodiversity, etc.), orange and yellow indicate average results, while green and blue indicates positive results (low modification, high quality, high biodiversity, etc.)).

	SCORES							
PARAMETERS	SEB9	SEB10	SEB11	SEB12	SEB17	ODO1	ODO6	EPH1
River Habitat Survey (RHS)								
Habitat Quality Assessment (HQA)	79	—	54	22	65	—	—	—
Habitat Modification Score (HMS)	685	—	2565	2140	780	—	—	—
Macroinvertebrates								
Biotic index (IBMWP)	31	—	72	89	70	—	—	—
% of Individuals - EPT	18	—	60.7	31.6	13	—	—	—
Physical-Chemical								
Dissolved Oxygen (mg/L)	4.47	—	6.51	3.09	4.25	—	—	—
pH	9.09	—	7.42	7.34	8.35	—	—	—
Conductivity (µS)	295	—	310	312	328	—	—	—
Temperature (°C)	16.5	—	16.6	16.8	21.47	—	—	—

Source: data collected by the authors.

3.4 KBA: Oued Tigrigra

BACKGROUND

This KBA is located around the river Tigrigra and associated wetlands and springs with a focal area in Aghbal spring in the city of Azrou (Figure 7).

SURVEY

Eight sites were surveyed for aquatic taxa on this KBA (Fig. 7), five in the Oued Tigrigra, one in Aghbal spring and the other in Dayat Afnounir.

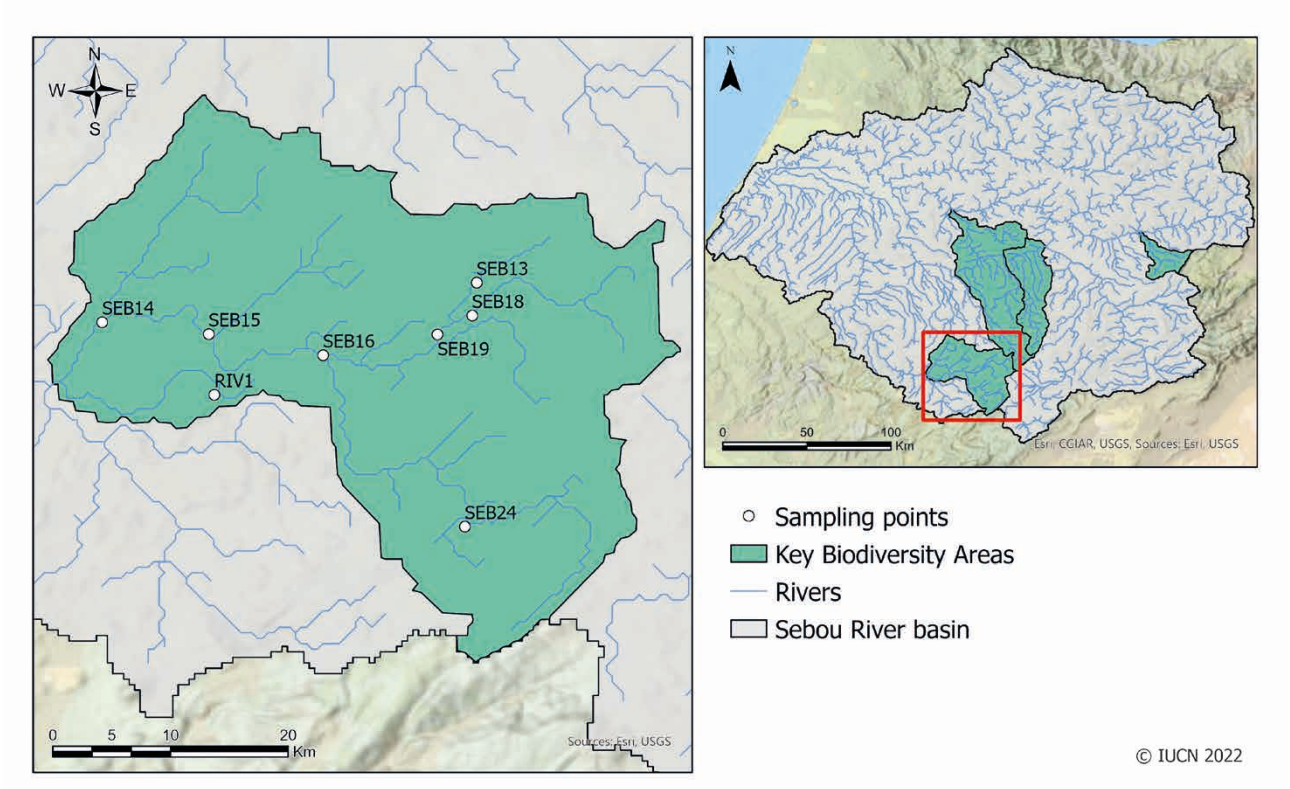


Figure 7. Map of the Oued Tigrigra KBA in green with the sampled sites as white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.

Left: Oued Tigrigra. Right: Oued Tigrigra (SEB15). © Manuel Lopes-Lima

Aïn Aghbal. © Ronaldo Sousa

DIVERSITY

We only detected the presence of a single trigger species, i.e. the odonate species *Calopteryx exul* in one site, but we detected diverse communities of molluscs, fish, plants and macroinvertebrates including several threatened taxa not previously reported for the KBA (Table 11). The river sites presented a high diversity, especially those in the middle and lower sections (Table 11).

Fish

The river stretching further away from the city is in better ecological condition with stable fish communities composed of native cyprinids. Two non-native species were detected for this river system, *Gobio gobio* and the highly invasive pumpkinseed *Lepomis gibbosus*. The trigger species *Cobitis maroccana* was not detected (Table 12).

Sampling in Oued Tigrigra. © Ronaldo Sousa

Molluscs

The target hydrobiid gastropods were not found in Aghbal spring, but a high diversity and the threatened *Melanopsis scalaris* were detected in the lower section of Oued Tigrigra (Table 12). As for the bivalve species, *Unio durieui* was originally included in the KBA as a trigger species, but this species has been erroneously included in the KBA, since it only occurs in Tunisia and probably eastern Algeria. It must have been confused with the congeneric species *Unio foucauldianus* which is also a Critically Endangered species. In the lower sections of the Tigrigra we detected *Unio foucauldianus* (Table 12).

Odonates

All investigated rivers still have a good association of dragonfly species that prefer to live in fast-moving water (rheophile) (Table 12). The larvae of some species have a semivoltine life-cycle, indicating the

Sampling in Oued Tigrigra. © Ronaldo Sousa

Table 11. Species richness and threatened species richness in the Oued Tigrigra KBA. Green corresponds to native and red to non-native species (× no species found, — not sampled).

	Species richness							
TAXA	**SEB13**	**SEB14**	**SEB15**	**SEB16**	**SEB18**	**SEB19**	**SEB24**	**RIV1**
Fish	×	1 (1)	2	1 (2)	×	1	×	×
Molluscs	×	×	×	×	×	×	×	×
Bivalves	×	2	1	1	1	1	×	×
Gastropods	×	6	2	1	2	3	3	×
Odonates	6	×	8	4	×	1	13	12
Crabs & Crayfish	×	×	1	1	×	×	×	×
Aq. plants	13	—	13	—	—	—	23	16
Macroinvertebrates								
Families	×	14	22	25	10	20	14	×
Shannon-Wiener diversity	×	1.5	1.58	2.1	0.33	2.15	1.87	×
TOTAL	6	9 (1)	27	8 (2)	3	6	39	28
	Threatened species richness							
TAXA	**SEB13**	**SEB14**	**SEB15**	**SEB16**	**SEB18**	**SEB19**	**SEB24**	**RIV1**
Fish	(1)	×	×	×	×	×	×	×
Molluscs								
Bivalves	×	1	1	×	×	×	×	×
Gastropods	×	1	×	×	×	×	×	×
Odonates	×	×	×	1	×	1	×	1
Crabs & Crayfish	×	×	×	×	×	×	×	×
Aq. plants	1	×	×	×	×	×	3	1
TOTAL	1 (1)	2	1	1	×	1	3	2

Source: data collected by the authors.

presence of permanent water. Species typical for pools and ponds were also absent in these lotic sites, another good indication of the good habitat quality of the rivers. *Calopteryx virgo meridionalis* (Critically Endangered for North Africa) occurs at one site (SEB15) and *Coenagrion mercuriale* (Endangered for North Africa) was present at two sites. Thirteen individuals of the trigger species *Calopteryx exul* (Endangered) were found at one site. Until the mid-nineties, this species still had a population at site SEB13. Given the habitat characteristics of the river Tigrigra at site SEB15, we still expect this trigger species to be present here, but unfortunately we arrived too late on the day to undertake a proper survey.

The one lentic pond (SEB24) we surveyed had a diverse and rich dragonfly fauna with very high numbers of *Enallagma deserti*, an endemic species of the Maghreb.

Aquatic plants

Four sites were surveyed within this catchment for aquatic plants, two of these were small streams,

Table 12. Target and detected species presence and abundance with the IUCN Red List Category in the Oued Tigrigra KBA (× no species found, — not sampled, IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

TRIGGER SPECIES		IUCN Red List Category	ABUNDANCE							
			SEB13	SEB14	SEB15	SEB16	SEB18	SEB19	SEB24	RIV1
Fish	*Cobitis maroccana*	VU	×	×	×	×	×	×	×	×
Molluscs										
Bivalves	*Unio durieui*	EN	×	×	×	×	×	×	×	×
Gastropods	*Horatia* sp. nov. *'aghbalensis'*	EN	×	×	×	×	×	×	×	×
	Melanopsis scalaris	EN	×	×	×	×	×	×	×	×
	Theodoxus numidicus	VU	×	×	×	×	×	×	×	×
	Melanopsis arbalensis	DD	×	×	×	×	×	×	×	×
Odonates	*Calopteryx exul*	EN	×	×	×	13	×	×	×	×
	Cordulegaster princeps	LC	×	×	×	×	×	×	×	×
Aq. plants	*Lepidium violaceum*	VU	×	—	×	—	—	—	×	×
NEWLY DETECTED SPECIES										
Fish			SEB13	SEB14	SEB15	SEB16	SEB18	SEB19	SEB24	RIV1
	Carasobarbus fritschii	LC	×	×	2	×	×	×	×	×
	Gobio gobio[A]	LC	×	×	×	10	×	×	×	×
	Lepomis gibbosus[A]	LC	×	50	×	×	×	×	×	×
	Luciobarbus labiosa	LC	×	27	148	16	×	34	×	×
	Scardinius erythrophthalmus[A]	LC	×	×	×	3	×	×	×	×
Molluscs			SEB13	SEB14	SEB15	SEB16	SEB18	SEB19	SEB24	RIV1
Bivalves	*Unio foucauldianus*	CR	×	25	32	×	×	×	×	×
	Pisidium casertanum	LC	×	450	×	1	2	5	×	×
Gastropods	*Melanopsis scalaris*	EN	×	50	×	×	×	×	×	×
	Ancylus fluviatilis	LC	×	1	×	×	×	8	×	×
	Peregriana peregra[6]	LC	×	89	×	×	1	1	3	×
	Physella acuta[7]	LC	×	211	10	×	×	111	66	×
	Physa fontinalis	LC	×	199	×	×	×	×	×	×
	Planorbarius metidjensis	NE	×	363	×	×	1	×	206	×
	Melanopsis sp.		×	×	29	21	×	×	×	×

Odonates		SEB13	SEB14	SEB15	SEB16	SEB18	SEB19	SEB24	RIV1
Calopteryx exul	EN	×	×	×	13	×	×	×	×
Coenagrion mercuriale	NT[2]	×	×	×	×	×	1	×	5
Orthetrum nitidinerve	NT[5]	×	×	×	×	×	×	×	1
Anax imperator	LC	×	×	×	×	×	×	2	×
Anax parthenope	LC	×	×	×	×	×	×	1	1
Brachythemis impartita	LC	×	×	2	×	×	×	×	×
Calopteryx haemorrhoidalis	LC	7	×	20	×	×	×	×	18
Calopteryx virgo	LC[1]	×	×	1	×	×	×	×	×
Chalcolestes viridis	LC	3	×	×	×	×	×	×	×
Coenagrion puella	LC	×	×	1	×	×	×	×	×
Coenagrion scitulum	LC[4]	×	×	×	×	×	×	11	×
Crocothemis erythraea	LC	×	×	×	×	×	×	×	4
Enallagma cyathigerum	LC	×	×	×	×	×	×	1	×
Enallagma deserti	LC	×	×	×	×	×	×	+1000	×
Erythromma lindenii	LC	×	×	×	×	×	×	1	+100
Gomphus simillimus	LC[4]	×	×	1	×	×	×	×	×
Ischnura graellsii	LC	2	×	×	×	×	×	1	×
Ischnura pumilio	LC	×	×	×	×	×	×	1	×
Lestes barbarus	LC	×	×	×	×	×	×	2	×
Libellula quadrimaculata	LC[3]	×	×	×	×	×	×	4	×
Onychogomphus forcipatus	LC	2	×	1	×	×	×	×	×
Orthetrum cancellatum	LC	×	×	×	×	×	×	45	×
Orthetrum coerulescens	LC	1	×	1	×	×	×	×	35
Platycnemis subdilatata	LC	5	×	12	8	×	×	1	×
Sympetrum fonscolombii	LC	×	×	×	×	×	×	+130	×
Sympetrum striolatum	LC	×	×	×	×	×	×	38	×
Trithemis annulata	LC	×	×	×	×	×	×	×	3
Anax sp.		×	×	×	4	×	×	×	×
Orthetrum sp.		×	×	×	1	×	×	×	×
Crabs & Crayfish		**SEB13**	**SEB14**	**SEB15**	**SEB16**	**SEB18**	**SEB19**	**SEB24**	**RIV1**
Potamon algeriense	LC	×	×	1	1	×	–	×	×
Aq. Plants		**SEB13**	**SEB14**	**SEB15**	**SEB16**	**SEB18**	**SEB19**	**SEB24**	**RIV1**
Scrophularia eriocalyx	EN	≤1	–	–	–	–	–	–	≤1
Apium repens	VU	–	–	–	–	–	–	1-3	×
Damasonium polyspermum	VU	–	–	–	–	–	–	✓	×
Rorippa hayanica	VU	–	–	–	–	–	–	✓	×
Agrostis stolonifera	LC	–	–	–	–	–	–	5	×
Antinoria agrostidea	LC	–	–	–	–	–	–	✓	×
Apium nodiflorum	LC	≤1	–	≤1	–	–	–	–	≤1
Arundo donax	LC	–	–	≤1	–	–	–	–	3-5
Callitriche truncata	LC	–	–	–	–	–	–	3-5	×
Carex acuta	LC	–	–	≤1	–	–	–	–	×
Cyperus longus	LC	3-5	–	1-3	–	–	–	–	3-5
Cyperus rotundus	LC	–	–	1-3	–	–	–	–	×

Damasonium bourgaei	**LC**	–	–	–	–	–	–	✓	×
Elatine macropoda	**LC**	–	–	–	–	–	–	1-3	×
Eleocharis acicularis	**LC**	–	–	–	–	–	–	30	×
Eleocharis palustris	**LC**	–	–	–	–	–	–	25	×
Epilobium hirsutum	**LC**	–	–	–	–	–	–	–	≤1
Isoetes velata	**LC**	–	–	–	–	–	–	✓	×
Juncus articulatus	**LC**	✓	–	–	–	–	–	–	≤1
Juncus bufonius	**LC**	–	–	–	–	–	–	✓	×
Juncus inflexus	**LC**	3-5	–	–	–	–	–	–	×
Lemna gibba	**LC**	✓	–	–	–	–	–	–	×
Lythrum borysthenicum	**LC**	–	–	–	–	–	–	≤1	×
Lythrum junceum	**LC**	–	–	–	–	–	–	–	≤1
Mentha pulegium	**LC**	≤1	–	✓	–	–	–	1-3	≤1
Mentha suaveolens	**LC**	✓	–	≤1	–	–	–	–	13
Myriophyllum spicatum	**LC**	–	–	–	–	–	–	≤1	×
Nasturtium officinale	**LC**	1-3	–	–	–	–	–	–	×
Nerium oleander	**LC**	–	–	3-5	–	–	–	–	×
Persicaria maculosa	**LC**	–	–	≤1	–	–	–	–	×
Polypogon monspeliensis	**LC**	✓	–	✓	–	–	–	–	≤1
Potamogeton pusillus	**LC**	–	–	–	–	–	–	≤1	×
Potamogeton trichoides	**LC**	–	–	–	–	–	–	3-5	×
Pulicaria arabica	**LC**	–	–	✓	–	–	–	–	×
Ranunculus lateriflorus	**LC**	–	–	–	–	–	–	✓	×
Ranunculus peltatus	**LC**	1-3	–	–	–	–	–	–	✓
Schoenoplectus litoralis	**LC**	–	–	–	–	–	–	–	60
Stuckenia pectinata	**LC**	–	–	–	–	–	–	10	×
Typha domingensis	**LC**	–	–	–	–	–	–	–	20
Veronica catenata	**LC**	3-5	–	–	–	–	–	–	1-3
Zannichellia palustris	**LC**	–	–	–	–	–	–	20	×
Chara vulgaris	**NE**	–	–	–	–	–	–	–	✓
Holoschoenus vulgaris	**NE**	–	–	–	–	–	–	–	3-5
Rumex pulcher	**NE**	–	–	✓	–	–	–	–	×
Sium latifoium	**NE**	35	–	–	–	–	–	–	×
Spergularia rubra	**NE**	–	–	✓	–	–	–	–	×
Chara sp.		–	–	–	–	–	–	5	×
Crypsis sp.		–	–	–	–	–	–	✓	×
Nostoc sp.		–	–	–	–	–	–	3-5	×

[A]Non-native species; [1]CR in North Africa; [2]EN in North Africa; [3]VU in North Africa; [4]NT in North Africa; [5]LC in North Africa; [6]assessed as *Radix balthica* in the IUCN Red List; [7]assessed as *Haitia acuta* in the IUCN Red List. **Source**: data compiled by the authors with categories from IUCN Red List.

a little degraded through casual use due to their proximity to settlements and probably never of high conservation value for plants. The third site is a large upland lake on the plateau between Azrou and Timahdit. Only a relatively small part of the lake was surveyed, involving a peninsula extending a short way into the lake and a small seasonal wetland cut off from the main lake by a minor road. Both of these areas are of exceptional value for conservation of wetland plants. Not only do they support a wide range of nationally and globally threatened species, but the vegetation structure is remarkable, with multiple

canopies of different plant species throughout the inundated and marginal areas.

Lepidium violaceum is listed in the KBA designation. This species was not found during surveys. Globally or nationally notable plant species recorded at Aguelmam Affenourir were: *Apium repens, Callitriche mathezii, Callitriche truncata* subsp. *truncata, Juncus heterophyllus, Damasonium polyspermum, Ranunculus lateriflorus, Rorippa hyanica* and *Potamogeton trichoides*. It is likely that a comprehensive survey of the site by Moroccan botanists would locate more notable species.

HABITAT

Aghbal spring is composed of sandy substrate, but it has been concreted a few meters after the spring with a small dam. The remaining KBA is mainly composed by a river network with good habitat for river species. The sites near Azrou are polluted and highly modified but it improves considerably downstream. Near Azrou, the streams are also degraded and modified by transport corridors.

THREATS

The river network is being heavily affected by water extraction for agriculture purposes and by pollution by the city of Azrou. Since the spring is a major point of attraction for the local community, it is being threatened by recreational activities.

CONSERVATION GUIDANCE

The Oued Tigrigra is still in good ecological condition, but is suffering a fast transformation. The Aghbal spring is being gradually transformed and the water level on Lake Affenourir is decreasing. Only two of the nine target species were found, but another eight threatened species were found. Therefore, the KBA seems appropriate but needs to change target taxa. A management plan for the water extraction should be implemented in this area. Protection of Aghbal and the surrounding springs and wastewater treatment plants are urgently needed to reduce the impact on the river network.

Aguelmam Affenourir should be separated from the Tigrigra Stream KBA for the purposes of conservation and allied with the other lakes on the plateau between Azrou and Timahdit. This plateau should be surveyed in more detail to document the range and extent of habitats of conservation value for wetland plants. The reasons for variation in the condition of different lakes and small pool complexes should be investigated and threats to the lakes identified. The entire plateau needs to be treated as a single management unit for the purposes of conservation of wetland-dependent plants.

Table 13. Habitat parameters measured per site in the Oued Tigrigra KBA (— not sampled, values coloured red indicate negative results (high modification, low quality, low biodiversity, etc.), orange and yellow indicate average results, while green and blue indicates positive results (low modification, high quality, high biodiversity, etc.)).

	SCORES							
PARAMETERS	SEB13	SEB14	SEB15	SEB16	SEB18	SEB19	SEB24	RIV1
River Habitat Survey (RHS)								
Habitat Quality Assessment (HQA)	—	60	71	60	—	64	—	—
Habitat Modification Score (HMS)	—	50	0	470	—	125	—	—
Macroinvertebrates								
Biotic index (IBMWP)	—	53	128	121	40	78	49	—
% of Individuals - EPT	—	1.66	66.08	57.66	2.03	42.57	13.76	—
Physical-Chemical								
Dissolved Oxygen (mg/L)	—	5.2	5.6	5.7	9.46	6.07	7.6	—
pH	—	9.99	9.74	9.9	9.3	10.2	10.3	—
Conductivity (µS)	—	461	514	502	503	495	238.2	—
Temperature (°C)	—	24	25	25	14	17.4	25.6	—

Source: data collected by the authors.

4 Freshwater biodiversity in additional sites

4.1 Aguelmam n'Tifounassine/Sidi Ali

BACKGROUND

It is composed by a complex of mountain wetlands from the upper Guigou river, Sebou basin.

We sampled 2 permanent shallow lakes (Aguelmam Sidi Ali and Aguelmam Tifounassine) that are important areas for birds. The lakes have been drying since the early 1900s and hosted an important endemic fish (*Salmo pallaryi*), that is currently extinct (Figure 8).

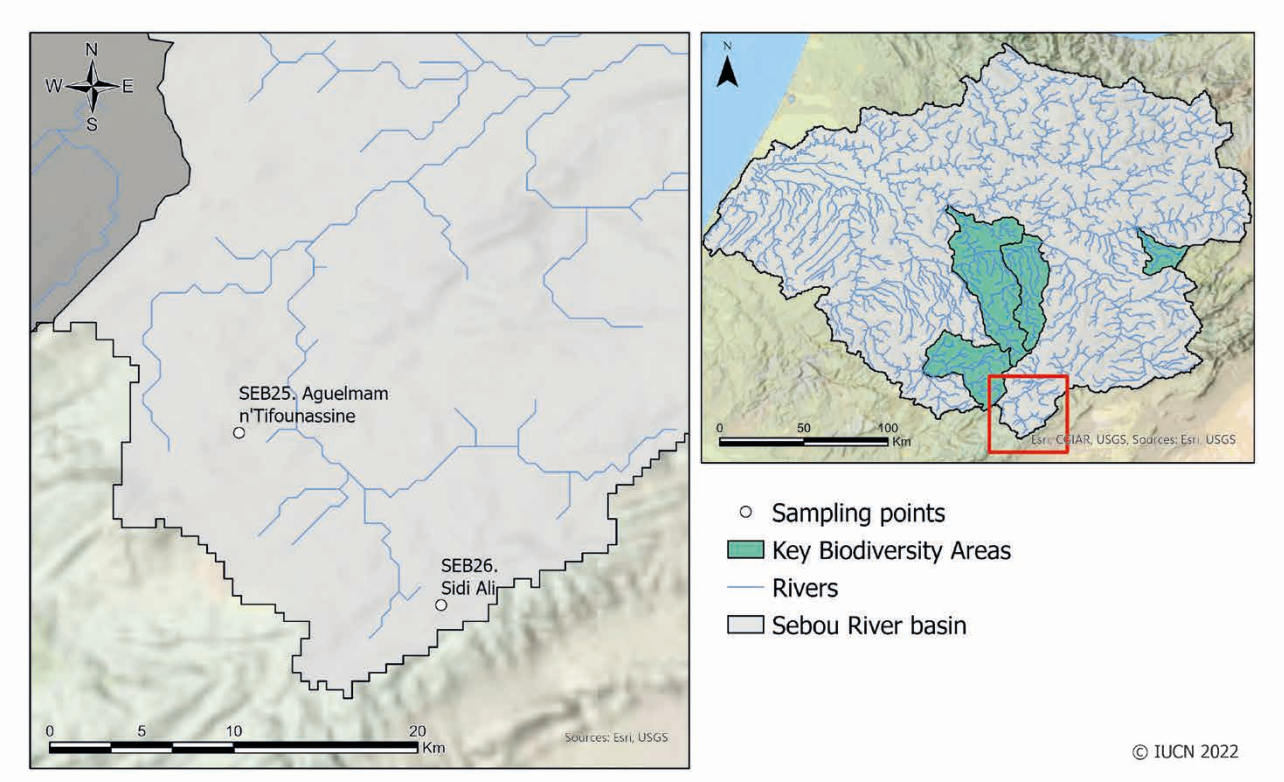


Figure 8. Map of the Aguelmam n'Tifounassine and Sidi Ali wetland areas with the sampled sites as white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.

SURVEY

We sampled both lakes, but we could not sample Sidi Ali with electrofishing, given that the conductivity was very high. Instead we checked the fish catches of all fisherman that were angling around the lake and interviewed them asking about the fish diversity in the lake.

DIVERSITY

The diversity of aquatic species is low in both lakes (Table 14). The high diversity of gastropods previously recorded for Aguelmam n'Tifounassine is now reduced to two common species, possibly due to salinization. No threatened species were found in the lakes.

Aguelmam n'Tifounassine. © Ronaldo Sousa

Left: Gastropod sampling at Aguelmam n'Tifounassine. Right: Preparing for fish sampling at Aguelmam n'Tifounassine. © Manuel Lopes-Lima

Aguelmam n'Tifounassin. © Ronaldo Sousa

Checking for fish species with local fishermen. © Ronaldo Sousa

Fish

Only non-native fish were detected in both lakes although we could not sample Sidi Ali properly due to the high conductivity of the water (Table 15).

Molluscs

Only a couple of molluscs were detected and no bivalves (Table 15).

Odonates

The diversity of odonates is low around the lakes (Table 15).

Aquatic plants

Aguelmam n'Tifounassine is a very large lake bordered on one side by steep hills with little human

Table 14. Species richness and threatened species richness in Aguelmam n'Tifounassine and Sidi Ali. Green corresponds to native and red to non-native species (× no species found, — not sampled).

	Species richness	
TAXA	**SEB25. n'Tifounassine**	**SEB26. Sidi Ali**
Fish	(2)	(5)
Molluscs		
Bivalves	×	×
Gastropods	2	×
Odonates	6	1
Crabs & Crayfish	×	×
Aq. plants	8	9
Macroinvertebrates		
Families	14	11
Shannon-Wiener diversity	1.88	0.93
TOTAL	16(2)	10(5)
	Threatened species richness	
TAXA	**SEB25. n'Tifounassine**	**SEB26. Sidi Ali**
Fish	×	×
Molluscs	×	×
Bivalves	×	×
Gastropods	×	×
Odonates	×	×
Crabs & Crayfish	×	×
Aq. plants	×	×
TOTAL	0	0

Source: data collected by the authors.

activity apart from stock grazing and in the remaining areas bordered by low-intensity agriculture. The lake itself supports vast populations of a small number of aquatic plant species, such as *Ranunculus peltatus*, *Stuckenia pectinata* and *Zannichellia palustris*, with extensive populations of charophytes. The second plateau lake, Aguelmam Sidi Ali Ta'nzoult, is another large lake, mainly bordered by low hills but with a good road and some developments which look to be aimed at tourism. Aguelmam Sidi Ali Ta'nzoult is highly mineralised with salt deposits along the margins. This is apparently a consequence of over-exploitation of water. The lake supports little in the way of wetland-dependent plants, apart from

Table 15. Species presence and abundance with the IUCN Red List Category in Aguelmam n'Tifounassine and Sidi Ali (× no species found, — not sampled, IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

SPECIES		IUCN Red List Category	ABUNDANCE	
Fish			**SEB25. n'Tifounassine**	**SEB26. Sidi Ali**
	Cyprinus carpio[A]	**VU**	×	✓
	Esox lucius[A]	**LC**	×	✓
	Perca fluviatilis[A]	**LC**	×	✓
	Rutilus rutilus[A]	**LC**	✓	✓
	Sander lucioperca[A]	**LC**	×	✓
	Tinca tinca[A]	**LC**	✓	×
Molluscs			**SEB25. n'Tifounassine**	**SEB26. Sidi Ali**
Gastropods	*Peregriana peregra*[3]	**LC**	1	×
	Physella acuta[4]	**LC**	2	×
Odonates			**SEB25. n'Tifounassine**	**SEB26. Sidi Ali**
	Anax imperator	**LC**	3	×
	Chalcolestes viridis	**LC**	1	×
	Coenagrion scitulum	**LC**	75	×
	Erythromma viridulum	**LC**	×	1
	Selysiothemis nigra	**LC**	4	×
	Sympecma fusca	**LC**	4	×
	Sympetrum fonscolombii	**LC**	4	×
Aq. plants			**SEB25. n'Tifounassine**	**SEB26. Sidi Ali**
	Juncus heterophyllus	**NT**	×	≤1
	Agrostis stolonifera	**LC**	×	≤1
	Eleocharis palustris	**LC**	1-3	≤1
	Juncus articulatus	**LC**	×	3-5
	Plantago major intermedia	**LC**[2]	✓	×
	Ranunculus peltatus	**LC**	15	×
	Stuckenia pectinata	**LC**	15	3-5
	Zannichellia palustris	**LC**	40	×
	Apium repens	**NE**[1]	✓	×
	Bolboschoenus sp.		≤1	≤1
	Chara sp. 1		3-5	3-5
	Chara sp. 2		×	1-3
	Chara sp. 3		×	15

[A]Non-native species; [1]VU in the Mediterranean; [2]assessed as *Plantago major*; [3]assessed as *Radix balthica* in the IUCN Red List; [4]assessed as *Haitia acuta* in the IUCN Red List. **Source**: data compiled by the authors with categories from IUCN Red List.

Salt extrusions around Sidi Ali Lake. © Ronaldo Sousa

charophytes which are clearly tolerant of the high salt levels and a small stand of *Juncus heterophyllus*.

Macroinvertebrates

Both lakes suffer from increased salinization of the water with negative impacts on the macroinvertebrate fauna. This is especially evident in Sidi Ali.

HABITAT

Both lakes are shallow and with no riparian area. Sheep grazing is probably the only impact to the lake banks. Macroinvertebrate indexes indicate poor habitat quality and also exceedingly high conductivity levels (Table 16).

THREATS

The major threat to the lakes is over-extraction of water with the consequent decrease in water levels. Additionally, this seems to be causing soil saline extrusion and increasing water conductivity. This should be exacerbated by predictions of increased climatic interannual variability and global warming. The introduction of non-native fish, overgrazing and organic pollution by animal and humans are additional threats.

CONSERVATION GUIDANCE

A management plan for water extraction should be implemented in this area. Protection of the lake area from overgrazing and replanting a riparian buffer, as well as stopping the active fish re-stocking should be the main priorities.

Table 16. Habitat parameters measured per site in Aguelmam n'Tifounassine and Sidi Ali (— not sampled, values coloured red indicate negative results (high modification, low quality, low biodiversity, etc.), orange and yellow indicate average results, while green and blue indicates positive results (low modification, high quality, high biodiversity, etc.)).

	SCORES	
PARAMETERS	SEB25. n'Tifounassine	SEB26. Sidi Ali
Macroinvertebrates		
Biotic index (IBMWP)	**57**	**46**
% of Individuals - EPT	**3.16**	**8.96**
Physical-Chemical		
Dissolved Oxygen (mg/L)	10.61	10.75
pH	10.31	9.76
Conductivity (µS)	**1491**	**1518**
Temperature (°C)	25.1	22.8

Source: data collected by the authors.

4.2 Dayat Iffer/Dayat Yfrah/Dayat Afourgah

BACKGROUND

Two shallow lakes near the border of Oued Imouzzer Kandar KBA. Dayat Iffer is set in woodland in the Central Plateau and Dayat Ifrah is a low-lying lake in an arable context. The lakes have the same problem that affect the whole region, i.e. lack of water (Figure 9).

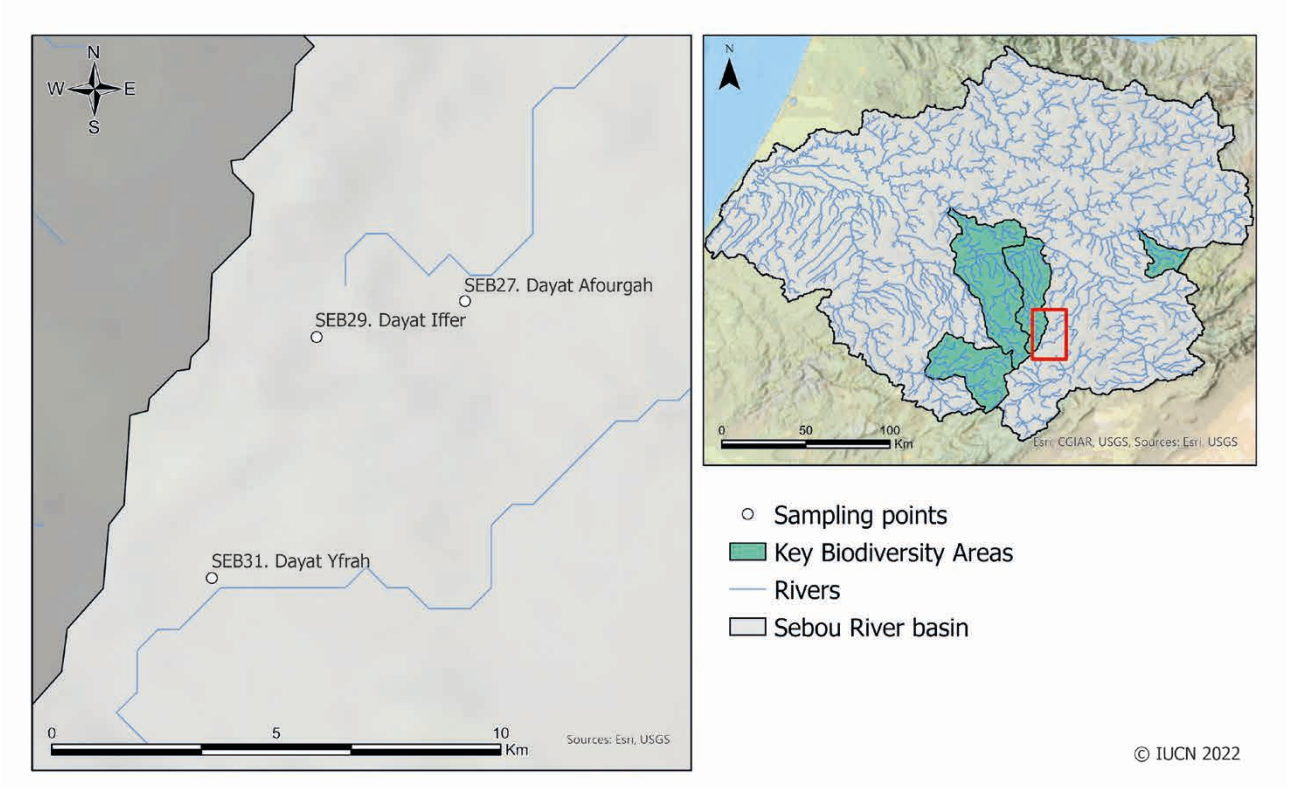


Figure 9. Map of the Dayat Iffer, Dayat Yfrah, and Dayat Afourgah wetland areas with the sampled sites as white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.

Dayat Iffer. © Ronaldo Sousa

Left: Molluscs' sampling at Dayat Iffer. Right: Fish sampling at Dayat Iffer. © Ronaldo Sousa

Left: Dayat Yfrah. Right: Electrofishing at Dayat Yfrah. © Ronaldo Sousa

SURVEY

Dayat Iffer and Dayat Yfrah were surveyed for all taxa, Dayat Afourgah was inaccessible by car due to road construction work. Nevertheless, the odonates team was able to sample by foot.

DIVERSITY

The diversity is higher than in other lakes in the region, but no threatened species were detected (Table 17).

Fish

Only non-native fish were detected. The detected trout *Salmo macrostigma* should not be endemic to the Iffer lake (Table 18).

Molluscs

Only very few common resilient species were detected (Table 18).

Table 17. Species richness and threatened species richness in Dayat Iffer & Dayat Yfrah. Green corresponds to native and red to non-native species (× no species found, — not sampled).

	Species richness		
TAXA	**SEB27. Afourgah**	**SEB29. Iffer**	**SEB31. Yfrah**
Fish	—	1 (5)	(1)
Molluscs	—		
Bivalves	—	1	×
Gastropods	—	2	1
Odonates	3	13	5
Crabs & Crayfish	—	×	×
Aq. plants	—	15	22
Macroinvertebrates			
Families	—	9	9
Shannon-Wiener diversity	—	1.96	1.25
TOTAL	3	31 (5)	27 (4)
	Threatened species richness		
TAXA	**SEB27. Afourgah**	**SEB29. Iffer**	**SEB31. Yfrah**
Fish	—	×	×
Molluscs	—	×	×
Bivalves	—	×	×
Gastropods	—	×	×
Odonates	×	×	×
Crabs & Crayfish	—	×	×
Aq. plants	—	×	×
TOTAL	0	0	0

Source: data collected by the authors.

Odonates

A diverse fauna of odonates was detected around lake Iffer. *Libellula quadrimaculata*, a relic of the Eurosiberian fauna in North Africa and classified as Vulnerable in North Africa was present. *Coenagrion scitulum* is Near threatened on the North African Red List. *Enallagma deserti* is not threatened, but the species is endemic to North Africa and has good population numbers in both lake Iffer and Yfrah (Table 18).

Aquatic plants

Dayat Iffer is a small but very deep lake set in woodland. At the time of the survey extensive bare margins were exposed and due to the steep slope of the margins, there was only a narrow fringe of marginal and aquatic plants. It is likely that this is normal for the site. The only species of note at the site was a small stand of *Apium repens* growing a seepage above the water level. Dayat Ifrah is a very large, shallow lake with an extensive draw-down zone extending from non-intensive agriculture through grassy marsh to bare mud supporting a small range of wetland-dependent plants. The standing water of the lake support a vast population of aquatic plants heavily dominated by *Zannichellia palustris*, with *Stuckenia pectinata* and sparse charophytes. The only species of note recorded at the site was *Apium repens* on the edge of the marshy grassland, although further surveys could locate more notable species (Table 18).

Macroinvertebrates

The two lakes exhibit a low diversity of macroinvertebrates, especially Iffer where high conductivity values were registered. The presence of non-native fish and low water levels could also explain the low diversity of this group (Table 17 and 19).

Table 18. Species presence and abundance with the IUCN Red List Category in Dayat Iffer and Dayat Yfrah (× no species found, — not sampled, IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

SPECIES		IUCN Red List Category	ABUNDANCE		
Fish			**SEB27. Afourgah**	**SEB29. Iffer**	**SEB31. Yfrah**
	Esox lucius[A]	LC	—	✓	×
	Gambusia holbrooki[A]	LC	—	✓	×
	Lepomis gibbosus[A]	LC	—	✓	×
	Rutilus rutilus[A]	LC	—	✓	✓
	Tinca tinca[A]	LC	—	×	×
	Salmo macrostigma[?]	DD	—	✓	×
	Onchorhychus mykiss[A]	NE	—	✓	×
Molluscs			**SEB27. Afourgah**	**SEB29. Iffer**	**SEB31. Yfrah**
Bivalves	*Pisidium casertanum*	LC	—	10	×
Gastropods	*Physella acuta*[6]	LC	—	10	34
	Planorbarius metidjensis	NE	—	5	×
Odonates			**SEB27. Afourgah**	**SEB29. Iffer**	**SEB31. Yfrah**
	Anax imperator	LC	1	12	×
	Anax parthenope	LC	×	1	×
	Coenagrion scitulum	LC[4]	×	2	×
	Crocothemis erythraea	LC	×	7	×
	Enallagma cyathigerum	LC	5	×	+100
	Enallagma deserti	LC	×	+100	3
	Erythromma lindenii	LC	×	+1000	12
	Erythromma viridulum	LC	×	20	100
	Ischnura graellsii	LC	×	4	×
	Libellula quadrimaculata	LC[3]	×	10	×
	Orthetrum cancellatum	LC	3	1	×
	Pyrrhosoma nymphula	LC	×	1	×
	Sympetrum fonscolombii	LC	×	×	+160
	Sympetrum meridionale	LC	×	1	×
Aq. plants			**SEB27. Afourgah**	**SEB29. Iffer**	**SEB31. Yfrah**
	Juncus heterophyllus	NT	—	×	×
	Agrostis stolonifera	LC	—	×	3-5
	Capsella bursa-pastoris	LC	—	×	≤1
	Chara aspera	LC	—	×	≤1
	Chenopodium rubrum	LC	—	×	≤1
	Cyperus fuscus	LC	—	≤1	1-3
	Eleocharis palustris	LC	—	✓	×
	Juncus articulatus	LC	—	≤1	✓
	Juncus bufonius	LC	—	1-3	≤1
	Myriophyllum spicatum	LC	—	3-5	×
	Nasturtium officinale	LC	—	×	≤1
	Nymphaea candida	LC	—	50	×
	Persicaria maculosa	LC	—	×	≤1
	Plantago major intermedia	LC[5]	—	✓	×
	Polygonum aviculare	LC	—	×	3-5
	Ranunculus peltatus	LC	—	×	≤1

Ranunculus sceleratus	LC	—	✓	1-3
Rumex crispus	LC	—	×	≤1
Rumex pulcher	LC	—	—	≤1
Schoenoplectus litoralis	LC	—	✓	×
Schoenoplectus tabernaemontani	LC	—	≤1	×
Stuckenia pectinata	LC	—	1-3	≤1
Veronica catenata	LC	—	✓	1-3
Zannichellia palustris	LC	—	×	75
Apium repens	NE[1]	—	✓	×
Carex hordeistichos	NE[2]	—	×	✓
Malva pumila	NE	—	×	≤1
Amaranthus sp.		—	×	≤1
Nitella sp.		—	≤1	×
Sparganium sp.		—	✓	×

[?]Possible non-native species; [A]Non-native species; [1]VU in the Mediterranean; [2]LC in the Mediterranean; [3]VU in North Africa; [4]NT in North Africa; [5]assessed as *Plantago major*; [6]assessed as *Haitia acuta* in the IUCN Red List. **Source**: data compiled by the authors with categories from IUCN Red List.

HABITAT

Table 19. Habitat parameters of Dayat Iffer and Dayat Yfrah (— not sampled, values coloured red indicate negative results (high modification, low quality, low biodiversity, etc.), orange and yellow indicate average results, while green and blue indicates positive results (low modification, high quality, high biodiversity, etc.)).

PARAMETERS	SCORES	
	SEB29. Iffer	SEB31. Yfrah
Macroinvertebrates		
Biotic index (IBMWP)	**35**	**31**
% of Individuals - EPT	**13.64**	**32.2**
Physical-Chemical		
Dissolved Oxygen (mg/L)	6.3	10.79
pH	8.79	9.84
Conductivity (µS)	**742.0**	**217.0**
Temperature (°C)	23.5	25.4

Source: data collected by the authors.

THREATS

Dayat Iffer appears to be relatively secure although there is evidence of nutrient enrichment which might be due to mobilisation of sediment in the draw-down zone by vehicles. The water level seems to be lower than usual. It is popular for low-intensity tourism and several fish and at least one species of aquatic plant (*Nymphaea candida*) appears to have been introduced. The potential effects of tourism need to be controlled. Dayat Ifrah does not appear to be directly threatened, although it is possible that the extensive draw-down zone may be partly due to over-exploitation of water and this should be investigated. It is vulnerable to agricultural intensification, particularly nutrient-enrichment and it would be valuable to establish a buffer zone between the lake margin and agriculture.

CONSERVATION GUIDANCE

These lakes should be protected by aquifer management plans. This needs to be linked to an assessment of methods for the development of alternative water supplies, almost certainly including artificial reservoirs to enable a reduction of exploitation of ground water.

4.3 Oued Sebou

BACKGROUND

Sample of the main channel of the Oued Sebou upstream and downstream of Allal Al Fassi dam (Figure 10).

SURVEY

It was difficult to find sites to sample upstream of the Allal Al Fassi dam, given that other dams are being constructed in the area and the river channel was full of silt. We managed to sample one site just above a small dam, but it was already filled with loose silt covering the substrate. We then sampled two additional sites a few kilometres above and one below Allal Al Fassi dam. Two additional sites (SEB35 and 36) were sampled only for dragonflies, one in the main Sebou channel and another on Oued Sidi Harazam, a tributary of the Oued Sebou, where it enters below Allal Al Fassi dam.

DIVERSITY

The upper section exhibits a lower diversity of most river species and macroinvertebrates. Four threatened species, three molluscs, *Potomida littoralis*, *Unio foucauldianus*, and *Melanopsis scalaris* and a fish *Cobitis maroccana*, were detected on the lower Sebou.

Odonates

Both Oued Sebou (SEB35) and its tributary Sidi Harazam harbour several North African threatened odonates. Good populations of *Onychogomphus costae*, an endemic species of Iberia and the Maghreb, are still present in both rivers. The spring waters of Sidi Harazam have populations of *Zygonyx torridus* and *Pseudagrion sublacteum*, the latter is a relict species of former wet periods in Africa and only has a handful of populations north of the Sahara.

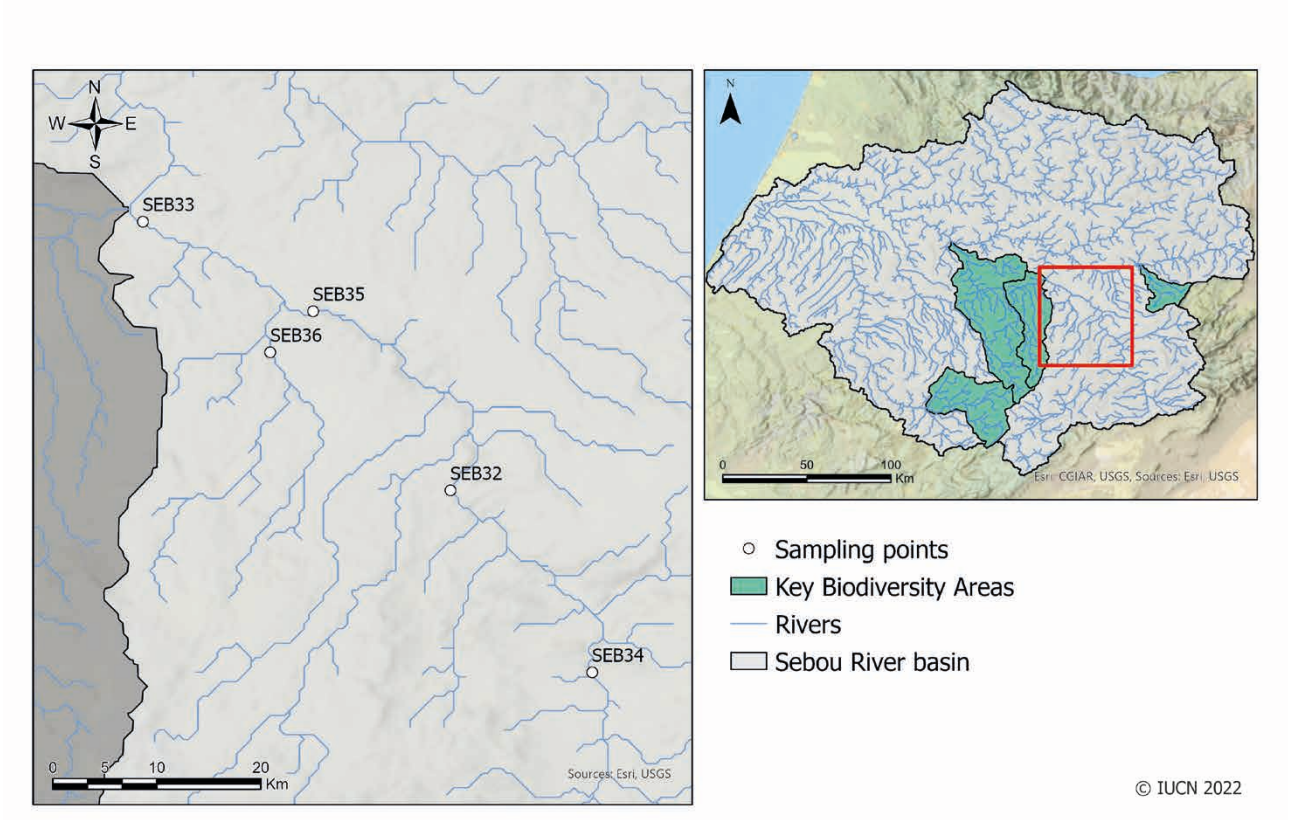
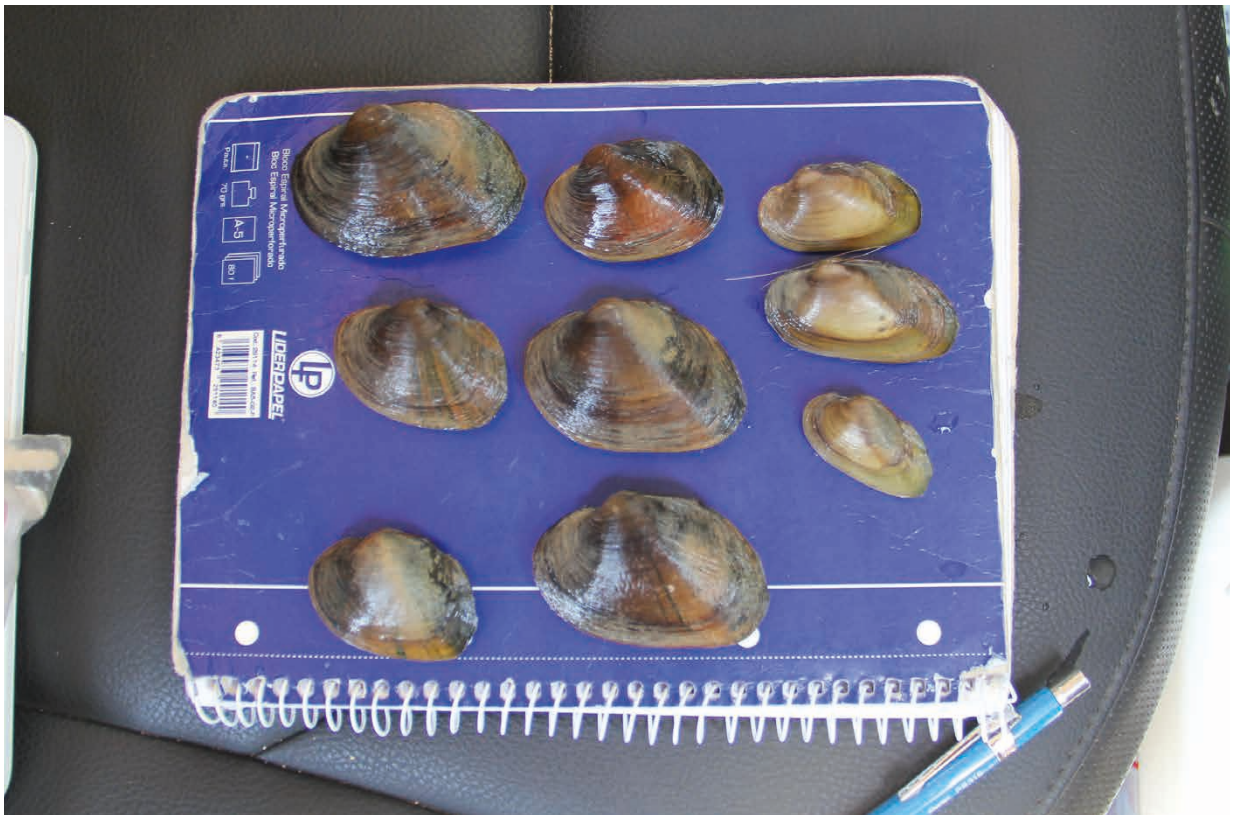


Figure 10. Map of the Oued Sebou sites with the sampled sites as white dots. Both perennial and intermittent stretches illustrated without distinction. Source: HydroSHEDS database from © World Wildlife Fund, Inc. (2006-2013), World Database of KBA and data collected by the authors.


Left: Sebou river dam (SEB34). Right: Sebou river (SEB34). © Ronaldo Sousa


Sebou river (SEB32). © Ronaldo Sousa


Left: Sebou river (SEB33). Right: the threatened Moroccan spined loach *Cobitis maroccana* collected at the Sebou river (SEB33). © Ronaldo Sousa



The threatened freshwater mussels *Potomida littoralis* (left columns) and *Unio focauldianus* (right column) collected at the Sebou river (SEB33). © Ronaldo Sousa

Sebou river. © Ronaldo Sousa

Table 20. Species richness and threatened species richness in Oued Sebou. Green corresponds to native and red to non-native species (× no species found, — not sampled).

	Species richness				
TAXA	**SEB32**	**SEB33**	**SEB34**	**SEB35**	**SEB36**
Fish	1	3(1)	2	—	—
Molluscs				—	—
Bivalves	×	2	×		
Gastropods	1	2	×		
Odonates	2	1	1	9	9
Crabs & Crayfish	×	×	×	—	—
Aq. plants	—	—	—	—	—
Macroinvertebrates					
Families	18	14	7	—	—
Shannon-Wiener diversity	2.25	2.02	1.34	—	—
TOTAL	5	8(1)	3	9	9
	Threatened species richness				
TAXA	**SEB32**	**SEB33**	**SEB34**	**SEB35**	**SEB36**
Fish	×	1	×	—	—
Molluscs	×	×	×	—	—
Bivalves	×	2	×		
Gastropods	×	1	×		
Odonates	×	×	×	×	×
Crabs & Crayfish	×	×	×	—	—
Aq. plants	×	×	×	—	—
TOTAL	0	4	0	0	0

Source: data collected by the authors.

HABITAT

The upper catchment of the Sebou presents shallow stretches, but they are highly dynamic and exposed to heavy floods in the wet season. The catchment is increasingly impacted by dam construction and decreasing water levels. The lower sections are impacted by agriculture practices, pollution and nutrient enrichment.

THREATS

The main impacts to the Sebou river biodiversity are dam construction, water extraction for agriculture and urban use. Soil erosion and siltation, pollution and eutrophication are disturbing the lower sections.

The spring of the tributary Sidi Harazam is now completely concreted and converted into an intensely used recreation area. Water from the source is now first used for several swimming pools.

CONSERVATION GUIDANCE

The area should benefit from the production of a management plan for the whole Sebou catchment area that should include water management, increase of riparian buffer areas and the maintenance of environmental flows. Wastewater treatment plants should be installed in main urban areas. Cattle overgrazing should be prevented near the river banks.

The protection of the lower Sebou would benefit several endangered species.

Table 21. Species presence and abundance with the IUCN Red List Category in Oued Sebou (× no species found, — not sampled, IUCN Red List Categories: **CR** Critically Endangered, **EN** Endangered, **VU** Vulnerable, **NT** Near Threatened, **LC** Least Concern, **DD** Data Deficient, **NE** Not Evaluated).

SPECIES		IUCN Red List Category	ABUNDANCE				
Fish			**SEB32**	**SEB33**	**SEB34**	**SEB35**	**SEB36**
	Cobitis maroccana	**VU**	×	14	×	—	—
	Carasobarbus fritschii	**LC**	×	6	×	—	—
	Gambusia holbrooki[A]	**LC**	×	4	×	—	—
	Luciobarbus labiosa	**LC**	×	13	11	—	—
	Luciobarbus guercifensis	**NE**	11	×	11	—	—
Molluscs			**SEB32**	**SEB33**	**SEB34**	**SEB35**	**SEB36**
Bivalves	*Unio foucauldianus*	**CR**	×	3	×	—	—
	Potomida littoralis	**EN**	×	43	×	—	—
Gastropods	*Melanopsis scalaris*	**EN**	×	48	×	—	—
	Melanopsis praemorsa	**LC**	×	7	×	—	—
	Physella acuta[4]	**LC**	13	×	×	—	—
Odonates			**SEB32**	**SEB33**	**SEB34**	**SEB35**	**SEB36**
	Onychogomphus costae	**NT**	—	1	—	5	6
	Orthetrum nitidinerve	**NT**[3]	—	—	—	2	1
	Anax imperator	**LC**	—	—	—	1	×
	Caloptryx haemorrhoidalis	**LC**	—	—	—	1	×
	Crocothemis erythraea	**LC**	—	—	—	2	1
	Erythromma lindenii	**LC**	2	—	—	17	×
	Ischnura graellsii	**LC**	—	—	—	×	1
	Orthetrum chrysostigma	**LC**	—	—	—	×	1
	Orthetrum coerulescens	**LC**	—	—	—	3	×
	Platycnemis subdilatata	**LC**	—	—	—	3	14
	Pseudagrion sublacteum	**LC**[1]	—	—	—	×	1
	Pyrrhosoma nymphula	**LC**[2]	5				
	Trithemis annulata	**LC**	—	—	—	5	5
	Zygonyx torridus	**LC**[2]	—	—	—	×	6

[A]Non-native species; [1]CR in North Africa; [2]NT in North Africa; [3]LC in North Africa; [4]assessed as *Haitia acuta* in the IUCN Red List. **Source**: data compiled by the authors with categories from IUCN Red List.

Table 22. Habitat parameters of Oued Sebou (— not sampled, values coloured red indicate negative results (high modification, low quality, low biodiversity, etc.), orange and yellow indicate average results, while green and blue indicates positive results (low modification, high quality, high biodiversity, etc.)).

PARAMETERS	SCORES		
	SEB32	SEB33	SEB34
River Habitat Survey (RHS)			
Habitat Quality Assessment (HQA)	63	42	65
Habitat Modification Score (HMS)	**435**	**375**	**700**
Macroinvertebrates			
Biotic index (IBMWP)	**74**	**74**	**32**
% of Individuals - EPT			
Physical-Chemical			
Dissolved Oxygen (mg/L)	8.57	8.30	8.58
pH	8.33	7.56	8.36
Conductivity (µS)	**536**	**1064**	**896**
Temperature (°C)	20.2	23.4	21.0

Source: data collected by the authors.

5 Threats and conservation guidance

The Sebou basin is not only important for the Moroccan population but also a hotspot for native and threatened species. The natural lakes of the Middle Atlas present important biodiversity values, being migration corridors that are temporarily used by migratory birds for nesting and overwintering purposes. The most important temporary wetlands of North Africa can be found in the Sebou basin and its many streams and rivers are home to a large number of endemic and threatened species.

However, the region is extremely water-scarce and precipitation data over the last 50 years have shown that the dry years are becoming more frequent than wet or normal years. With a population of 6.2 million people relying on the basin for its water sources (23% of the Moroccan population), the basin faces significant challenges in terms of water scarcity that will only increase with increasing population growth and the most probable climate change trend. The primary challenges identified include:

- Overexploitation of surface and groundwater resources for agricultural use.
- Pollution of the surface and groundwater by solid waste and industrial activities.
- Livestock and agricultural activities causing the multiplication of pathogenic microorganisms such as bacteria and waterborne pests.
- Use of contaminated water for agricultural purposes (irrigation of riparian fields, livestock watering …), domestic or other forms constitutes a real danger to the health of local inhabitants and livestock.
- Overexploitation of forests around lakes and overgrazing.
- Excessive harvesting of resources by local populations, particularly with regards to hunting, poaching of birds and their eggs.
- Development of rural habitat close to lakes and rivers.
- High concentration of nitrates with an alarming upward trend.
- Introduction of non-native species, especially fish.

In order to ensure the protection of the significant richness of both native and threatened species in the Sebou river basin, it is of the utmost importance to preserve and extend the number of national parks and protected areas. Considering the study that was done by the experts in the Sebou river basin, it would be a key step to extend the scope of some Key Biodiversity Areas and add additional areas of protection for the areas with high biodiversity. Furthermore, it would be important to look at the management of these critical freshwater biodiversity areas to ensure the ecosystem services they provide are conserved. In order to better protect these sites, the following recommendations should be considered (see Annex 2 for recommendations per KBA or area):

- Developing proper freshwater biodiversity conservation and aquifer management plans.
- Maintaining the environmental flow, particularly in areas of high biodiversity or hosting threatened species.
- Restoring river banks and re-naturalizing springs, as well as preventing cattle overgrazing in river banks, especially in the spring systems near Ifrane (KBA Oued Tizguite and Oued Ouaslane) and Aghbal (KBA Tigrigra).
- Reviewing wastewater processes to inform upgrades and develop better facilities to reduce pollution from urban areas, especially in the springs of Aghbal (KBA Tigrigra).
- Improving the regulation of recreational activities to prevent habitat degradation.
- Putting in place a monitoring and legal framework system for KBAs. For example, the high biodiversity value of the lower section of river Bouhlou, which hosts one of the world's 100 most threatened species, *Pseudunio marocanus* (assessed as *Margaritifera marocana* in the IUCN Red List), could justify the extension of Tazekka natural park.
- Training workshops on the conservation of freshwater biodiversity with stakeholders.
- Implement management measures concerning non-native species, especially those focusing on prevention.

6 Conclusions

In order to face the environmental challenges of the Sebou basin, several innovative actions have been currently taken. In 2019, the Sebou Water fund was officially launched in the framework of the WAMAN (Water MANagement) Sebou project. The Sebou Water fund is a sustainable financing mechanism based on the payment for ecosystem services, contributing towards sustainable watershed management and the restoration of biodiversity and cultural activities. Six priority lakes with threatened water sources have been identified for implementation in the Sebou water fund, where the first round will focus on demonstrating how water and soil conservation management, sustainable agriculture and the protection of natural ecosystems contribute to the overall water supply in the Sebou basin.

The Sebou river basin has a high value as a biodiversity hotspot. A total of 21 species found in this study were listed as threatened with extinction in the IUCN Red List. The lower section of the Bohlou river in the Tazekka natural park holds one of the best-recruiting populations of the freshwater mussel *Pseudunio marocanus* (assessed as *Margaritifera marocana* in the IUCN Red List) listed among the world's 100 most threatened species (Baillie & Butcher, 2012). To increase our knowledge on the freshwater biodiversity and especially the detected threatened species, further studies are necessary to get an overview of the full extent of the river basin (Nogueira et al., 2021). Priority areas for conservation of this freshwater biodiversity should be identified and listed as protected areas. Some of the sites in this study should be included as extension or as new Key Biodiversity Areas. Finally, some of the current KBA require more measures to protect freshwater biodiversity. It is important to ensure the continuation of correct management for the survival of threatened species in the assigned protected regions.

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Annexes

Annex 1. Site location for the surveys of the distinct freshwater groups (Macroinvertebrates, Fish, Odonates, Bivalves, Gastropods, and Plants) and habitat assessments (River Habitat Survey – RHS), and water physical-chemical parameters.

SITE	DATE	HABITAT	LATITUDE	LONGITUDE	M. INVERT.	FISH	ODONATES	BIVALVES	GASTROPODS	AQ. PLANTS	RHS	PHYSICAL CHEMICAL	eDNA
KBA. OUED BOUHLOU													
SEB01	19/08/2018	River/Oued Bouhlou	34.14684	−4.42407	✓	✓	✓	✓	✓	✓	✓	✓	—
SEB02	19/08/2018	River/Oued Bouhlou	34.12567	−4.40377	✓	✓	✓	✓	✓	✓	✓	✓	—
SEB03	18/08/2018	River/Oued Bouhlou	34.04521	−4.26755	✓	✓	—	✓	✓	—	✓	✓	—
SEB04	18/08/2018	River/Oued Bousbâa	34.02598	−4.35396	✓	✓	✓	✓	✓	✓	✓	✓	—
SEB22	19/08/2018	Spring/Aïn Sahla	34.10414	−4.31752	—	—	—	✓	✓	—	—	—	—
SEB23	19/08/2018	Spring/Aïn Fendel	34.09550	−4.43878	—	—	—	✓	✓	—	—	—	—
KBA. OUED IMOUZZER KANDAR													
SEB05*	18/08/2018	Lake/Dayat Hachlaf	33.54418	−4.99946	—	—	—	—	—	✓	—	—	—
SEB06*	18/08/2018	Lake/Dayat Aoua	33.65049	−5.03680	—	—	✓	—	—	✓	—	—	—
SEB07*	18/08/2018	Lake/Dayat Aoua	33.65278	−5.01448	—	—	—	—	—	—	—	—	—
SEB07b*	11/06/2019	Lake/Dayat Aoua (side pool)	33.64633	−5.01872	—	—	✓	—	—	✓	—	—	—
SEB08*	18/08/2018	Lake/Dayat Hachlaf	33.55771	−4.98938	—	—	—	—	—	—	—	—	—
SEB20	18/08/2018	Lake/Dayat Hachlaf outlet	33.58796	−4.97972	✓	✓	—	✓	✓	—	✓	✓	—
SEB21	18/08/2018	Spring/Aïn Sultan	33.72100	−5.00492	—	—	—	✓	✓	—	—	—	—
KBA. OUED TIZGUITE & OUED OUASLANE													
SEB09	16/08/2018	River/Oued Tizguite	33.55357	−5.11628	✓	✓		✓	✓		✓	✓	—
SEB10	16/08/2018	Unknown river	33.77196	−5.25313	—	—	✓	—	—	—	—	—	—
SEB11	16/08/2018	Lake/Dayat Aguemguem	33.74978	−5.19554	✓	✓	✓	✓	✓	✓	✓	✓	—
SEB12	16/08/2018	Unknown river	33.79506	−5.18206	✓	✓	✓	✓	✓	✓	✓	✓	—
SEB17	16/08/2018	Oued Tizguit	33.58566	−5.15066	✓	✓	—	✓	✓	✓	✓	✓	—
ODO06	08/06/2019	Shallow waterline	33.89302	−5.24242	—	—	✓	—	✓	✓	—	—	—
EPH001	08/06/2019	Temporary shallow pool	33.76873	−5.22832	—	—	✓	—	—	✓	—	—	—
ODO01	09/06/2019	Stream	33.49411	−5.07574	—	—	✓	—	—	—	—	—	—

SITE	DATE	HABITAT	LATITUDE	LONGITUDE	M. INVERT.	FISH	ODONATES	BIVALVES	GASTROPODS	AQ. PLANTS	RHS	PHYSICAL CHEMICAL	eDNA
KBA. OUED TIGRIGRA													
SEB13	10/06/2019	River/Oued Tigrigra	33.46551	−5.24124	—	✓	✓	—	—	✓	—	—	—
SEB14	17/08/2018	River/Oued Tigrigra	33.43476	−5.52868	✓	✓	—	✓	✓	—	✓	✓	—
SEB15	10/06/2019	River/Oued Tigrigra	33.42583	−5.44762	✓	✓	✓	✓	✓	✓	✓	✓	—
SEB16	17/08/2018	River/Oued Tigrigra	33.40981	−5.36029	✓	✓	—	✓	✓	—	✓	✓	—
SEB18	17/08/2018	Spring/Aïn Aghbal	33.44001	−5.24647	✓	—	—	✓	✓	—	—	✓	—
SEB19	18/08/2018	River/Oued Tigrigra	33.42547	−5.27291	✓	✓	—	✓	✓	—	✓	✓	—
SEB24	11/06/2019	Lake/Dayat Afnounir	33.27890	−5.25207	✓	✓	✓	✓	✓	✓	—	✓	—
RIV001	10/06/2019	Shallow River	33.37958	−5.44325	—	—	✓	—	—	✓	—	—	—
OTHER KEY SITES													
SEB25	09/06/2019	Lake/Dayat Tifounassine	33.15460	−5.09683	✓	✓	—	✓	✓	✓	—	✓	—
SEB26	09/06/2019	Lake/Dayat Sidi Ali	33.07050	−4.99812	✓	✓	—	✓	✓	✓	—	✓	—
SEB29	09/06/2019	Lake/Dayat Iffer	33.60640	−4.90787	✓	✓	✓	✓	✓	✓	—	✓	—
SEB31	09/06/2019	Lake/Dayat Yfrah	33.56582	−4.93058	✓	✓	✓	✓	✓	✓	—	✓	—
SEB32	10/06/2019	River/Oued Sebou	33.83403	−4.64657	✓	✓	—	✓	✓	—	✓	✓	—
SEB33	11/06/2019	River/Oued Sebou	34.06638	−4.91227	✓	✓	—	✓	✓	—	✓	✓	—
SEB34	10/06/2019	River/Oued Sebou	33.67684	−4.52414	✓	✓	—	✓	✓	—	✓	✓	—
SEB35	12/06/2019	River/Oued Sebou	34.04200	−4.85000	—	—	✓	—	—	—	—	—	—
SEB36	12/06/2019	Oued Sidi Harazam	34.03400	−4.88000	—	—	✓	—	—	—	—	—	—
SEB27*	09/06/2019	Lake/Dayat Afourgaa	33.61493	−4.87882	—	—	✓	—	—	—	—	—	—

* Dry or partially dry. **Source**: data compiled by the authors.

Annex 2. Overview of the conservation recommendations for each KBA and additional site in the Sebou river basin.

Name	Area type	Conservation guidance
Oued Bouhlou	KBA	– Maintenance of ecological flows for fish and molluscs – Campaigns to the local authorities and populations on channel management – Extension of Tazekka natural park along the river sown to its mouth, considering presence of *Pseudunio marocanus* (assessed as *Margaritifera marocana* in the IUCN Red List) – Non-native species control – Large-scale management program – Survey of full extent of population in river needed
Oued Imouzzer Kandar	KBA	– Protection through aquifer management plan – Development of alternative water supplies (including artificial reservoirs) – Maintenance of ecological flows for fish and molluscs
Oued Tizguite and Oued Ouaslane	KBA	– Reduction of recreation activities – Stop active re-stocking of crayfish – Non-native species control – Prevention of cattle overgrazing – More controlled protection of spring system near Ifrane
Oued Tigrigra	KBA	– Change the target taxa for this KBA – Management plan for water extraction – Protection of Aghbal and surrounding springs – Separate Aguelmam Affenourir from Tigrigra Stream KBA for the purposes of conservation. It should be allied with the other lakes on the plateau between Azrou and Timahdit. Detailed survey needed of this region.
Aguelmam n'Tifounassine/Sidi Ali		– Management plan for water extraction – Prevention of cattle overgrazing – Increase of riparian buffer areas – Stop active fish re-stocking
Dayat Iffer / Dayat Yfrah / Dayat Afourgah		– Protection through aquifer management plan – Development of alternative water supplies (including artificial reservoirs)
Oued Sebou		– Water management plan – Increase of riparian buffer areas – Maintenance of ecological flows for fish and molluscs – Installation of wastewater treatment plans – Prevention of cattle overgrazing

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