



## THE MAJOR THREATS TO THE ENDANGERED BARBARY MACAQUE *MACACA SYLVANUS* IN NORTH AFRICA

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### Abstract.

The order Primates is one of the most species-rich groups of mammals. According to the IUCN, the main threats to primate species are habitat loss and fragmentation, logging, impact of livestock and increased hunting pressure. Primates contribute greatly to regeneration of forests and it is obvious today that great effort needs to be made to conserve the habitats they inhabit. The Barbary macaque *Macaca sylvanus* is the only surviving non-human primate in North Africa. It is actually restricted to small and fragmented habitats in Morocco and Algeria. A very large number of studies indicated that this primate is in decline and its population is estimated to have declined at a rate exceeding 50% over the last three generations. This article aims to review the major threats and challenges to the Barbary macaque conservation. Data were gathered from research articles, scientific books, communications, thesis and PhD dissertations of the authors and of other researchers. Results showed that the major threats to the survival of Barbary macaques are habitat loss and degradation, population fragmentation, capture and trade of macaques, effects of human activities on Barbary macaques' behaviour and ecology, conflict with inhabitants, decrease in water availability to macaques, and infectious disease risks. Based on this review, we recommend several measures to reduce the likelihood of the Barbary macaque becoming extinct in many regions of North Africa.

*Key words:* The Barbary macaque; Morocco; Algeria; population decline; habitat loss; illegal capture; macaque-human interaction; human effects; conservation.

### INTRODUCTION

The world now is facing the potential risk of environmental degradation, pollution and impacts of climate change. In the last decades, the demand for natural resources had increased because of the urban and rural population growth. Consequently, biodiversity has been declining at an alarming rate. Currently, there are more than 142 500 species on The IUCN Red List, with more than 40 000 species threatened with extinction (IUCN 2021). Therefore, appropriate actions and measures should be applied to preserve wildlife and ecosystems. North Africa has a rich and varied biological diversity and it contains several mammal species. In this region, the only surviving non-human primate is the Barbary macaque *Macaca sylvanus*. This macaque is the only macaque species

that occurs beyond Asia (Fooden 1982). It inhabited the southern parts of Europe and all of North Africa (Joleaud 1931; Delson 1980; Fa 1984; Camperio Ciani 1986a; Majolo et al. 2013) and is now restricted to small and fragmented habitats in the Moroccan Rif, Middle and High Atlas, and in the Algerian areas of Chiffa, Grande Kabylie and Petite Kabylie (El Alami et al. 2021). This macaque occupies a wide range of habitats. It occurs mainly in cedar and oak forests, but it can also be found in habitats with junipers, Aleppo pine, Barbary thuya, and in Mountain ridge (Drucker 1984; Fa et al. 1984; El Alami et al. 2013). Several groups of Barbary macaques live in tourist sites, where they are affected by the presence of visitors providing food to them (Fa 1981; 1982; Unwin & Smith 2010; Maréchal et al. 2011; El Alami

et al. 2012; El Alami & Chait 2013).

The total Moroccan Barbary macaque population is now estimated to be 5 000–6 000 (Waters et al. 2007; van Lavieren & Wich 2009), a large decline since 2003, when the Moroccan population was estimated to be c. 10 000 (Camperio Ciani & Palentini 2003). The Algerian population was recently estimated to be c. 5 075 – 6 200 (Ahmim & Labiod 2020). A very large number of studies indicated that this primate is in decline. Its population is estimated to have declined at a rate exceeding 50% over the last three generations (Wallis et al. 2020). Several recent studies concluded this decline on habitat destruction, impact of livestock grazing, the population fragmentation, the illegal capture of macaques and the effects of human activities on Barbary macaques' behaviour (Cuzin 2003; Camperio Ciani et al. 2005; Waters et al. 2007; Van Lavieren & Wich 2009; Maréchal et al. 2011; El Alami et al. 2012, 2013; Namous et al. 2017). *Macaca sylvanus* has been classified as an endangered species (Endangered A2bcd) on the IUCN's Red List (IUCN 2021) and was listed in CITES Appendix I (CITES 2017). Barbary macaques are an essential component of North Africa ecosystems, contributing to forest regeneration. The removal of Barbary macaques can have major cascading impacts on ecological communities (El Alami 2014). In recent years, the roles of these monkeys in their ecosystems have been more widely appreciated. This article aims to review the major threats and challenges to the Barbary macaque conservation in North Africa.

#### MATERIEL AND METHODS

The Data were gathered from research articles, scientific books, communications and PhD dissertations. Publications about the main threats and challenges to the Barbary macaque conservation were searched using bibliographic databases (Scopus, Crossref), academic search engines (Google Scholar and Semantic Scholar), and academic social networks (ResearchGate and Academia.edu). From 10 January 2021 to 25 January 2022, we searched all types of publications using search terms in English and French (e.g. *Macaca sylvanus*, Barbary macaque, Barbary macaque decline, Barbary macaque threats, Barbary macaque conservation, Barbary macaque ecology, Barbary macaque behaviour, Barbary macaque and human impacts, Barbary macaque habitats, Barbary macaque facts, Barbary macaque problems, Barbary macaque in Morocco and Alge-

ria, Barbary macaque in North Africa, etc.). Then we sorted search results from most recent to oldest articles and we selected publications related to the topic of this paper. This review paper is based on 12 published works of the authors and on 44 publications of other researchers.

#### RESULTS AND DISCUSSION

Results of this review showed that the most serious threat to *Macaca sylvanus* is the destruction and degradation of its natural habitats. Barbary macaque populations are also threatened by the impacts of habitat fragmentation, capture and trade of macaques, effects of human activities on the Barbary macaques' behaviour and ecology, decrease in water availability, and by infectious disease risks.

#### Habitat loss and degradation

The destruction and degradation of the Barbary macaque's forest habitat is the most serious threat to the species (Wallis et al. 2020). Severe 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 (Taub 1977; Fa et al. 1984; Camperio Ciani 1986b; El Alami et al. 2013). In the Moroccan Middle Atlas, severe habitat loss is mainly caused by extensive logging of cedar trees, occurring within and outside national parks (Wallis et al. 2020). In this region, the population decline is attributed to the loss of cedar forests, which has significantly decreased due to the growing impact of overgrazing and consequent forest degradation (Camperio Ciani et al. 2005). This study reported that only 14% of the terrain surveyed could be classified as intact. In the Moroccan High Atlas, the main factors responsible for the decline of the Barbary macaque are the habitat degradation and the impact of livestock grazing (El Alami 2014). As deforestation for agriculture and overgrazing continues, the remaining forest becomes increasingly fragmented. Consequently, the Barbary macaque is now restricted to small, fragmented relict habitats (Cuzin 1996, 2003; El Alami et al. 2013; Namous et al. 2017). In Algeria, habitat degradation is among the main threats to the survival of Barbary macaques (Wallis et al. 2020; Ahmim & Labiod 2020).

Natural habitats of the Barbary macaque are characterized by a greater specific diversity and a better temporal distribution of resources. As deforestation for agriculture and overgrazing continues, the re-

maining habitats become increasingly fragmented. Habitat loss and degradation negatively impact the ecology and behaviour of Barbary macaques. For example, in the Middle Atlas of Morocco, Barbary macaques stripped bark and sucked male flowers to get sap and the increase in bark stripping would likely result from a decrease in plant species diversity, due to an increased human pressure, which induces a low dietary diversity (Ménard & Quarro; 1999). The habitat degradation also may affect the ability to adapt to extreme conditions such as low temperatures, strong winds and precipitation during winter. McFarland and Majolo (2013) reported the death of 30 wild Barbary macaques during an exceptionally cold and snowy winter of 2008-2009 in the Middle Atlas. To minimize negative impacts of logging on Barbary macaque sleeping areas, Campbell et al. (2018) suggested avoiding logging in topographical depressions and maintaining cedar densities greater than 250 per hectare with average breast height greater than 60 cm.

#### Population fragmentation

In North Africa, the Barbary macaque survives today in the Moroccan Rif, Middle and High Atlas, and in the Algerian areas of Chiffa, Grande Kabylie and the Petite Kabylie. Algerian and Moroccan populations are small and highly fragmented, with large gaps (up to around 700 km) existing between them. In Algeria, seven widely separated isolates remain today in Chiffa, Bejaia, Djurdjura, Aqfadou, Kerrata, Babors and Guerrouch and this sub-populations are completely separated by distances of 50-200 km. Von Segesser et al. (1999) reported that the Algerian Barbary macaque population had a mean expected heterozygosity of about 65%.

In Morocco, the Barbary macaque populations living in the Rif, in the Middle Atlas and in the High Atlas are now completely separated by distances of 50-500 km and within the three areas, the remaining isolates are also separated by distance and by other barriers to migration of macaques (El Alami et al. 2021). The High Atlas population of *Macaca sylvanus* is now distributed in three geographically separated areas: the western High Atlas, the central High Atlas and the oriental High Atlas. In the central High Atlas, the population is fragmented to eight isolates: two isolates in Oued Lakhadar, two in Oued Ahansal, one in Ouzoud, two in the Middle Oued El Abid, and one isolate in the High Oued El Abid (Cuzin 2003; El Alami et al. 2013; El Alami 2014). In the western

High Atlas, Cuzin (2003) defined two isolates, one in the northern Ourika and the second in southern Ourika. Recent data (Namous et al. 2017) reported that all groups living in the region of Ourika constitutes a single population. In the oriental High Atlas, according to the data available (Cuzin 1996, 2003), there are two isolates: one in the national park of the oriental High Atlas and a second population in the reserve of Tagoulalelt. In the Rif, the distribution of the Barbary macaque is restricted to seven regions 1. Djebel Moussa, 2. Fath Lemhar, 3. Djebel Buzetune, Kelti Kaiat, Sidi-Salah, 4. Djebel Bouhassim, 5. Djebel Tazonte, 6. Djebel Tissouka, Lakraa, Talassemmane, 7. Djebel Tizirene (Taub 1977; Fa 1982; Fa et al. 1984; Waters et al. 2007). According to the data currently available on habitats, the population of the Rif may be divided into separate isolates. In the Middle Atlas, population is now distributed in three geographically separated areas: the eastern zone, the central zone and the southern zone. In the eastern zone (Tamjilt, Taffert, and Tahafourt), Barbary macaques are rare and it is about 100-200 individuals survived in this desolate region (Fa et al. 1984). The population living in southern zone (region of Midelt, Tounfite, El Ksiba), is separated from the central zone of the Middle Atlas by a large barren plain lying in southern curve from Khenifra to Midelt. The central zone of the Middle Atlas contains the majority of all North African population of the Barbary macaque. According to the data currently available on habitats, only small parts of forests are still relatively intact and undisturbed, with the remaining forests degraded or highly degraded and the latter unsuitable habitat for macaques (Camperio Ciani et al. 2005). We can therefore assume that the Barbary macaque population living in the central zone of the Middle Atlas is fragmented into several isolates.

#### Capture and trade of macaques

Several studies showed that the capture of macaques is present in the central High Atlas (El Alami et al. 2013; El Alami & Chait 2014) in the Middle Atlas (Van Lavieren 2004; 2008), in the Rif (Waters & El Harrad 2013) and in many localities in Algeria (F. Belbachir pers. comm. 2007). Infant of *M. sylvanus* are offered both openly and covertly for sale on markets across Morocco (Wallis et al. 2020) and captured macaques are sold to foreign tourists or trainers of monkeys (El Alami 2014). An estimated 300 infant macaques were smuggled into Europe annually in the first decade of the millennium (Van Lavieren

2008). Although legislation in Morocco and Algeria prohibits the trade in Barbary macaques, these animals were found for sale as pets on two websites (Bergin et al. 2018). Van Uhm (2016) reported that criminal networks with a high degree of organization have been found in the illegal trade in Barbary macaques. Foulquier (2008) showed that the last 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 group anthropization and systematic poaching of the young individuals. The High Commission for Water, Forests, and the Fight against Desertification, authorities responsible for the biodiversity conservation in Morocco, collaborates with local people, researchers, and with many non-governmental organizations to confiscate illegally-held macaques.

#### **Effects of tourism activities**

Several Barbary macaque groups live in tourist sites in the central High Atlas (region of Ouzoud), the western High Atlas (region of Ourika), the Middle Atlas (Ifrane, Azrou, Aglmam Azagza, etc.), the Rif, and in many Algerian localities. In tourist sites, the Barbary macaques can facilitate ecotourism, but the inclusion of human food and human disturbance often results in the modification of macaques' behaviour and ecology (Fa 1981; 1982, Unwin & Smith 2010; Maréchal et al. 2011; El Alami et al. 2012; El Alami & Chait 2013; El Alami & Chait 2015a). The study of Maréchal et al. (2011) reported that feeding by tourists may overall have negative impacts on the health of Barbary macaques, being linked in particular to larger body size, elevated stress levels and more alopecia. Barbary macaque groups living in tourist sites also showed a lower-energy search strategy that minimized foraging and moving, allowing more resting time (El Alami et al. 2012). These authors also indicated that 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.

#### **Barbary macaque-human conflict**

In the central High Atlas, there are increasing problems of conflict with inhabitants due to crop raiding. In this area, Barbary macaques are viewed unfavourably and this is mainly due to crop raiding and the competition with livestock for food resources

(El Alami & Chait 2015b). Barbary macaques in the western High Atlas used large parts of their home range very infrequently, concentrating their activities around and within crops (Namous & Znari 2018). In this region, the low availability of acorns is compensated by crop-raiding and this has generated a permanent conflict with local people. In the Ourika Valley, nearly 50% of the diet of macaques in summer was composed of fruits including several cultivated species along with important vegetative parts. The mean annual percent eaten or damaged by the macaques was 30% (Namous et al. 2015). The macaques have a preference for walnuts, plums and apples, yet these differences are likely a result of the frequency and abundance in which the preferred crops are grown as well as time of harvest (Namous et al. 2015).

In the Middle Atlas, human-macaque conflict between forestry and the macaques has arisen because monkeys bark-strip which damage commercially important trees and reduce their value (Camperio Ciani et al. 2001). In this area, human disturbance, especially combination of Amazigh shepherd, dog and sheep/goats, have an effect on Barbary macaque troops ranging behaviour, linked to seasonal effects on their home range (Robert & Lyon, 2012). In addition, macaques avoided areas used by local shepherds, to reduce the risk of attack by shepherds' dogs, but approached roads to increase the chances of provisioning by tourists (Waterman et al. 2019). In the Middle Atlas, Ménard et al. (2014) showed that human pressure had a negative impact on density and that density responded positively to patch size.

In the Rif, young men and boys working as shepherds hunt and kill macaques when they encounter them in the forest (Waters et al. 2019). These authors have developed a successful strategy to stop hunting macaques by sharing general information about the macaques and conducting community projects benefiting villagers' health. Dogs in this area kill macaques and domestic livestock in the forest, and local shepherds believed these dogs to be feral (Waters et al. 2018). Another study of these authors reported three Barbary macaque mortalities that were due (or very likely due) to dogs, but not all dog-macaque interactions ended in the death of a macaque (Waters et al. 2017).

In Algeria, national park officials indicated that the primary problem faced by Barbary macaques is the conflict with mountain settlers, agricultural farmers and crop producers. Growth in human populations in the mountainous regions has resulted in a rise in



infrastructure development in and around these areas, increasing the chances of macaque and human interaction through crop raiding, feeding interactions, as well as vehicle accidents (Benrabah 2015).

#### Decrease in water availability to macaques

In many regions of the Moroccan Middle Atlas, shepherds have increasingly settled near water sources. As shepherd tribes move into the forest, they often enclose open water sources with cement wells to be able to extract water for their herds. As a result, Barbary Macaques and other wildlife have been excluded from water sources in areas where it was previously accessible to them (Camperio Ciani et al. 2001). In the central High Atlas, the decrease in water availability is among the main factors responsible for extinction and the decline of the species in some regions such as in the reserve of Tazerkount (El Alami 2014).

#### Infectious disease risks

Today, several groups of *M sylvanus* live in the tourist sites in Morocco, Algeria and Gibraltar. In addition, increasing human population pressure and decreasing natural resources have enhanced opportunities for contact between humans and macaques. Therefore, the risks of disease transmission between macaques and humans increase. In 2012 a fatal Encephalomyocarditis virus outbreak involving four Barbary macaques occurred at a rescue centre for wild and exotic animals in Central Italy (Cardeti et al. 2016). One study has shown that the studied Barbary macaque was infected with different types of parasites such as *Entamoeba coli*, *Trichuris trichiura* and *Hymenolepis nana* (Benhamouche 2017). The Barbary macaque is susceptible to canine distemper and the disease is often fatal (Martin 1950). Although pathogen transmission from humans to Barbary macaques is seems to be a rare, infections are of great concern and require quick countermeasures from public health professionals in Morocco, Algeria and Gibraltar. Disease prevention programs should be focus on monitoring health parameters in order to reduce the risk of disease transmission to Barbary macaques.

#### CONCLUSION

The major threats and challenges to the Barbary macaque conservation are habitat loss and degradation, population fragmentation, capture and trade of macaques, effects of human activities on Barbary

macaques' behaviour, conflict with inhabitants, decrease in water availability to macaques, and infectious disease risks. Based on this review, we recommend several measures to reduce the likelihood of the Barbary macaque becoming extinct in Morocco and Algeria: (1) conduction of additional scientific research on the ecology and ethology of the species, (2) Manage human-Barbary macaques interactions to increase public tolerance for this primate, (3) encouraging development projects involving local people in the surveillance and conservation of this endangered macaque, (4) provide the public with information on the benefits of Barbary macaques, (5) increasing surveillance of the forests and other habitats of macaques, and (6) implementing disease prevention programs to monitor health parameters in order to reduce the risk of disease transmission to Barbary macaques.

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