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Biodiversity Loss in the Moroccan central High Atlas, its Impact on Local Ecosystems and National Economy, and Wildlife Conservation Strategy: Findings from 20 years of Research

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ABSTRACT
The central High Atlas (CHA) covers an area of 12 791 km² including 5 730 km² labeled "Unesco Global Geopark" by UNESCO in September 2014. It has a rich biological diversity, characterised by numerous different ecosystems, habitats, and species, especially mammals. In this area, there were the last observations of several carnivore species in Morocco as the case of the Barbary lion (1942), the panther (1983), and the striped hyena (2022). The mountain ecosystems of the CHA are strategic for Morocco because of their various socioeconomic and ecological roles. Mammals have important roles in the food webs of practically every ecosystem. The removal of mammal species can have major impacts on ecological communities, destabilizing ecosystems and their food webs. Consequently, extinction and decline of mammals of the CHA have negative impacts on local ecosystems and on national economy. Our previous studies indicated that biodiversity has been declining in this area at an alarming rate in recent years. This article summarizes data collected and published by the author et al. on mammal diversity in the CHA Mountains during the two last decades (2003-2023). In addition, new data were recorded and reported here. Data on mammal species and ecosystems were collected on different aspects of mammalian ecology, especially distribution and population status; anthropogenic impact on habitats and species; illegal capture, killing and trade of mammals; effects of tourism activities on ecology and ethology of mammals; human-mammals conflict; ecological and economic consequences of biodiversity loss; and the main actions and ways to preserve biodiversity and ecosystems in the CHA.

1. Introduction:

Biodiversity is the variety of life on Earth at any level of organization, from molecules to ecosystems **[1]**. Biodiversity is essential for the processes that support all life on Earth, including humans. Biodiversity loss has been largely assessed through species extinctions. Actually there is an increasing decline of biodiversity due to anthropogenic impact **[2]**. Of the world's 5 490 mammal species, 79 are extinct or extinct in the wild, 188 are critically endangered, 449 endangered and 505 vulnerable **[3]**. According to the IUCN, 469 reptiles are threatened with extinction and 22 are already extinct or extinct in the wild; 1 895 amphibians are in danger of extinction; 8 500 plants are threatened with extinction, with 114 already extinct or extinct in the wild; 2 639 invertebrates are threatened with extinction; 1 147 freshwater fishes are threatened with

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extinction. The estimated background extinction rate is one extinction per 100 years per 10 000 species **[4]**, but the number of extinctions today is about 6500 species per 100 years per 10 000 species, so the estimated rate would represent a several-thousand–fold increase over the background rate of extinctions **[2]**.
Biodiversity loss threatens the planet, life and the Humanity **[5]**. Morocco was ranked as the second richest country in term of biodiversity in the Mediterranean Basin after Turkey **[6]**. It has a rich biological diversity, characterised by numerous different ecosystems, habitats, and species. Morocco has 24 000 fauna species, of which 2 640 are endemics, and 7 000 flora species, of which 22% (879 taxa) are endemic. Therefore the Moroccan fauna and flora are characterised by a high rate of endemism and relict species **[7]**. Despite efforts to manage threats and pressures to biodiversity, it is still in decline in this country. Many species have become extinct and others were at risk of extinction. Currently 422 plant species, considered to be present in Morocco, are listed in the IUCN Red List, of which 43 are national endemics **[8]**. Among the plant species listed as critically endangered, endangered, vulnerable or near threatened in the 2022 IUCN Red List **[9]**: *Carex fissirostris, Leptochloa ginae, Scrophularia eriocalyx, Carum asinorum, Cirsium ducellieri, Euphorbia nereidum, Pinguicula fontiqueriana, Carum lacuum, Leobordea tapetiformis, Epilobium psilotum, Carum jahandiezii, Dracaena draco* and *Cupressus dupreziana* **[8-9]**. Among the extinct birds (or at least are critically endangered) in Morocco, we cite the African ostrich *Struthio camelus*, the white-headed Duck *Oxyura leucocephala*, the wild guinea fowl *Numida meleagris*, the Iberian imperial eagle *Aquila adalberti*, the lappet-faced vulture *Torgos tracheliotus*, the black vulture *Aegypius monachus*, and the demoiselle crane *Anthropoides virgo* **[10]**. More than 25 species of birds are listed as critically endangered, endangered, vulnerable or near threatened in the IUCN Red List **[9]**. Among the extinct reptiles in Morocco, we cite the West African crocodile *Crocodylus suchus*. More than 24 species of reptiles and amphibians are listed as critically endangered, endangered, vulnerable or near threatened in the IUCN Red List **[9]**.
The CHA covers an area of 12 791 km² including 5 730 km² labelled "Unesco Global Geopark" by UNESCO in September 2014 **[11]**. It has a great diversity of habitats and of plant and animal species **[10-17]**. This area is home to a variety of animal species especially mammals with more than 24 wild mammal species **[16]** and more of 100 birth species **[10]**. Among the extinct mammals in Morocco we can cite the Atlas lion *Panthera leo* **[18]**, the hartebeest *Alcelaphus buselaphus* **[19]**, the addax *Addax nasomaculatus* **[20]**, the scimitar oryx *Oryx dammah* **[21]**, and the Cheetah *Acinonyx jubatus* **[22]**. Morocco has 18 threatened mammal species **[9]**. Other mammals have become rare or extinct such as the panther *Panthera pardus*, the caracal *Caracal caracal* and the serval *Leptailurus serval* **[23-24]**. Several other mammals become less abundant such as the striped hyena *Hyaena hyaena*, the crested porcupine *Hystrix cristata*, the Barbary sheep *Ammotragus lervia* and the Cuvier's gazelle *Gazella cuvieri* **[16-17,25-26]**. Many species are listed as critically endangered, endangered, or vulnerable according to the IUCN Red List **[9]**: the Barbary macaque *Macaca sylvanus*, the Barbary sheep *Ammotragus lervia*, the Dorcas gazelle *gazella dorcas*, the Western gerbil *Gerbillus hesperinus*, the common bent-wing bat *Miniopterus schreibersi*i, the Mediterranean monk seal *Monachus monachus*, the short-beaked common dolphin *Delphinus delphis*, and the sperm whale *Physeter macrocephalus*.
The forest ecosystems of the CHA are strategic because of their various socioeconomic and ecological roles. Since the beginning of 20th century, habitats were subject to destruction and pressures from human activities, consequently many species were extinct **[12-13,16-17,27-29]**. In this area, there were the last observations of several carnivore species in Morocco as the case of the panther (1983: **[24]**), the Barbary lion (1942: **[30]**), and the striped hyena *Hyaena hyaena* (2022: **[29]).** Our previous studies indicated that biodiversity has been declining in this area at an alarming rate in recent years and blamed this decline on habitat destruction, impact of livestock grazing, the habitat and population fragmentation, the illegal wildlife capture, and general disturbance effects of human activities **[10,12,15-16,26-28,31-33]**.
In the CHA Mountains, biodiversity loss and degradation of ecosystems are proceeding at an accelerating pace, but the consequences of the current decline in biodiversity for socio-ecological systems represent a critical knowledge gap for policy-makers. The objective of this study was to investigate the biodiversity loss in the Moroccan CHA Mountains, to understand and analyze its potential impact on ecosystems and economy, and to propose recommendations for the protection of the threatened species.

2. Material and methods:

2.1. The CHA Mountains:

The study was conducted in the CHA Mountains, region of Beni Mellal – Khenifra, Morocco (Figure 1). This area has a great diversity of habitats and of plant and animal species **[10,12,15-16]**. Altitudes range between 600 and 4 071 m. The study area has a Mediterranean climate with four distinct seasons: winter, spring, summer, and autumn **[34]**. Temperatures range from 5.9 ◦C (in winter) to 40.3 ◦C (in summer) **[35]**. The CHA Mountains encompass an area of 12 791 km² and have a rich and varied biological diversity. The terrain, mainly calcareous, consists of steep mountain slopes and rocky gorges dissected by swiftly running streams. Altitudes range between 600 m and 4 071 m and the climate varies from semi-arid to humid **[34]**. The habitat types are principally pure forests of holm oak *Quercus ilex*, forests of holm oak mixed with *Juniperus phoenicea*, *Juniperus oxycedrus, Pistacia lentiscus, Phillyrea* sp. and *Arbutus unedo*, forest of Barbary thuya

Tetraclinis articulata (pures or mixed with other junipers), forests of Aleppo pine *Pinus halepensis*, sparse cork oak *Quercus suber* and open forests of *Juniperus thurifera* **[12].** The following plant species were common in the study area are *Ziziphus lotus*, *Acacia gummifera*, *Ceratonia siliqua*, *Rhus pentaphylla, Withania frutescens*, *Euphorbia resinifera,* Genista sp., *Quercus ilex*, *Juniperus phoenicea*, *Juniperus oxycedrus, Pistacia lentiscus, Phillyrea* sp., *Arbutus unedo*, *Tetraclinis articulata*, *Pinus halepensis*, *Quercus suber*, *Juniperus thurifera*, *Erinacea anthyllis*, *Bupleurum spinosum*, *Alyssum spinosum*, *Cytisus balansae* and *Artemisia* sp. **[12,26,32]**. The CHA includes 22 geosites of exceptional interest and these mountains also contain eight sites of biological and ecological interest: 1. Wabzaza (31°57' N-06°20' W), 2. Ouzoud (32°00' N-06°44' W), 3. Imi n'Ifri (31°43' N-06°58' W), 4.Tamga (31°55'-32°02' N-06°03'-06°12' W), 5.Bou Tferda (32°15' N-05°55' W), 6. Assif M'Goun (31°30′31″ N, 6°26′39″ W), 7. Haut Oued Lakhdar (31°50' 85"N 07°5'31" W), and 8. Assif Ahançal-Melloul (31°59'55"N 06°07'54"W) **[14]**.

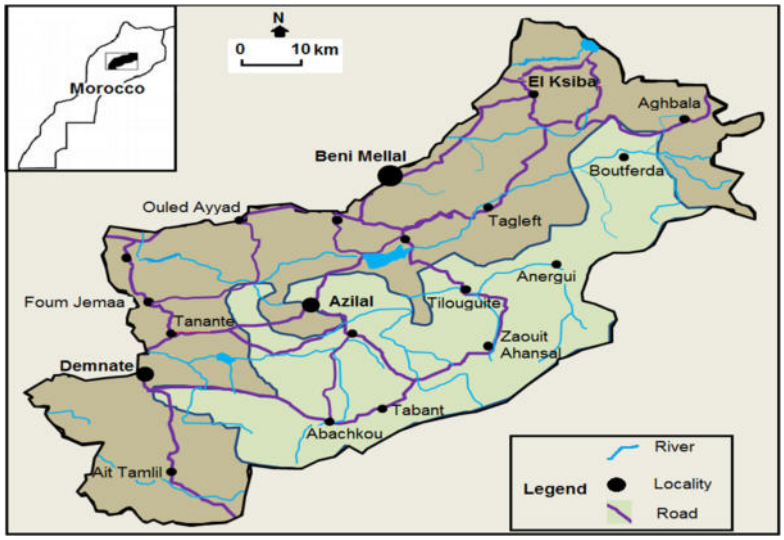

Figure 1. The CHA map showing the main rivers, roads and localities. The rectangle on the inset indicates the location of the study area in Morocco.

2.2. Data collection:

This article summarizes data collected and published by the author (El Alami *et al.*) on mammal diversity in the CHA Mountains during the two last decades (Table 1). In addition, new data were recorded and reported here. Data on mammal species and ecosystems were collected, between January 2003 and January 2023, on different aspects of mammalian ecology, especially distribution and population status, human and natural impact on habitats; illegal capture, killing and trade of mammals; effects of tourism activities on ecology and ethology of mammals; human-mammals conflict; consequences of mammal biodiversity loss; and the main actions and ways to preserve biodiversity in the CHA. The main studies and research of the author (El Alami *et al.*) on mammal biodiversity in the Moroccan CHA during 2003-2023 is given in the Table 1. During these studies, different methods were used to study the mammal species, such as the combination of standardised interviews and the direct survey. During surveys, new information was collected. Based on information gathered through interviews we conducted surveys. Due to the mountainous topography it was not possible to delineate and walk transects or to conduct systematic field surveys. Together with 27 assistants we conducted 52 surveys. Direct method (observation) and indirect method (signs of presence) were used to gather information about the "presence/ absence" and the abundance of each species.

During the study period, interviews were carried out with 1 100 local people. The focus was on shepherds and firewood collectors. Interviews were administered in the local language (Tamazight), which is the first language of the author. Interviews were about the mammal species living actually in the region and the species which have disappeared. We asked the interviewees about the abundance of each species and about the last observation of each species. Question about disadvantages of the presence of the wild fauna were asked. The local name of each species was noted and colour pictures of mammals were shown. At the end of interviews, we conducted a general discussion with each interviewee about the wild fauna, especially about their ecological roles, their importance in the encouragement of tourism and about the importance of the conservation of these animals. The national and regional status of mammal species was established based on the works of Cuzin [23;24]. Species are classified into one of nine Red List Categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE) **[9]**.

Table 1. The main studies and research of the author (et al.) on mammal biodiversity in the Moroccan CHA during 2003-2023.

Genre	Study years	Study and *Research* subject	References
The Barbary macaque *Macaca sylvanus*	2008	Activity budgets and diet of *M.sylvanus*	El Alami *et al.,* 2012; *American Journal of Primatology* **[36]**
	2007-2008	Seasonal variation in activity budget and diet of *M.sylvanus*	El Alami and Chait, 2012; *Mammalia* **[37]**
	2008	Terrestriality of *M.sylvanus* in tourist and wild sites	El Alami and Chait, 2013; *Mammalia* **[38]**
	2004-2008	Distribution and status of *M.sylvanus*	El Alami *et al.,* 2013; *Oryx* **[12]**
	2004-2009	Eco-ethology of *M.sylvanus*	El Alami, 2014a; *ecologia mediterranea* **[39]**
	2008-2009	Human-macaque interaction in the tourist region of Ouzoud	El Alami and Chait, 2014; *African Journal of Ecology* **[31]**
	2007-2014	Etho-ecological study of *M.sylvanus*	El Alami, 2014b; *Ph.D in Ecology, Caddi Ayyad University* **[40]**
	2007-2008	Seasonal variations of terrestriality in a tourist site	El Alami and Chait, 2015a; *Revue de primatologie* **[41]**
	2004-2009	Human-macaque conflict	El Alami and Chait, 2015b; *Revue de primatologie* **[42]**
	2003-2007	Demographic study of *M.sylvanus*	El Alami and Chait, 2016a; *Revue de primatologie* **[69]**
	2007-2012	Diet of *M. sylvanus*	El Alami and Chait, 2016b / *Revue de primatologie* **[70]**
	2007-2020	Distribution, population status and ecology of *M.sylvanus* in North Africa	El Alami *et al.,* 2021a; *Int. J. Sci. Res. in Biological Sciences* **[13]**
	2005-2021	Major threats to *M.sylvanus in* North Africa	El Alami *et al.,* 2022a; *European Journal of Ecology* **[28]**
	2016	Human impact on *M.sylvanus* populations	El Alami, 2016a; *Éditions Universitaires Européennes* **[15]**
	2007-2015	The Barbary macaque in the tourist valley of Ouzoud	El Alami and Chait, 2018; *Les Éditions chapitre.com* **[43]**
Mammal species	2012-2016	Current and extinct wild mammals	El Alami, 2016b; *Éditions Universitaires Européennes* **[16]**
The Cuvier's gazelle *Gazella cuvieri*	2014-2016	Ecological survey of the Cuvier's gazelle	El Alami, 2019a; *Mammalia* **[26]**
The boar *Sus scrofa*	2006-2018	Ecological study of the wild boar *Sus scrofa*	El Alami, 2019b; *American Journal of Innovative Research and Applied Sciences* **[32]**
Ecological Problems	2012-2020	Assessment of citizens' Behaviours toward Ecological Problems	El Alami and Chait, 2020; *Journal of Agricultural, Environmental and Veterinary Sciences* **[44]**
The Eurasian Otter *Lutra lutra*	2019-2020	Distribution of the Eurasian otter and human-otter interaction	El Alami *et al.,* 2020; *IUCN Otter Spec. Group Bull.* **[27]**
	2020	Pollution in the Oum Er Rbia River and its impact on *Lutra lutra*	El Alami and Fattah, 2020; *Journal of Analytical Sciences and Applied Biotechnology* **[45]**
Biodiversity	2012/2020	Biodiversity in the M'goun global geopark	El Alami *et al.,* 2021b; *Journal of Analytical Sciences and Applied Biotechnology* **[14]**
Carnivores	2015-2021	Status, threats and conservation of native carnivores	El Alami and Fattah, 2021; *Moroccan Journal of Biology* **[17]**
	2021	Human–carnivore conflict management	El Alami and Fattah, 2022; *Oryx* **[33]**
	2019-2021	Assessment of human-canid conflict	El Alami *et al.,* 2023 (accepted, in press); *Canid Biology & Conservation* **[46]**
	2019-2022	Rediscovery of the striped hyena Atlas after 22 years	El Alami *et al.,* 2022b; *Oryx* **[29]**

3. Results and discussion:

3.1. Status of mammal species in the CHA:

At the end of the 20th century, wild mammals were at least represented by 27 species in the CHA of Morocco (list of rodent is not exhaustive). Four mammal species were extirpated during the 20th century. Actually, mammals are at least represented by 23 species in the CHA. Six species are listed in the IUCN Red List. Although 17 species, of the mammals of the CHA are not threatened by extinction in their global range **[9]**, eight species are today rare or less abundant in the CHA, and only nine mammal species are not threatened and are abundant or more abundant.

3.1.1. Extinct mammals in the CHA:

In the CHA, four mammal species were extirpated during the 20th century (Figure 2). One species, the Barbary lion *Panthera leo leo* (Extinct in the wild **[9]**), was extirpated during 1930s and 1940s. The last observation in nature in the world of this species was in the study area in 1942 (Tizi n'Tichka, CHA) [30]. Results of interviews over 20 years showed that 100% of the interviewees confirmed that the panther *Panthera pardus* (Near Threatened **[9]**), the serval *Leptailurus serval* (Least Concern **[9]**) and crested porcupine *Hystrix cristata* (Least Concern **[9]**) were extirpated from the CHA during the last decades of the 20th century. The last observation of the panther in Morocco was in 1983 in this area (Azilal, CHA) **[24]**.

1 **2** **3** **4**

Figure 2. Extinct mammals in the CHA: 1. the Barbary lion, 2. the serval, 3. the crested porcupine and 4. the panther (Photographed in the Rabat Zoo by Ilyas El Alami, August 2017).

3.1.2. Mammal biodiversity in the CHA:

Actually, mammals are at least represented by 23 species in the CHA of Morocco. Six species are listed in the IUCN Red List **[9]**, i.e. 26% of the mammal species of the CHA are threatened with extinction. The threatened species according to the IUCN Red List are: the Barbary macaque *Macaca sylvanus* (Endangered), the Barbary sheep *Ammotragus lervia* (Vulnerable), the Cuvier's gazelle *Gazella cuvieri* (Vulnerable), the Dorcas gazelle *Gazella dorcas* (Vulnerable), the striped hyena *Hyaena hyaena* (Near Threatened), the Eurasian otter *Lutra lutra* (Near Threatened) (Figure 3).

1 **2** **3** **4**

Figure 3. Some threatened mammals in the CHA: 1. the Barbary sheep, 2. The Barbary macaque, 3. the Cuvier's gazelle, and 4. the Eurasian otter in the CHA (Photographed by the author).

Although 73.9%, i.e. 17 species of the mammals of the CHA are not threatened by extinction in their global range **[9]**, eight species, i.e. 34.7% of the actual mammals, are rare or less abundant in the CHA. The threatened mammal species in the CHA, listed as Least Concern in the IUCN Red List are: the red fox *Vulpes vulpes*, the wild cat *Felis silvestris*, the Egyptian mongoose *Herpestes ichneumon*, the Common genet *Genetta genetta*, the North African Gerbil *Gerbillus campestris,* the Algerian *mouse Mus spretus*, the Black rat *Rattus rattus*, and the Shaw's jird *Meriones shawi*. In the CHA, only nine mammal species are not threatened and are abundant or more abundant: the wild boar *Sus scrofa,* the African wolf *Canis lupus lupaster*, the least weasel *Mustela nivalis*, the Algerian hedgehog *Erinaceus algirus*, the cape hare *Lepus capensis*, the house mouse *Mus musculus*, the striped rat *Lemniscomys barbarous*, the brown *rat Rattus rattus*, and the Barbary ground squirrel *Atlantoxerus getulus* (Figure 4).

Figure 4. Some mammals of the CHA: (1) the red fox , (2) and (3) the African wolf, (4) the Barbary ground squirrel, (5) the wild boar, and (6) wild cat. the common genet in CHA, Morocco (Photographed by the author).

The distribution of the endangered Barbary macaque the CHA is restricted to 10 small areas in the main valleys **[12,23-24].** El Alami *et al.* **[12]** sighted a total of 35 groups and counted a total of 644 individual in this area. They also indicated a dramatic decline of the Barbary macaque populations and that the remaining Barbary macaque habitat forests become increasingly fragmented in the CHA. *Macaca sylvanus* is actually restricted to small and fragmented habitats in the Moroccan Rif, Middle and High Atlas, and in the Algerian areas of Chiffa, Grande Kabylie and the Petite Kabylie **[47]**. A very large number of studies indicated that this primate is in decline **[12-13,24,28,48,36,49-52]**.

Results of field observation and from interviews with local people showed that wild boar are currently very abundant in the CHA, and that the species mainly occupy mixed forests of *Quercus ilex, Arbutus unedo, Tetraclinis articulata, Juniperus oxycedrus* and *Juniperus phoenicea.* The range of wild boar in the CHA continues to increase and this animal causes today important damage to the harvests **[32]**. In addition, the number of cases of attacks of inhabitants by wild boars continues to increase during the two last decades **[32]**. The species are today known to cause extensive damage to crops and are a major concern to the local populations. this study has shown that the increase in wild boar populations is due to the regression of its natural predators, the high adaptability of this mammal and the destruction of its natural habitats. However, wild boars play complex and important ecological roles. The regulation of wild boar populations depends on a good understanding of the dynamism of the factors that influence its population.

The last population of the Cuvier's gazelle in the CHA occurs in the high summits of the mountains of Ait Tamlil and Anghomar **[26]**. The species is threatened by overhunting and habitat destruction. In Morocco, this species is threatened by overhunting, habitat destruction, a highly fragmented population and the risk of local extinction **[24]**.

In the CHA, the Eurasian otter occurs in the river of Oum Er Rbia and its tributaries, especially Oued El Abid, Oued Ahansal, and Oued Tassaouat **[24,27]**. In the Middle Oum Er Rbia River, otters are facing extreme threats by human-induced habitat destruction, in particular gravel and sand extraction from the river bed, disturbances by local people, pollution, low water quality and vegetation burning **[27]**.

The last observation of the striped hyena in the CHA Mountains was in 2000 and the majority of researchers have believed that the species has completely disappeared from this area. On 20 April 2022, however, an adult hyena was killed by an inhabitant in the region of Faryata, in the CHA **[29]**. Our previous studies **[17,29]** showed that the range of the striped hyena has declined in this area and that the greatest threats to the long-term survival of this carnivore are overhunting, habitat destruction and highly fragmented populations.

3.2. Major threat to mammal species:

3.2.1. Habitat loss, degradation and fragmentation:

The effects of human activities and the human-wildlife conflict may act as factors in the deterioration of natural habitats and the decline of biodiversity. The destruction and degradation of forest habitats is the most serious threat to mammal populations in the CHA **[12-14,17,26-33,44,46].** Habitat loss, fragmentation and degradation have been caused by domestic and industrial consumption of wood, use of fire, clearing for cultivation and overgrazing by sheep and goat herds **[12]**

(Figure 5). As deforestation for agriculture and overgrazing continues, the remaining forest becomes increasingly fragmented. Consequently, mammals are now restricted to small, fragmented relict habitats. In Morocco, severe habitat loss, fragmentation and degradation have been reported in many regions **[53-56]**. In the CHA, the mammal populations are fragmented to several isolates and the sub-populations are completely separated by large distances. For example, the Barbary macaque population is fragmented to eight isolates in the CHA **[12-13,23-24]**. In the other regions of Morocco, populations of this species are small and highly fragmented, with large gaps (up to around 500 km) existing between them. The Barbary sheep, the Cuvier's gazelle and the Dorcas gazelle are have been extirpated from many regions, they currently survive in small fragmented isolates in this area **[24,26]**.

The flow of the main rivers of the CHA has decreased in the last decade. The low flow is due to the building of dams, to water abstraction for irrigation and to river flow droughts. Rivers receive agricultural drainage from agricultural lands and the treated and untreated industrial and domestic wastewater from many towns and villages. In addition, some rivers of the CHA also are subject to heavy exploitation due to sand and gravel extraction and our results showed that the banks and the bed of the Middle Oum Er Rbia river are extensively exploited by humans **[27]** (Figure 5). This study indicated a dramatic decline of *Lutra lutra* population in this region since the companies began extracting sand and gravel from the river. The removal of riparian vegetation has been one of the major impacts on the river ecosystem **[57]**.

1 **2** **3** **4**

Figure 5. Mammal habitat degradation in the CHA, Morocco: 1 and 2. forest degradation, 3. destruction of the Middle Oum Er Rbia river, and 4. negative effects of overgrazing (Photographed by the author).

3.2.2. Drought, climate change and pollution:

In the CHA, as in many regions of Morocco and of the world, climate change is making droughts more frequent, severe, and pervasive. It is also contributing to more water shortages. Water scarcity (Figure 6) is a serious problem to ecosystems and wildlife. For example, the filling rate of the Bin El Ouidane dam, one of the main dam of the CHA and of Morocco, was only 10% in 2022 (Figure 6). In many regions of the CHA, shepherds have increasingly settled near water sources. As shepherd tribes move into the forest, they often enclose open water sources with cement walls to be able to extract water for their herds. As a result, wildlife, including mammals, has been excluded from water sources in areas where it was previously accessible to them.

River pollution has increased rapidly in the past few years in the CHA. For example, we reported in 2020 [45] that the Oued Oum Er Rbia, one of the major rivers of Morocco, was polluted by olive mill wastewater (Figure 6). These olive oil mills produce, as a waste material, a dark liquid rich in toxic substances **[58]**. Another study **[59]** showed that The vulnerability of water resources pollution of the River of Oum Er Rbia and its tributaries is due to strong agricultural and industrial activity including oil mills, phosphate extraction, livestock farming, and sugar beet processing **[59]**. The pollution of the Oued Oum Er Rbia River by olive mill wastewater may have serious consequences on *Lutra lutra* and their survival **[27]**. In this area, the decrease in water availability is among the main factors responsible for extinction and the decline of the Barbary macaque in some regions such as in the reserve of Tazerkount, located in the central High Atlas **[40]**.

1 **2** **3** **4**

Figure 6. Drought (1. the Bin El Ouidane dam, 2. the Oum Er Rbia river) and pollution of the Middle Oum Er Rbia river (3 and 4) (Photographed by the author).

3.2.3. Illegal capture, killing and trade of mammals:

Several studies showed that the capture and the killing of wild mammal species, especially the Barbary macaque, the Cuvier's gazelle, the Dorcas gazelle, the striped hyena, the red fox, the Algerian hedgehog, the Barbary ground squirrel, the African wolf, the least weasel, the common genet and the cape hare are present in the CHA **[12-14,17,26,28,31-32,46]** (Figure 7). Live mammals, such as Barbary macaque infants, are sold to foreign tourists or trainers of monkeys [40] and carcasses of death mammal are used for traditional medicine and in magic **[17]** (Figure 8). In the CHA, the inhabitants continue to use illegal techniques such as poisoning and the firearms for killing wild mammals, especially the carnivore species, the wild boar, gazelles, and the cape hare (Figure 9). They use other techniques, such as animal trapping, to capture mammals, especially the Barbary macaque, gazelles, wild boars, the cape hare, and the Barbary ground squirrel (Figure 9). Detrimental effects of poaching include the spread of zoonotic diseases, endangering species, and in some cases causing population decline or extinction. Morocco's High Commissioner for Water and Forests and the Fight against Desertification has developed several measures actions to combat illegal wildlife trade. The capture of macaques is present in regions in the High and Middle Atlas, and in the Rif **[12,31,60-62]**. The capture of wild Barbary macaques has a direct impact on its wild population. Foulquier **[63]** showed that the populations of Barbary macaques in the Middle Atlas have a very low reproduction rate and that the abnormally low proportion of young individuals due mainly to human impact and capture of macaques.

1 **2** **3** **4**

Figure 7. A Carcass of the African wolf (1) and of the common genet (2) killed by inhabitants, adult hyaena killed by inhabitants (3), and young Babary macaque captured by an inhabitant in the CHA (a, b, and d: Photographed by the author).

Figure 8. Wild native mammal body parts displayed for sale in traditional markets of the CHA (the Cuvier's gazelle, the Dorcas gazelle, the striped hyena, the red fox, the crested porcupine, the Algerian hedgehog, the Barbary ground squirrel, the African wolf, the least weasel, and the cape hare) (Photographed by the author).

1 **2**

Figure 9. Some techniques for killing wild mammals in the CHA: 1. a trap designed for the capture of wild boars, 2. bullets used to hunt animals, found in areas where hunting is prohibited (Photographed by the author).

3.2.4. Effects of tourism activities:

Several mammal species live in tourist regions in the CHA, such as the Barbary macaque, the wild boar, the Eurasian otter, and the red fox. In tourist sites, the mammal biodiversity can facilitate ecotourism, but the inclusion of human food and human disturbance often results in the modification of mammals' behaviour and ecology **[31,36,38,42].** For example, Barbary macaque groups living in tourist sites (Figur 10) showed a lower-energy search strategy that minimized foraging and moving, allowing more resting time **[36].** In addition, the tourist groups showed more aggressive behaviour, which were likely related to higher levels of competition for the clumped human foods it consumed and that Barbary macaques exploit additional food resources to become more omnivorous **[28,36,40].**

1 **2**

Figure 10. Barbary macaques feed on garbage (1) and anthropogenic disturbance of macaques in the tourist site of Ouzoud, CHA (Photographed by the author).

3.2.5. Human-mammals conflict:

In the CHA, there are increasing problems of conflict between inhabitants and wild mammals. In this area, several species are viewed unfavourably due to crop raiding or livestock depredation (Table 2). In the study area, the main mammal species responsible for crop raiding and the competition with livestock for food resources are the wild boar, the Barbary macaque, and the rodent species. Crop raiding and livestock depredation incur a heavy economic loss to the villagers, resulting in negative attitudes toward wild mammals. The main mammal species responsible for livestock depredations (Figure 11) are: the African wolf, the red fox, the common genet, the Eurasian otter, and the least weasel. This study confirmed that the predation of domestic animals is the greatest source of conflict between humans and wild mammal carnivore species. Consequently, local people generally have negative attitudes about these predators. To protect their livestock, local people hunt and kill carnivores, and these killings are a primary threat to many carnivore species. Today, human-carnivore conflicts are a global problem, it occurs in different forms all over the world **[64].**

In the CHA, the wild boars and the Barbary macaques use large parts of their home range very infrequently, concentrating their activities around and within crops. In this region, the decrease and loss of the availability of natural resources are compensated by crop-raiding and this has generated a permanent conflict with local people. In many regions of CHA, the Barbary macaques are viewed unfavourably and this is mainly due to crop raiding and the competition with livestock for food resources **[42,65-67]**. In the CHA, there is a conflict between local people, especially fishermen, and otters due to the competition for fish, and that there is an increase in negative interactions between otters and inhabitants **[27]**.

Table 2. Main mammal species known to destroy to agricultural crops or to cause damage on livestock in the CHA.

Species	Human-mammals conflict causes	References
The wild boar *Sus scrofa*	Destruction of agricultural crops; attacks on humans; competition with livestock.	El Alami, 2019 **[32]**
The Barbary macaque *Macaca sylvanus*	Crop raiding, competition with livestock, competition with humans for wild berries and fruits.	El Alami *et al.,* 2013; El Alami, 2014; El Alami and Chait, 2014, 2015, 2018 **[12,31,40,42,43]**
African wolf *Canis lupus lupaster*	Livestock depredation (goats, sheep, and cows).	El Alami, 2016; El Alami *et al.,* 2021, 2023; El Alami and Fattah, 2021 **[14,16,17,46]**
The red fox *Vulpes vulpes*	Predation of domestic poultry and rabbits, and on domestic bird eggs.	El Alami, 2016; El Alami *et al.,* 2021, 2023 **[14,16,46]**
The least weasel *Mustela nivalis*	Predation of domestic birds and their eggs.	El Alami, 2016 **[16]**; this study
The Eurasian otter *Lutra lutra*	Competition with humans for fish.	El Alami *et al.,* 2020; El Alami and Fattah, 2020 **[27,45]**
The Common genet *Genetta genetta*	Predation of domestic poultry and rabbits.	El Alami, 2016; El Alami *et al.,* 2021, 2023 **[14,16,46]**
The Algerian hedgehog *Erinaceus algirus*	Predation of juvenile birds and bird eggs.	El Alami, 2016 **[16]**; this study
The Barbary ground squirrel *Atlantoxerus getulus*	Crop raiding of almond fruits.	El Alami, 2016 **[16];** this study
Rodents (excluding the Barbary ground squirrel)	Damage in cereal crops.	El Alami, 2016 **[16]**; this study

1 **2**

Figure 11. Corpses of a sheep (1) and a goat (2) attacked and killed the African wolf in the central High Atlas of Morocco (Photographed by the author).

3.3. Ecological consequences of mammal biodiversity loss:

Mammals have important roles in the food webs of practically every ecosystem. They are important pollinators and important predators and dispersers of seeds and fruits. The removal of mammal species can have major impacts on ecological communities, destabilizing ecosystems and their food webs. The extinction and decline of mammals have negative impacts on ecosystems and on economic activities of local people. In the CHA, Barbary macaques are an essential component of natural ecosystems, contributing to forest regeneration and restoration. The removal of Barbary macaques can have major cascading impacts on ecological communities **[28,39-40]**. Artiodactyls play important ecological roles. They promote seed dispersal in a large number of plants, accelerate the regeneration of some plant species, they are predators of insects, and they play an important role in the aeration of soil. In the CHA, carnivore species have major roles in the regulation of prey populations, especially the wild boar, rodents, reptiles, birds, mollusks, and insects. Carnivores can reduce herbivore species and this regulatory role is important for maintaining vegetation. Herbivores also affect ecosystems through consumption of vegetation, and by acting as key prey for predators. Rodents play a key role in spurring growth of new trees in the forest by spreading seeds. Populations of animal species that eat insects (mammals, amphibians, birds, arachnids, reptiles and other insects, etc.) are often limited by the amount of insect food available to them.

In the CHA, the population of wild boar increased significantly and this increase is due mainly to the decline of its natural predators **[32]**. The populations of the predators of wild boar have declined, especially the panther, the African wolf and the red fox **[14,17,23-24,46]**. Actually, the wild boar is considered the main pest animal in this area and it has a negative impact on biodiversity and causes important damage to the agricultural harvests **[16,32]**. Several studies showed that the persecution of predators resulted in their decimation, and consequently affected the structure of animal communities **[68]**.

3.4. Economic consequences of mammal biodiversity loss:

The extinction and decline of mammals have negative impacts on natural ecosystems of the CHA. Biodiversity loss and ecosystem degradation can degrade ecosystems, diminishing ecosystem services of value to society (loss of natural capital). The Mountain ecosystems of the CHA are strategic for Morocco because of their various socioeconomic and ecological roles. They are living and working environments for local populations, they provide water for irrigation and fresh water for most of the urban population living in the lowlands, and they are the source of wood and of various forest products. Water resources of the region are extremely important, as they are used in the strategic economic zone of Morocco (Tadla, Doukkala and the inshore zone Casablanca-Safi). The Beni Mellal-Khenifra Mountains are the source of many important Moroccan rivers, especially the Oum Er Rbia River and its the tributaries. This River is one of the major rivers in Morocco and is 550 km long. The most important tributaries of the Oued Oum Er Rbia River are Oued El Abid, Oued Derna, Oued Tessaoute, Oued Lakhdar, Assif Melloul and Oued Ahansal Rivers. The Oum Er Rbia River and its tributaries have 15 dams with a water capacity of 5 100 Million cubic meters, which represents 33% of the water capacity of Morocco. According to the Hydraulic Basin Agency of Oum Er Rbia, the total irrigated area by Oum Er Rbia River and its tributaries is approximately 323 000 hectares, and the hydropower production in the Hydraulic Basin of Oum Er Rbia is about 1 887 Million kilowatt hours (kwh) per year (70% of hydropower production in Morocco). Water of the rivers and dams of the CHA is used to irrigate crops and pastures and provides domestic and stock water to dry land farms; it is critical to agricultural production in many Moroccan regions, especially the plain of Tadla. This plain covers an area of approximately 3 600 km² and is one of the most fertile plains in Morocco. This plain is a source of a large number of agricultural products, which plays a very important role in Morocco's economy. Healthy ecosystems of the CHA are essential for sustainable development in Morocco. Biodiversity conservation is the first step towards the protection of ecosystems in this area and of the sustainability of their economic, social and ecological services.

3.5. Mammal species conservation:

Conservation efforts on behalf of the mammal species should consider the local people's opinion regarding human-mammal conflict and the advantages and disadvantages of their presence, the ecology and ethology of mammal species in human modified environments. To conserve mammal species in the CHA, urgent actions may need to be taken. It is important to help young people living in the villages to continue their studies in order to increase their possibility to access good jobs providing adequate wages and social security benefits, and consequently, they will become less abundant from the exploitation of habitats. The initiation of development projects and the rural education action plans revives local economies. It is important to involve residents to protect livestock and crops from wild mammals, such as a livestock guard dogs, monitoring and pasturing of livestock, agricultural fences, and natural repellents (fish or garlic natural emulsion; lavender, soybean, peas, and beans; smoke; Chili peppers; etc.). Education to raise the awareness of the local people about the ecological and economic roles of wild mammals can involve inhabitants, local authorities and associations in the surveillance of the native carnivore species and of local habitats (Figure 12). Scientific research allowed us to better understand the effects natural factors and of humans on wildlife and ecosystems, and to determine the main factors responsible for the species extinction and mammal population decline.

It also is important to establish and manage new protected area, specifically for the endangered species in locations where it is extant, to increase the surveillance of wild habitats to minimize the effects of overgrazing and degradation of habitats due to transformation of forests to cultivated lands, to enforce the existing law against illegal capturing, empoisoning and killing of wild fauna (Figure 12), to conduct more scientific research on the effects of human activities and behaviours on biodiversity and ecosystems, to initiate wildlife volunteering programs in the CHA, to place clear information panels for tourists and sufficient training of the local tourist guides to reduce human disturbance of wild mammals in tourist regions, and to prepare and elaborate compensation programs to assist local people by reimbursing them for losses attributable to wild mammals.

1 **2**

Figure 12. Education to raise the awareness about biodiversity conservation (1) and detection and fighting against the poaching of young Barbary macaques in the CHA (2).

We also note the existence of many tourist sites and of local and artisanal products with a strong territorial link and a real potential for economic development in the CHA. These mountains have a rich and varied geological and biological diversity

and they are rich in sites favourable to ecotourism, geotourism, mountain tourism and to specleology. The encouragement of ecotourism can contribute to sustainable development of the area and to the conservation of biological diversity and of species. The CHA cover the territory of the M'Goun UNESCO Global Geopark, and it includes 22 geosites of exceptional interest: 1. Ait Attab synclinal basin (by Oulad Ayyad), 2. Ait Attab synclinal basin (by Afourer), 3. Bine El Ouidane Lake, 4. Azilal "Chocolate Marnes" training, 5. Ouzoud Waterfalls, 6. Imin Ifri natural bridge, 7. 8. 9. 10. Dinosaur footprints, Iouaridene, 11. Dinosaur footprints, Ait Blal, 12. Rock engravings, Tizi-n-Tighist, 13. Geological landscape at Bougal (Taghia) near Abachkou, 14. Tizi-n-Tighza paleo-dam, entrance to the Ait Bou Guemmez valley, 15. Ace Dinosaur Footprints, Ibaqualliwn, 16. Lamellibranchs of Tizi n Tighrist, Jbel Azourki, 17. Geological panorama of Zaouit Ahançal, 18. Zaouit Ahancal, 19. Ride of Talmest, 20. Ait Abdi Cliff, 21. "Cathedral" of Mastfrane, and 22. Aoujgal cliff granarie. It also contains eight sites of biological and ecological interest: 1. Wabzaza, 2. Ouzoud, 3. Imi n'Ifri, 4. Tamga, 5. Bou Tferda, 6. Assif M'Goun, 7. Haut Oued Lakhdar, and 8. Assif Ahançal-Melloul. The touristic site of Ouzoud (Fig. 13) is one of the most visited sites in Morocco and in the North Africa and the site of Imi n'Ifri is one of the most visited site in Morocco. CHA contains footprints of herbivorous and moving tracks of carnivorous dinosaurs of Iouariden in Sidi Boulkhalf (Fig. 13), they are printed on tilted layers of siltstones of the Iouaridene formation (165 Ma). Moreover, footprints tracks of small carnivorous 'Coelulosaurian', small dinosaurs from the lower Jurassic, are clearly visible on the right side in the road located at few km from Ait Blal.

1 **2**

Figure 13. (1) The tourist site of Ouzoud waterfalls, (2) footprints of dinosaurs in Iouariden, CHA, Morocco (1: Photographed by the author; 2: M'Goun UNESCO Global Geopark site).

The CHA also has a rich and varied patrimony of medicinal plant species. For example more than 80 medicinal plants, used for medicinal purposes in Morocco and worldwide, grow spontaneously in this area [71] (e.g. Fig.14). In the CHA, spontaneous medicinal plants could become potential sources of local economic development.

1 **2** **3**

4 **5** **6**

Figure 14. Some spontaneous medicinal plants of the CHA: *1.Euphorbia resinifera, 2. Pistacia lentiscus, 3. Caralluma europea, 4. Artemisia herba-alba, 5. Ceratonia siliqua , 6. Capparis spinosa , 7. Tetraclinis articulata , 8. Ajuga iva , 9. Rosmarinus officinalis , 10. Thymus sp., 11. Laurus nobilis , 12. Olea europaea L. var sylvestris, 13. Rubia sp., and 14. Hyoscyamus albus.*

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References:

1. Borges, P.A.V., Gabriel, R., Fattorini, S. (2021). Biodiversity Erosion: Causes and Consequences. In: Leal Filho, W., Azul, A.M., Brandli, L., Lange Salvia, A., Wall, T. (eds) Life on Land. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham.
2. *Ceballos, G., García, A., Ehrlich, P.R. (2010). The Sixth Extinction Crisis Loss of Animal Populations and Species. Journal of Cosmology,* 8, 1821-1831.
3. IUCN (2009). The IUCN Red List of Threatened Species. Retrieved from https://www.iucn.org/content/extinction-crisis-continues-apace (Accessed on 08 February 2023).
4. Pimm, S., Jenkins, C. (Eds.) (2009). Extinction and the practice of preventing them. In Sohdi, N., Ehrlich, P. Conservation Biology for All, Oxford University Press, New York, pp. 181-198.
5. Cardinale, B., Duffy, J., Gonzalez, A. *et al.* (2012). Biodiversity loss and its impact on humanity. *Nature*, 486, 59-67.
6. Moroccan Environment Department (2009). Quatrième Rapport National sur la Biodiversité. Secrétariat d'État chargé de l'Eau et de l'Environnement, Département de l'Environnement, Maroc. pp.112.
7. Rankou H., Culham A., Jury S., Christenhusz M.J.M. (2013). The endemic flora of Morocco. *Phytotaxa*, 78 (1), 1-69.

8. Fennane M., De Montmollin B. (2015). Réflexions sur les critères de l'UICN pour la Liste rouge: cas de la flore marocaine. *Bulletin de l'Institut Scientifique, Section Sciences de la Vie,* 37, 1-11.
9. IUCN (2022). The IUCN Red List of Threatened Species. https://www.iucn.org
10. El Alami A., El Alami I. (2018). Les oiseaux du Haut Atlas central marocain- Découverte et inventaire de l'avifaune des montagnes d'Azilal. Les Éditions du Net; ISBN: 978-2-312-06232-7.
11. UNESCO Global Geopark (2017). M'Goun UNESCO Global Geopark (Morocco): Valleys, natural curiosities, fossilised footprints, engravings and authentic Berber villages. UESCO Report.
12. El Alami A., Van Lavieren E., Aboufatima R., Chait A. (2013). A Survey of the Endangered Barbary Macaque *Macaca sylvanus* in the Central High Atlas Mountains, Morocco. *Oryx - The International Journal of Conservation*, 47 (03), 451-456.
13. El Alami, A., Van Lavieren E., Ahmim M., Namous S., Fattah A., Znari M., Chait A. (2021a). Distribution, Population Status and Ecology of the Endangered Barbary Macaque Macaca sylvanus in North Africa. *International Journal of Scientific Research in Biological Sciences*, 8(6), 69-77.
14. El Alami, A., Fattah, A., Bouzekraoui, H. (2021b). Biodiversity, an essential component for the M'goun global geopark development. Journal *of Analytical Sciences and Applied Biotechnology*, 3(2), 103-106.
15. El Alami, A. (2016). Influence de l'Homme sur les populations du magot: Cas du Haut Atlas central. Éditions Universitaires Européennes,
16. [El Alami A. (2016). Les mammifères sauvages actuels et disparus de l'Atlas d'Azilal, Maroc: Distribution géographique, statut et menaces. Éditions universitaires européennes.
17. El Alami, A., Fattah A. (2021). Status, threats and conservation of native carnivores in the M'Goun UNESCO Global Geopark, central High Atlas, Morocco. *Moroccan Journal of Biology*, 18, 1-9.
18. Cabrera, A. (1932). Los mamíferos de Marruecos. Trabajos del Museo Nacional de Ciencias Naturales, Madrid. *Série Zool.* pp. 363.
19. Panouse, J.B. (1957). Les Mammifères du Maroc: Primates, Carnivores, Pinnipèdes, Artiodactyles. *Travaux de l'Institut Scientifique Chérifien et de la Faculté des Sciences-Série zoologique*, 5, 1-206.
20. Heim De Balsac, H. (1948). Etat actuel de nos connaissances concernant la faune des mammifères du Maroc. *Vol. Jubilaire Soc. Sci. Nat. Maroc*, 289-303
21. Valverde, J.A. (1957). Aves del Sahara español. Estudio ecologico del desierto. Instituto de Estudios Africanos, Consejo Superior de Investigacion cientificas. Madrid. 487 pp.
22. Aulagnier, S., Bayed, A., Cuzin, F., Thevenot, M. (2015). Mammifères du Maroc : extinctions et régressions au cours du XXème siècle. *Travaux de l'Institut Scientifique, Série Générale* 8, 53-67.
23. Cuzin F (1996). Répartition actuelle et statut des grands Mammifères sauvages du Maroc (Primates, Carnivores, Artiodactyles). *Mammalia,* 60, 101-124.
24. Cuzin, F. (2003). Les grands mammifères du Maroc méridional (Haut Atlas, Anti Atlas et Sahara): Distribution, écologie et conservation. Thèse de doctorat, Université de Montpellier II, Montpellier, France.
25. Maghnouj, M. (1999). Quelques espèces de mammifères de la cédraie au Maroc : cas du singe magot. *Forêt méditerranéenne* 3, 1001-105.
26. El Alami, A. (2019a). A survey of *the Vulnerable* Cuvier's gazelle in the Mountains of Ait Tamlil and Anghomar, Central High Atlas of Morocco. *Mammalia,* 83(1), 74-77.
27. El Alami, A., Fattah, A. Chait, A. (2020). A Survey on the Eurasian Otter *Lutra lutra* and Human-Otter Interaction in the Middle Oum Er Rbia River, Morocco. *IUCN Otter Spec. Group Bull.*, 37(4), 219-231.
28. El Alami, A., Van Lavieren, E., Chait, A. (2022a). The major threats to the Endangered Barbary macaque Macaca sylvanus in North Africa: Threats to the Barbary macaque. *European Journal of Ecology*, *8*(2), 43-50.
29. El Alami, A., Bouzid, E., Fattah, A. (2022b). Rediscovery of the striped hyaena Hyaena hyaena in the central High Atlas after 22 years. *Oryx,* 56(5), 650-650.
30. Black, S.A., Fellous, A., Yamaguchi, N. and Roberts, D.L. (2013). Examining the Extinction of the Barbary Lion and Its Implications for Felid Conservation. *PLOS ONE*, 8(4), 1-12.
31. El Alami A., Chait A. (2014). Distribution of the Endangered Barbary macaque and Human-Macaque Interaction in the tourist region of Ouzoud, Central High Atlas of Morocco. *African Journal of Ecology*, 53 (3), 375-377.
32. El Alami, A. (2019b). Étude écologique du sanglier S*us scrofa barbarus* et de son impact sur la biodiversité dans les montagnes du Haut Atlas central d'Azilal, Maroc. *American Journal of Innovative Research and Applied Sciences*, 8(1), 24-33.
33. El Alami, A., Fattah, A. (2022). Human–carnivore conflict management in the central High Atlas mountains of Morocco. *Oryx, 56*(1), 10-11.
34. Ouchbani, S., Romane, F. (1995). Gradient climatique et répartition de la végétation dans l'Atlas de Béni Mellal (Maroc). *Bulletin de l'Institut Scientifique*, 19, 53-64.
35. Sauvage, C.H. (1963). Le quotient pluviométrique d'Emberger, son utilisation et la représentation géographique de ses valeurs au Maroc. Annale du Service de Physique du Globe et de Météorologie du Maroc. Institut Scientifique Chérifien, Rabat, Maroc.
36. El Alami A., Van Lavieren E., Aboufatima R., Chait A. (2012). Differences in Activity Budgets and Diet Between Semiprovisioned and Wild-Feeding Groups of the Endangered Barbary Macaque (*Macaca sylvanus*) in the Central High Atlas Mountains, Morocco. *American Journal of Primatology,* 74, 210-216.
37. El Alami A., Chait A. (2012). Seasonal variation in activity budget and diet of the endangered *Macaca sylvanus* in the tourist valley of Ouzoud, Central High Atlas, Morocco. *Mammalia,* 76, 245-250.

38. El Alami A., Chait A. (2013). Comparison of the terrestriality of Barbary macaques (*Macaca sylvanus*) between tourist and wild sites in the region of Ouzoud, Morocco. *Mammalia* 78 (4), 539-542.
39. El Alami A. (2014a). Distribution, démographie et comportement des populations du magot (*Macaca sylvanus*) dans le Haut Atlas central et leurs interactions avec les populations locales humaines. *Ecologia mediterranea*, 4(2), 93.
40. El Alami, A. (2014b) Distribution, démographie et comportement des populations du magot (*Macaca sylvanus*) dans le Haut Atlas central et leurs interactions avec les populations locales humaines. PhD Thesis, Faculty of Sciences Semlalia, University Caddy Ayyad, Marrakech, Morocco.
41. El Alami A., Chait A. (2015a). Variations saisonnières de terrestrialité chez le magot (*Macaca sylvanus*) dans le site touristique des cascades d'Ouzoud (Maroc). *Revue de primatologie* : *Varia*, 6, (2015).
42. El Alami A., Chait A. (2015b). Roles of tourism in the local people opinion regarding human-macaque conflict in the central High Atlas, Morocco. *Revue de primatologie*: *Varia*, 6, (2015).
43. El Alami A., Chait A. (2018). Le macaque de Barbarie dans la vallée touristique d'Ouzoud, Haut Atlas central Marocain : Écologie, éthologie et conservation. Les Éditions CHAPITRE.COM.
44. El Alami, A., Chait, A. (2020). Assessment of Citizens' Knowledge, Attitudes and Behaviours toward Ecological and Environmental Problems in Morocco for Natural Resources Conservation and Sustainable Waste Management. *Journal of Agricultural, Environmental and Veterinary Sciences*, 4(4), 53-70.
45. El Alami, A., Fattah, A. (2020). Olive mill wastewater causing pollution in the Oum Er Rbia River and potential environmental effects and impact on the Eurasian Otter. *Journal of Analytical Sciences and Applied Biotechnology*, 2(2), 110-115.
46. El Alami A., Fattah A., El Alami R., El Alami I., Atif K., Chait A. (2023, "in press"). Assessment of human-canid conflict and suggested mitigation strategy in the central High Atlas Mountains, Morocco. Canid Biology & Conservation.
47. Wallis, J., Benrabah, M.E., Pilot, M., Majolo, B., Waters, S. (2020) *Macaca sylvanus: The IUCN Red List of Threatened Species*. e.T12561A50043570.
48. Camperio Ciani, A., Palentini, L., Arahou, M., Martinoli, L., Capiluppi, C., Mouna, M. (2005). Population decline of *Macaca sylvanus* in the middle atlas of Morocco. Biological Conservation, 121, 635-641.
49. Waters, S., Aksissou, M., El Harrad, A., Hobbelink, M.E. & Fa, J.E. (2007). Holding on the Djebela: Barbary macaque *Macaca sylvanus* in northern Morocco. Oryx, 4, 106-108.
50. Van Lavieren, E., Wich, S.A. (2009). Decline of the Endangered Barbary macaque *Macaca sylvanus* in the cedar forest of the Middle Atlas Mountains, Morocco. Oryx, 44, 133-138.
51. Maréchal, L., Semple, S., Majolo, B., Qarro, M., Heistermann, M., Mac Larnon, A. (2011). Impacts of tourism on anxiety and physiological stress levels in wild male Barbary macaques. Biological Conservation, 144, 2188-2193.
52. Namous, S., Znari, M., Ait Baamrane, M., Naimi, M., Aourir, M., Siess, J., Mokhtari, S. (2017). Size and structure of the southernmost population of the Endangered Barbary macaque *Macaca sylvanus* in the western Moroccan High Atlas. *Oryx*, 51(4), 694-700.
53. Taub, J.M. (1977). Geographic distribution and habitat diversity of the Barbary macaque *Macaca sylvanus*. *Folia Primatologica*, 27(2), 108-33.
54. Fa, J.E., Taub, D.M., Menard, N., Stewart, P.J. (1984). The distribution and current status of the Barbary macaque in North Africa. In Fa J.E. editor, The Barbary macaque: a case study in conservation, Plenum Press, New York, pp. 79-111.
55. Camperio Ciani, A. (1986). La *Macaca sylvanus* in Marocco: sopravvivenza o estinzione. Osservazioni personali e dati storico-demografici. *Antropologia contemporanea*, 9(2), 117-132.
56. Ménard, N, Vallet, D. (1986). Le régime alimentaire de *Macaca sylvanus* dans différents habitats d'Algérie : II – régime en forêt sempervirentes et sur les sommets rocheux. *Revue d'Ecologie (la Terre et la Vie*), 41, 173-192.
57. Mason, C.F. (1995). Habitat quality, water quality and otter distribution. *Hystrix* 7(1-2), 195-207.
58. Hamdi, M. (1991). Nouvelle conception d'un procédé de dépollution biologique des margines, effluents liquides de l'extraction de l'huile d'olive. Thèse de doctorat, Université de Provence, 180 pp.
59. Barakat, A., El Baghdadi, M., Rais, J., Aghezzaf, B., Slassi M. (2016). Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. *International Soil and Water Conservation Research*, 4(4), 284-292.
60. Van Lavieren, E. (2004). The illegal trade in the Moroccan Barbary macaque (Macaca sylvanus) and the impact on the wild population. Thesis report, Msc Primate Conservation, Oxford Brookes University.
61. Van Lavieren, E. (2008). The illegal trade in Barbary macaques from Morocco and its impact on the wild population. *Traffic Bulletin*, 21, 123-130.
62. Waters, S. and El Harrad, A. (2013). A note on the effective use of social media to raise awareness against the illegal trade in Barbary macaques. *African Primates*, 8, 67-68.
63. Foulquier A. (2008). Etude démographique d'une population de (Macaca sylvanus) Dans la région d'Azrou dans le Moyen Atlas. PhD thesis, University of Paul Sabatier, Toulouse, France.
64. Torres, D.F., Oliveira, E.S. and Alves, R.R.N. (2018). Conflicts Between Humans and Terrestrial Vertebrates: A Global Review. *Tropical Conservation Science* 11, 1-15.
65. Namous S., Znari M. Siess J., Aourir M., Hichami N. (2015). Crop-raiding Barbary macaques (*Macaca sylvanus*) in the Ourika Valley, western High Atlas Mountains, Morocco: a case of human-animal conflict. In: Africa Congress for conservation Ecology, El Jadida, Morocco.
66. Namous S., Znari M. (2018). Home range and habitat use of crop-raiding Barbary macaques in the Upper Ourika valley, western High Atlas Mountains, Morocco. *International Journal of Avian & Wildlife Biology*, 3(1), 36-39.

67. Waters S., El Harrad A., Bell S., Setchell J.M. (2019). Interpreting People's Behavior toward Primates Using Qualitative Data: a Case Study from North Morocco. *International Journal of Primatology*, 40, 316-330.
68. Fulgione, D. and Buglione, M. 2022. The Boar War: Five Hot Factors Unleashing Boar Expansion and Related Emergency. *Land* 11(6), 887.
69. El Alami, A., Chait, A. (2016). Étude démographique du magot (*Macaca sylvanus*) dans le site touristique des cascades d'Ouzoud (Maroc). *Revue de primatologie Varia*, 7 (2016).
70. El Alami, A., Chait, A. (2016). Etude de l'alimentation du magot *Macaca sylvanus* dans le site touristique des cascades d'Ouzoud (Maroc) Diet of the Barbary macaque *Macaca sylvanus* in the tourist site of Ouzoud, Morocco. *Revue de primatologie* Varia 7.
71. El Alami, A., Farouk L., Chait, A. (2016). Étude ethnobotanique sur les plantes médicinales spontanées poussant dans le versant nord de l'Atlas d'Azilal (Maroc). *Alge. J. Nat. Products*, 4 (2), 271-282.