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| **B I O L I F E** | **O R I G I N A L A R T I C L E** |
| **Anthropogenic Actions on Population Density of the Barbary Macaques in Eastern Middle Atlas, Morocco**    **Faical Boutlib1\*, Camille M.F. Deman2, Jad Tahouri3, Raja Guemmouh4**    ***1,4*** *Laboratory of Biotechnology and Preservation of Naturals Resources,**Department of life sciences, Faculty of Sciences Dhar el Mahraz, University Sidi Mohamed Ben Abdellah, Fez- Morocco.*  ***2****Moroccan Association for Protection of Heritage and Barbary Macaques, Fez, Morocco.*  *3 Laboratory of Geodynamic and Naturals Resources, Department of Geology, Faculty of Sciences Dhar el Mahraz, University Sidi Mohamed Ben Abdellah, Fez- Morocco* | |
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| **ABSTRACT**  The Barbary Macaque (Macaca sylvanus) lives in the forest biotopes of Algeria and Morocco. It is found mostly in the cedar forests of the Middle Atlas Mountains, where it lives in structured groups. In the Eastern Middle Atlas, in addition to cedar forests, it also lives on rocky outcrops. In these places, the groups are not isolated by habitat degradation and caves are used as dormitories. In the Eastern Middle Atlas, we counted the existing monkeys by a simple scan. The study showed that the remaining populations of monkeys have a large turnover of individuals. We summarize that the high proportion of young individuals and good preservation in the Eastern Middle Atlas. that there is neither strong anthropization of the groups nor poaching of the young macaques.  **Key words:** Anthropization, Barbary macaque, Conservation in situ, demography, Morocco, Eastern Middle Atlas. | |

INTRODUCTION

**T**he Barbary macaque (*Macaca sylvanus*, (Linnaeus 1758) is the only non-human primate in northern Africa. This species is placed into silenus-sylvanus group, one of the four phylogenetic groups (Abegg and Thierry, 2002).This palaeoendemic species was historically distributed throughout the Mediterranean region, but since the Pleistocene (Simons 1972; Camperio Ciani 1986), its population and distribution have shrunk to relict locations in Morocco and Algeria (Fa 1984). Furthermore, studies have shown that this and other macaques have experienced successive bottlenecks during the Pleistocene glaciations (Scheffrahn et al. 1993; Modolo Lara.et al. 2005). Consequently, Barbary macaque is currently listed as endangered in the IUCN red list of threatened species (IUCN 2011).

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Barbary macaque can be found in both low and high elevation areas (Cuzin 2003), occupying a wide range of habitat types including forests, desert dunes, rocky cliffs and summits of high mountains. However, the population density of this species varies widely with habitat type (Fa J.E, Taub D.M., Ménard N., Stewart 1984; Ménard N.1985b; Camperio Ciani 1986; Ménard N.&Vallet 1993a; Scheffrahn et al. 1993). Furthermore, but natural history and literature have shown significant population fluctuation (Taub D.M.1975; 1977; Hodges, 2006; Van Lavieren 2008).

In Morocco, Barbary macaques are found mainly in high-altitude cedar forests in the Middle Atlas, where the population is estimated to be between 10,000-15,000 animals (Mehlman 1989). In the Middle Atlas, which contains 70% of the total population of Morocco (Camperio Ciani 1986), this number has dropped by about 65% over the last three decades (Taub 1977) to 5000 (Van Lavieren & Wich 2009; Ménard et al. 2009). Furthermore, Barbary macaques are distributed in the cedar forests of Sidi M'Guild, Ifrane, and Michlifen, green oak groves of Ain Leuh, El Hammam, between Azrou and Ain Leuh and Aliouane south forests. The population of this species is also found in the mixed forests of cedar and oak in Tamgilt and Taffert in the Middle Eastern Atlas (Boutlib F., Guemmouh R. et Deman C.M.F. 2016). The Barbary macaque can be used as a flagship species for the endangered fauna and flora of Moroccan ecosystems.

Various authors (e.g. Deag 1974; Taub 1975; Drucker 1984) have noted Barbary macaque’s capacities to colonize various habitats due to its great adaptability to a wide range of habitats. On the contrary, these reports did not consider the amount of available resources in these habitats and the dispersal preference of the animal populations. Among anthropogenic actionsthe fragmentation of habitats by overgrazing is responsible for the decline of wild Barbary macaque populations in Morocco. This factor has favored also the isolation of the remaining subpopulations (Hayasaka, Fujii, Horai 1996). Indeed, overgrazing is exacerbated by the succession of years of drought and accentuated by the sedentarization of pastoralists (Mouna M., Arahou, Camperio Ciani 1999). Its increase leads to the loss of biodiversity impacting the ecology of feeding behavior of barbary macaques .The major impact, it should be clear, is caused by the continuous growth of flocks pastured by the Berbers. This growth however contrasts with the extremely poor living condition of this population. The presence of tourists and their frequent physical interactions with Barbary macaque could affect the normal behavior of these primates. This change in behavior manifests itself through the increase in assaults and the reduction of affiliation behaviors. Thus, tourism can increase the level of physiological stress of animals with negative consequences on their health and their reproduction. A study carried out by Maréchal L.et al (2011) has highlighted these impacts on male Barbary macaques in the Ifrane National Park, specifically the factors affecting these animals, namely levels of anxiety and stress. Anxiety levels in males increased with the number of tourists present and with the rate of macaque/human interactions, whether these interactions were neutral, food or aggressive (Maréchal L. et al.2011; Ménard N. & Vallet D.1997). In addition, the supply and feeding of Barbary macaques by tourists by the roadside are increasingly exposed to poaching and traffic accidents and tourism is also responsible for a growing deterioration of the forest environment (Boutlib F., Guemmouh R. et Deman C.M.F. 2016). The main threat to the species (Camperio Ciani et al. 2005), because the destruction of the forest cortege, caused mainly by overgrazing, degrading for crops, logging, increasingly reduces the area of ​​the habitats of the Barbary macaques, thus fragmenting populations of the species in small isolates, thus weakening the whole of the Barbary macaque population (Camperio Ciani, Martinoli L., et al. 2001 ;Ménard and Vallet 1986, 1997; Ménard et al. 2009) in the Middle Atlas, where some forest management practices were considered inappropriate, such as cutting old cedars offering monkey refuges and reducing or eliminating green oak which was an important resource for macaques (Camperio Ciani et Casillo P. 1996).

Therefore, this study aims to investigate and document populations of Barbary macaques in the Eastern Middle Atlas Mountains and compare findings with those of Taub (1977) .The Barbary macaque population of this area was estimated to be between 100 and 200 individuals, reported to be endemic to pockets of cedar and green oak forests and maritime pines to the south of Djebel Tazekka (Taub 1977).For an accurate comparison, we chose the same study area used in Taub (1977, 1978) population studies of this species.

MATERIALS AND METHODS

**Study site**

The Eastern Middle Atlas, located between latitude 33° 30′ 0″ N and longitude 4° 30′ 0″ W, has the highest peaks of the entire Mesa-Atlantic chain (Rahou 1996). This area is noted for relatively high plant species richness, distributed along elevation and geographical gradients. The topography of the Middle Atlas is steep and rocky making it inaccessible.

The Eastern Middle Atlas is the northern part of the Middle Atlas (**Fig. 1**) includes the Tazekka National Park (but macaques were not found in this region). It also includes three sites of biological and ecological interest; Bou Iblane 1 and 2 and Taffert (the existence of the Barbary macaques), El Adrej, Bou Nacer, Jbel Tichoukt (**Fig. 2**).

The Tazekka massif is very humid and has one of Morocco’s highest rainfall. Surrounded by the mountains of Djebel (Dj.) Moussa o Salah (alt. 3218 m), Dj. Bou Iblane (alt.3260m) and Dj. Bou Nacer of the Guelb er Rahal range (approx Alt. 3400m). Guelb er Rahal range dictates the local weather conditions due to rain shadow and the eastern region’s predominant dry arid vegetation. On the humid western aspect, water rushes into the deep valleys creating small rivers and permeates the rock to emerge later as springs. It is a significant water source for the local Moroccan people.

Below Tamgilt in approximately 103 ha of mixed cedar and oak forest; A small area around Taffert at Tine H'lilt; and at Tahafourt approximately 100 ha of mixed cedar forest between 1400-1700m altitude about 5 km south of Herhraoua. In the zone of Tallet, The green oak is mixed with boxwood, red juniper, and Alfa. Maritime pine replaces green oak on marly limestone at approx. 2000m; Cedar is very sparse and low at higher altitudes. (It is well known in the extreme western zone with a subhumid and humid bioclimate, and at Dj Tazekka at low altitude mixed with cork oak and green oak), whereas at Tanemilt there is pure cedar forest; Chamephytes dominate the base altitude; *Alyssum spinosum*, *Bupleurum spinosum* and *Chamerops humilus* at times mixed with green oak and Aleppo pine and reforested areas (valley of OuedTaffert-Karya, and valleys of Oued Mdaoud); Alfa steppes (low altitude southern and Eastern regions, bioindicator of arid and semi-arid bioclimates); Tetraclinae (northern slope of the Jbel Aghezdis in a semi-arid bioclimate); Red Juniper (Oued Beni-Mansour, southern slope of Guelb er-Rahallaisse); Aleppo Pinewood *Pinus halepensis* (Beni Bou-Illoul, Tamgilt, Mukraz and on the southern slope of Guelb er-Rahal in a subhumid microclimate (Fennane 1982).Aleppo pine is sporadic in the region between Bou-Iazitene and Ich Tiffirassine. It covers marly limestone soil in areas associated with *Rosmarinus officinalis*-*Tetraclinetum* spp. (Fennane 1982); In the east of Tamgilt on the southern side, it is interspersed with red juniper and Green Oak. It is also located on the sides of the Rawyana valley; Marine pine *Pinus pinaster* is found mainly in cool and cold subhumid and humid temperate climates, generally on marly and other limestone (Bou Iblane, Bou Nacer); Buxaie (at the bottom of the valleys of Beni-Mansour), Subaery of Bab-Azhar;Thuriferaie (It forms a discontinuous band above the cedar and oak groves in a subhumid bioclimate and the high mountain stage); Xerophytes spinous covers the alpine summits of Dj. Bou Iblane, Dj Moussa o Salah, and the peaks of the Guelb er Raha range,. where we noticed that macaque groups tolerated a sole human to a distance of about 40m when on steep slopes. In this region, the ecosystem appears to be degenerating, with thin, discontinuous cedar and green oak forests of poor quality (Taub 1977; Waters et al. 2015).

# Data Collection

Data collection was carried out between 10th January 2014 and 28th June 2015 within the study areas. Study areas were mapped using a 50 m quadrant grid system based on visibility in the habitat (Ménard et Vallet 1993a). For counting a population of Barbary macaque in the study area, we used stratified sampling by transect method with a line transect (Altmann 1974) and width repeated-transect method (Caughley 1977; National Research Council 1981; Pinto et al. 1993).When we found a group, we stopped and started counting the individuals, I distinguished six age-sex categories (**Table-1**). Adult males are always the last to flee, so we paid special attention to males during group observations (Waters et al. 2015). These males were identified by individually distinct physical characteristics (scars or their box) observed with binoculars at a distance of about 30-40 m.

Table 1. Age-sex class of Barbary macaques used to determine group composition

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| **age-sex class** | **definition** |
| Adult male>5 years | full body size; fully developed testicles |
| Adult female >5 years | full body size; differentiated from males at a distance by the appearance of genitals and/ or presence of elongated nipples |
| Unknown adults >5 years | Adults of unidentified sex; full body size |
| sub-adults>3-5 years old and juveniles >1-3 years old | Blonde in color; slender body; smaller than full body size |
| Infant(6 month - 1 years) | small size; between 20-50 cm |
| Babies (between 0-6 month) | les nouveau-nés ont des poils noirs (-20cm) |

The groups of Barbary macaques were studied in five following sites: 1) Mdaoud (33°44’37 "N; -4, 11 ' 54 ° W). Rocky lawns dominate the stratum of Chamephytes under green oak and Aleppo pine (endemic) and maritime pines (reforested). 2) Karya (33 ° 41'4.15 "N; - 4 ° 13'11.88" W), a forest of green oak and red juniper (east of Tamgilt) (*Juniperus oxycedrus*). 3) Tamgilt (33 ° 35'40.15 "N; 4 ° 1'28.21" W) brushwood of juniper and Aleppo pine (*Pinus halepensis*). 4) (Beni Bou-Illoul) in Tanemilt (33 ° 46'32 "N; 4 ° 12'57" W) Cedar forest (*Cedrus atlantica*). 5) Taffert (33 °39'55 "N;-4°11'40"W) Cedar forest (*Cedrus atlantica*). The latter two sites constitute 75% of the site of Biological and Ecological Interest of Bou Iblane 2 (including the Tanemilt site), while the Taffert site constitutes 100% of the site of Biological and Ecological Interest of Taffert (**Fig. 2**), as it lies outside Bou Iblane 2.

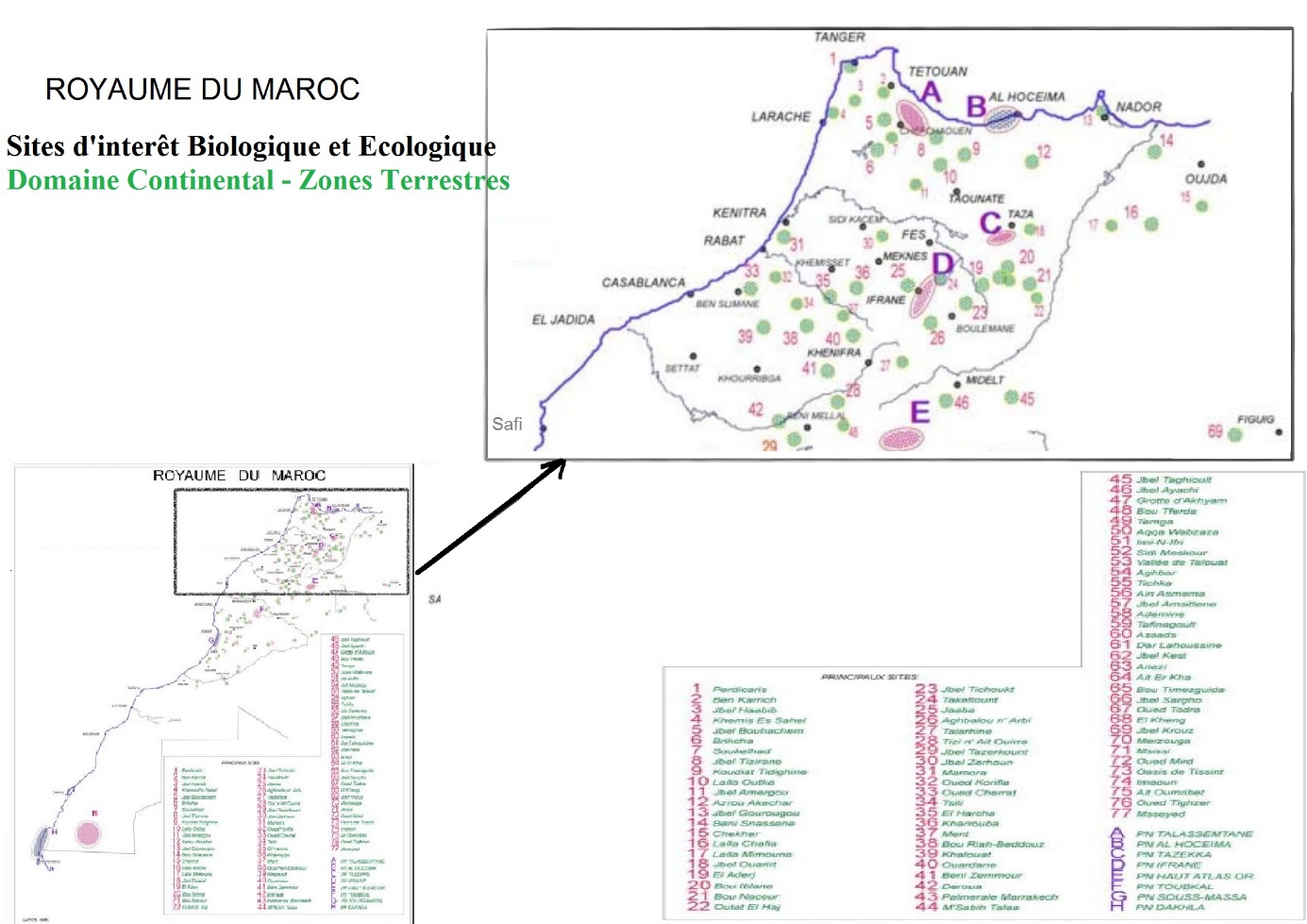
Outside Bou Iblane 1 and 2 lie the Mdaoud and Karya sites which are crossed by one river each (Oued Taffert at Karya and Oued ouled Mdaoud). The floodplains of these rivers are characterized by a great abundance of doum (dwarf palm) (*Chamerops humilus*). In these sites, monkey shelter in caves of the precipitous valley walls due to the absence of Atlas cedar. The GPS locations were recorded for all groups sighted.

Although the importance of the different threats to the monkeys is variable depending on the region considered, human pressure, habitat degradation and loss are identified as the main causes of the decline of this species (Conservation Action Plan for the Barbary Macaque in Morocco, 2012). The effect of the three anthropogenic factors (poaching, grazing, and tourism) and habitat degradation has an effect on the population density of the Barbary macaques in Eastern Middle Atlas. The grazing was measured by an ordinary scale, noting; 0: forest-rich woodland and no sign of goat grazing, bush plants, and turf present; 1: poor undergrowth in the forest, most shrubs modificated by grazing with most herbs removed 2: no presence of grass with the presence of livestock debris. This means the presence of a high grazed route. The degradation of the forest was measured by an ordinary scale, noting; 0: no trace of cutting trees and trees are not sick; 1: there are traces of cutting the trees and the trees are not very sick.The type of forest was measured on an ordinary scale: 2, all cedars or all oak; 1, cedar mixed with oak or oak mixed with another tree; 0.5, rare cedars or rare oak; (Mehlman 1989). For tourism, data were collected by the "scan sampling" method (Altmann J.1974), which collects on the presence of the tourist. Noting by; 1: presence of tourists close to the monkey group (distance ≤ 100 m); 0: absence of tourists. For poaching, the data were collected on an additive scale in the form of a questionnaire targeting indigenous peoples and forest administrations. These questionnaires were measured on an additive scale; 0: no poaching; 1: last poaching of juveniles in more than one year; 2: One or more poaching has been detected in less than one year. Between January 2014 and June 2015, the 325 days (3250 hours including 10 hours per census day) we identified and counted each group based on the morphological characteristics described by Ménard in 1985 and 1993 (Ménard N. et al 1985a, 1993a).

When the groups crossed an open area like a paved road or clearing, we recorded the number and the group’s composition. We distinguished six age-sex categories.

To avoid errors due to the often rapid movement of individual macaques through open spaces, I had to count ten times for each group.Lincoln-Peterson index has been used for to calculate density. ;

Figure 1.Localisation of the Eastern Middle Atlas in northern Morocco



With D is the density of population, N is a total number in the area, S is the land area.

We calculated the sex-ratio (male/females) for all mature and young individuals. We calculated also sex ratio of adults and young/adult females. Data collection was based on noninvasive behavioral observation.

# Statistical Analysis

The data was analyzed in IBM SPSS 21. Regression analysis was used to compare macaque densities across Karya, Tamgilt, Taffert, and Tanemilt in the Eastern Middle Atlas region.

With , are fixed, represents the error.

A non-parametric Mann-Whitney U test was used to compare the home range size and the density of distribution. MANOVA was used to assess the effect of the three anthropogenic factors-poaching, grazing and tourism-and habitat degradation on the population density of the Barbary macaques in Eastern Middle Atlas.

RESULTS

The composition and most complete numbers of each group taken during the survey period are detailed in Appendix A. The size of the macaque groups in this study varied from 16 to 73 individuals (20 groups = 831 individuals) with an average size of 41.55 individuals (**Fig.** 3). Due to the rapid movement of group members, we were unable to identify the sex of some adults. Of those recorded, the average overall adult sex ratio was almost 1: 1.1.06.

DISCUSSION

The abundance of food resources is generally the primary factor determining monkey population density (Iwamoto 1978; Southwick et al. 1983; Altmann et al.1985). The Macaque’s adaptive capacity explains the number and variety of habitats they live in (Deag 1974; Drucker 1984). Group size appears to correlate with group size recorded across similar habitats in different locations. In the deciduous oak forest in Algeria a group of 53 individuals was recorded (Menard & Vallet 1993).

The first study of the density of the Barbary macaque in the Middle Atlas was carried out in 1968 by Deag (1974) in Ain Kahla. He found a density of 70 individuals per km2 (ind/km2) with a focal method similar to ours. In 1977, Taub (1977) evaluated the density at around 44 ind/km2 by a transect method carried out at Ain Kahla and in the Ifrane forest of Ras El Ma and Michlifen. Thirty years later, there was a significant decrease in the average Barbary macaque density from 25-30 ind/km² in 1994, to 7-10 in/km² in 2002 (Camperio Ciani et al. 2001) (**Fig.** 5).

These figures are relatively comparable to those obtained in our study, although the method and the total number are different. Macaques’ densities in the various habitats are declining even faster than habitat degradation itself (Camperio Ciani et al. 2005). The density of the population in the Middle Atlas clearly shows a progressive and drastic decline particularly in cedar habitat and degraded underbrush (Camperio Ciani et al. 2005).

Our results indicate a Barbary macaque population density ranging from three to nine ind. /km², the lowest being observed at Mdaoud and the highest in the Karya place (**Fig.**6).

For a group of wild macaques, the sexes were balanced with a roughly 1:1 female to male ratio per group, and the percentage of young macaques varies greatly depending on habitat. Previously, Menard recorded young macaques in the order of 50% of the group total (Ménard and Vallet 1993a; 1996; Ménard N. 2002); however, we have illustrated that there are between 55% and 161% (Appendix A).

Comparing the groups makes it possible to highlight the important imbalances in group proportions of young versus adults. In this study, we found the adult sex ratio to vary between 1:0.8 and 1:1.3 compared to Drucker’s (1984) data which decreased from 1:1.05 in 1980 to 1:0.36 (Drucker et al. 2002) by 1994 and 1995. The male to female ratio of approximately 1:1.06 is replicated across other species that live alongside macaques in similar habitat and regions of distribution (Ménard and Vallet 1996; Water et al. 2015).

Indeed, retrospective studies by Deag (1974) and Fa et al (1984) in Ain Kahla, (Ménard and Vallet 1996) in Algeria in the Djurdjura National Park and Akfadou, mentioned relatively constant youth/adult ratios. The reduction of the proportion of young macaques in groups of Barbary macaques has been interpreted as a significant indicator of population decline. In these studies, the ratio of young to adult is between 53 and 174% (table 3), with a 50% average across all habitats (**Fig.** 7).

This equilibrium seems very variable between the groups studied and oscillates between 52% and 100%. Southwick et al. (1980) have estimated that when the proportion of young people falls below one and a half times the proportion of adult females, the population begins to decline. Whereas we found that not all populations declined as some groups had an average of twice as many young as adult females (**Fig.**7, **Fig.** 8and **Fig.**9).

In a favorable wildlife habitat, the birth rate is higher than the mortality rate and the population increases

(Ménard and Vallet 1993a). The rapid increase in group size can induce its division into subgroups. Fission and migration are two common phenomena in Barbary macaque populations (Ménard N. et al. 1985b; 1990; Ménard and Vallet 1993a; 1993b). Females generally remain in their native groups and inter-group migration tends to be a male behavior (Paul and Kuster, 1987). Migration of Barbary macaques occurs over short distances (Ménard and Vallet, 1996). In this study, we found a group that had expanded to73 individuals. This group, which is located in the Karya escarpments south of Taffert, has not undergone fission or division into subgroups, despite anthropogenic actions in the region. This directly contradicts the explanations suggested by Ménard et al. (1985a; 1990), Ménard and Vallet (1993a; 1993b).

The proportion of immature animals in the population that survive the dry season (summer) correlates to habitat conditions, such as food availability and predator pressures. We suggest, therefore, that better population demographic indicators are the ratio of immature to mature individuals and the ratio between males to females. We also propose that these ratios are a better way to determine if group fission and migration have occurred. Thus, we can more eﬀectively monitor the decline of this species and its natural habitat (Camperio Ciani et al. 1999; Camperio Ciani and Castillo 2000).

Camperio Ciani (2005) proposed that population density declines due to habitat degradation, overgrazing, tourism and poaching of young monkeys. We postulate that according to our results these factors do not appear to affect population density. The majority of the Eastern Middle Atlas environment is exposed, rocky, water eroded and sometimes inaccessible to humans, with an altitude between 1200m to 3400m. During our study, the topography dictated that we follow the rocky escarpments and ridges similar to the conditions of the Rif’s mountain study conducted by Waters et al. (2015). These areas are impossible to graze, steep and dangerous areas that are

naturally resistant to human interference. Our results show that habitat degradation, overgrazing, tourism and poaching does not cause a decline in population density of Barbary macaques in the region studied (**Table 6**).

The Barbary macaque has been classified as a territorial species (Cooper 2001) however, the frequency of territoriality in wild Barbary macaques varies greatly depending on habitat (Deag 1985). Barbary macaques can have more extensive home ranges averaging between 11.7 ha and 25 ha in the Moroccan Middle Atlas (Fooden 2007; Fa et al. 1986, Drucker 1984) and (Machairas et al. 2003) precisely because of their terrestrial adaptability, topography, and variability of tree cover.

In Djurdjura, the home range was estimated to be 2.8 km² (Ménard & Vallet 1996). The present data show that the home range colonized by Barbary macaques can reach up to 31.2Km2. The population density regression analysis supports this showing that population density is relative to home range size. Home range size differs significantly between groups. It is consistently smaller in nocturnal species compared to diurnal species, and terrestrial species tend to have larger home ranges than arboreal ones. Terrestrial species movements are restricted to two dimensions and their habitats are typically food sparse similarly frugivores tend to have larger home ranges than folivorous.

Comparisons between ecological categories are complicated by the close relationship between home range size and group size (Milton & May 1976). Large home ranges occur where food supplies are widely and sparsely dispersed (Milton & May 1976). Large group size will increase the distance that each individual will have to move per day to collect food (Smith D.G. 1981, Smith, E.O. and Peffer-Smith, P.G., 1982 ); and group size may be affected by the distribution of food supplies (Crook 1972).

The decrease in the density of the Barbary macaque groups may be affected by habitat and resource degradation (Camperio Ciani 2005, Ménard & Vallet 1996). However, in the present study, the adjusted R2 value is proven robust and tested with a different sample from the same population, such that home range size explains almost 94% of the density variation. The regression analysis of the home range size and density reveals that the variation of density of Barbary macaques in Eastern Middle Atlas is very significant. Several hypotheses can be put forward to explain this large population: Their habitat is mainly rocky and inaccessible for shepherds and their sheep; These populations are far from civilization and well protected from anthropization (poaching, overgrazing ...); Climactic conditions are severe. In Bou Iblane the snow remains eight months during the year (wet continental bioclimate), making it an inhospitable human terrain; An abundance of nutritious varied resources.

The objective of this study is to provide information on the current status of the Barbary macaque, a potential emblematic species of the Eastern Middle Atlas.

This study demonstrates the existence of the Barbary macaque in the Eastern Middle atlas with a large population of 831 individuals across 20 groups. This is an even larger population than that recorded in the Rif, where Taub estimated the population of Barbary macaques to be between 100 and 200 individuals (Taub 1975; 1977).

This data provides a reference for a broader survey of the state of conservation of Barbary macaques in the Eastern Middle Atlas. The evidence provided shows that the regions studied; Karya, Mdaoud, Tamgilt, Tanemilt, SIBE Bou Iblane 1 and 2, SIBE Taffert and El Adrej may be key regions for long-term conservation of the species, and that National Park establishment and conservation in situ would be of great benefit to this endangered endemic species.

# Compliance with ethical standards

This study was a purely observational study. All applicable international, national and institutional guidelines for the care and use of animals were followed. All procedures performed in studies involving animals were in accordance with the ethical standards of the institutions at which the studies were conducted.

Conflicts of Interest

Authors declare that there is no conflict of interests regarding the publication of this paper.

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