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POPULATION STRUCTURE, POPULATION DENSITY AND INDIVIDUAL CATCHABILITY OF *TESTUDO GRAECA* IN THE CENTRAL JBILETS (MOROCCO)

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TESTUDO GRAECA
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POPULATION SIZE
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MOROCCO

ABSTRACT. – Accurate information on density, structure and vulnerability of wild populations occupies a central place in conservation biology. A mark-recapture study was carried out during the 2003 activity season in a population of *Testudo graeca* in the Central Jbilets (Morocco). Juveniles were poorly represented in our data set, suggesting that juvenile numbers are actually low in our population and/or that tortoises are easier to capture after the behavioural shift of the acquisition of sexual maturity. Although the studied population was localised in a severely over-grazed area, the estimated adult and sub-adult population density, six individuals/ha, was relatively high comparatively to available estimates in other places. However, within three months of fieldwork, it was possible to capture most of the adults (60%), suggesting that *Testudo graeca graeca* populations are very sensitive to illegal and repeated harvesting. Long-term monitoring of the population is required to better appreciate the demographic trend of this population.

INTRODUCTION

Terrestrial chelonians are characterised by a relative long reproductive life span, a delayed maturity, and a relatively low hatching success and juvenile survivorship. These demographic characteristics render tortoise's populations particularly sensible to the loss of adults. This group is often threatened by human activity: pet-trade, hunting for food, or habitat destruction (Van Abbema 1997) all entails strong erosion in many populations. *Testudo graeca graeca*, from North Africa, Greece and Spain is a typical example of this general trend (Ernst & Barbour 1989, Iverson 1992). Although imprecisely quantified, all experts agree that populations decline markedly in almost all areas (Lambert 1995, Stubbs 1989). In such a context, accurate information on the demographic characteristics and vulnerability of populations are urgently required to eventually pull the emergency cord and to set up conservation plans. We particularly need to better understand the proximate factors responsible of the declines. Unfortunately our current knowledge on the ecology and long-term demographic variations of this species is very limited. For example, intensive studies have been carried out on very few populations, restricted to the northern part of the distribution range, notably in Spain (Donana National Park: Andreu 1987, Andreu *et al*. 2000, Diaz Paniagua *et al.* 1995, 1996, 1997, Keller 1993, Keller *et al*. 1997, 1998) and Greece (Hailey 1988, 1990, 2000, Hailey *et al*. 1988). North African populations remain largely unstudied (Bayley & Highfield 1996, El Mouden *et al*. 2002, Lambert 1969, 1981, 1982; Slimani *et al*. 2002,) whereas the loss of suitable habitats for *Testudo graeca graeca*, mostly due to overgrazing, is particularly important and tends to increase over time (Quezel 2002).

The aim of this paper is to estimate the population density and the population structure of *Testudo graeca graeca* in a typically over-grazed area in central Morocco. Such estimations are essential for comparisons with other modified or preserved North-African areas, both for long-term surveys and on a less protracted time scales to identify the sources of declines. In this paper we also report data on individual catchability as an index of vulnerability of wild populations to intensive harvesting for pet trade.

MATERIALS AND METHODS

Study area: The study area is located in the central Jbilet mountains about 25 Km north of Marrakech, in the western of Morocco (31°37'N, 8°02'W, and an average of 580 m above sea level). The region is arid, with average mean annual rainfall of 240 mm, most of them occurring between September and February (El Mouden *et al.* 1999, Znari *et al.* 2002). Average air temperature in the hottest month (July) can reach 39°C and the minimal annual temperature is normally above 0°C in January (Emberger 1933, Le Houérou 1989). Vegetation consists mainly of Jujube bushes (*Ziziphus lotus*), with some widely scattered Acacia (*Acacia gummifera*) (typical arid vegetation) and retams (*Retama monosperma*). Most of habitat is open, hard bare ground with stony soils on the flats and low hillsides that surround small sandy, pebbly or stony wadies. Seasonal over-grazing by domestic livestock (sheep and goat) strongly affects the vegetation. A simple visual inspection of study area reveals two major and different plant assemblages: a relatively rich and diversified plant community under Jujube, protected against over-grazing by the spiny structure of this shrub, and a lesser diversified plant community out of the Jujube, with a very scattered plant cover.

Animals: From mid February to the end of May 2003, 164 individuals were captured in the field, on a 32.5 ha searching area. Midline carapace length was recorded with a vernier calliper (accuracy ± 0.1 mm). Incising notches in the marginal scutes identified each individual. For short term (<year) and rapid identification, the adults were numbered on the carapace with a non-toxic paint. In our study area, tortoises are protected against illegal harvesting by local populations and there is no natural predator capable to kill the adults; consequently paint marking is unlikely to expose the tortoises to increased mortality. Adult were sexed using classical criteria for Testudinae (Andreu *et al.* 2000, Slimani *et al.* 2002). Chelonian exhibit strong inter individuals variations in age and size at maturity (El Mouden *et al.* 2002, Lagarde *et al.* 2001). In our population, the minimum size for maturity is 100 mm in both males and females (El Mouden *et al.* 2002, Slimani *et al.* 2002). Generally, the minimum size at maturity is larger than the minimum size at which we can determine the sex. Consequently, individuals larger than 100mm in carapace length contain both adults and sub-adults that can be readily sexed. For simplicity, we considered individuals with a carapace length smaller than 100mm as juveniles, without any reference to their sex. In the study area, growth was highly seasonal (El Mouden *et al.* 2002), the number of scute rings provided an accurate age estimate (Castanet & Cheylan 1979, Galbraith & Brooks 1987, 1989, Germano 1998). We counted the scute rings on the second right pleural scute because it generally suffers less from erosion than the others. We counted only those rings that formed around the entire scute. We verified our ability to count these scute rings by comparing scute ring counts from the right pleural scutes, abdominal scutes and marginal scutes. Only consistent data were used in this study. Nevertheless, it was difficult to assess accurately the age of old animals (>20 years) because annual growth rate decreases dramatically, scute rings became very thin and difficult to discriminate. Old animals were grouped in a single age class: > 20 years old.

From 2000 to 2003, all the dead animals we found in the study area were collected and measured.

Capture-Recapture: In 2003, the population was monitored from February to May, during the period of maximal activity (Andreu *et al.* 2000, Slimani *et al.* 2002). Six capture-recapture sessions of 10 days each were carried out from February 15 to the end of May. Population estimates were obtained using CAPTURE (Otis *et al.* 1978). The capture procedure assumes a closed population (i.e. no births, no deaths and no migration) and is generally used for experiments covering short period of time (Otis *et al.* 1978). Because juvenile mortality may be high, we focussed our analysis on males and females with a carapace larger than 100 mm, the minimum size for sexual maturity. Annual survival rates of adults are classically high in adult tortoises population and should not have heavily influenced our estimates. Because the inter individual variations in age and size at maturity is classically high in *Testudo* (Lagarde *et al.* 2001), we can not exclude that some of the animals were sub-adults. That's why we qualify this size class as constituted by adult and sub-adult tortoises together. We can not exclude the possibility of immigration or emigration, our preliminary data showed however that adult exhibit a high philopatry (unpublished data) and that individuals movements remained localized, at least during the 3 months study period. CAPTURE provides the opportunity to test several models, including heterogeneity of captures probability in the population (Mh), time-specific variation in the probability of capture (Mt), behavioural response after initial capture (Mb), and the different combinations between these models (Mth, Mtb, Mbh, Mtbh; Chao *et al.* 1992). The goodness of fit test suggests that the appropriate model would be Mtb. Nevertheless, we rejected this model because it is very unlikely that a behavioural response to capture occurred according to the capture method and the life style of tortoises. Then, the model we used for population estimates was Mth, a model suggesting heterogeneity of trapping probability (according to the influence of reproductive status on behaviour for example), and a time effect on capture probability (according to the climate effect on ectothermic activity) (Lagarde *et al.* 2002). In the results, we first considered non-corrected data that provide an index of the visible part of the population; we then used CAPTURE to better appreciate more realistically the number of individuals that were present during our investigations. The comparisons of different catchability estimates were performed using a Chi2 test. All the statistics were performed using STATISTICA 6.1 computer program.

RESULTS

Visible population structure

The visible age frequency distribution of individuals captured in the field was characterized by the lack of juveniles aged from 2 to 5 years old (Fig. 1). Most of the individuals we observed in the field (74%) were larger than 100 mm in carapace length and 72% more than 7 years old. The age distribution was not significantly different between males and females (Chi-square: 16.6278, d.f=11, p=0.11). Females were significantly distributed in the larger size classes however (Chi-square: 63.4,

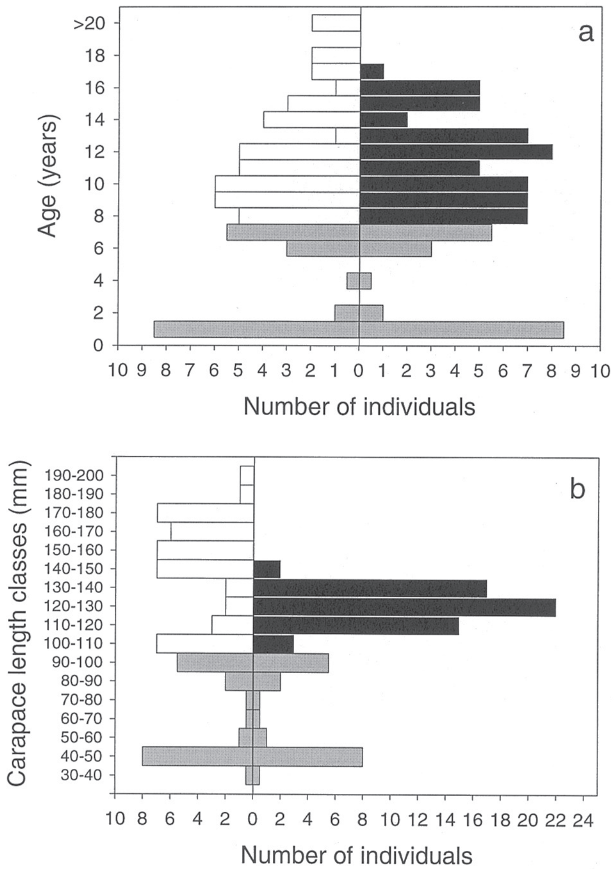

Fig. 1. – *Testudo graeca graeca* population structure in the Central Jbilets, Morocco. Age distributions (1a) and size distributions (1b) were represented for juveniles (grey bars), adult and sub-adult females (white bars) and adult and sub-adult males (black bars).

d.f.=9, p<0.001), the larger females attained 190 mm, the larger males148 mm (Fig. 1).

The visible size distribution differed significantly between dead and live animals in juveniles (Chi-square = 12.63, d.f.= 5, p=0.027), but not in adult and sub-adult males (Chi-square = 1.9, d.f.=9, p=0.42), nor in adult and sub adult females (Chi-square = 9.12, d.f.= 5, p=0.86) (Fig. 1, 2).

Population estimates and catchability

We captured 57 adult and sub-adult females and 72 adult and sub-adult males. The estimated population size was 192±20 (±SD) with a 95% confidence interval ranging from 162 to 246 leading to a 5.9 individuals/ha population density. Approximately two thirds (60%) of the adults and subadults were captured in 3 months. When performed separately on males and females, population size estimates were respectively 121±19 (95% confidence interval 95-175) and 100±18 (95% confidence interval 76-151), giving a sex-ratio of 1.2.

DISCUSSION

Visible population structure

The age (and size) distribution observed in our study population exhibits a pattern typical from Chelonian populations (Fig. 1) (Stubbs *et al.*1985, Stubbs & Swingland 1985), including other *Testudo graeca* populations (Andreu 2000, Braza *et al.* 1981, Diaz-Paniagua *et al.* 2001a,b, Lambert 1982). Notably, most of the individuals that have been captured were adults or sub-adults, juveniles being almost invisible to the investigators, whatever the season. Such a distribution highly biased toward old individuals may be interpreted as an indicator of a low reproductive rate linked to severe population dynamic problems such as an absence of the renewal of the generations (Stubbs & Swingland 1985). We believe that such pattern could be enhanced by the very low catchability of juveniles as observed in many reptiles (Madsen & Shine 2000, Nagy 2000). The number of males and females we caught increased dramatically when the animals approach to the size or age for sexual maturation (Fig. 1). Juveniles are under strong selection to reach sexual maturity; they remain very cryptic and very difficult to catch whereas adults exhibit a more conspicuous life-style, especially during sexual activities (Lagarde *et al.* 2002). This trend is very obvious when considering the size distribution of animals we found dead in the field. The "missing" juvenile class was indeed observed in dead animals (Fig. 2). In snakes, the juvenile component of the population is often missing as well; a study revealed that adults are at risk and are killed in large number during reproduction whilst

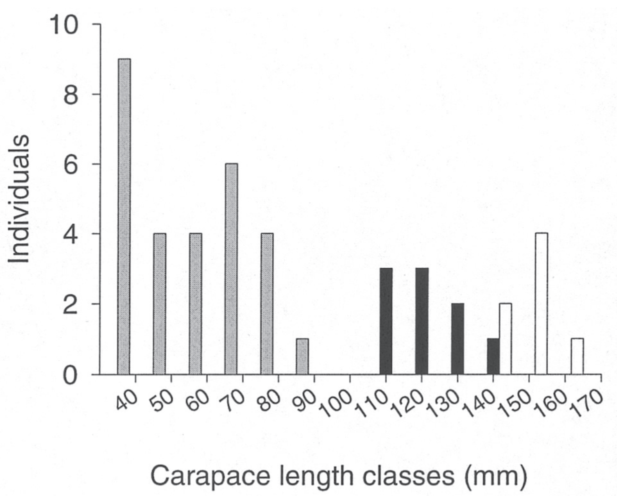

Fig. 2. – Size distribution of *Testudo graeca graeca* of dead individuals in the Central Jbilets population, Morocco. Size distributions were represented for juveniles (grey bars), adult and sub-adult females (white bars) and adult and sub-adult males (black bars).

juveniles remain sheltered under cover (Bonnet *et al*. 1999). In a funny way, the phenomenon (dead *versus* live animals) that reveals the juvenile part of the populations is opposed in snakes compared to the current study. Nevertheless, the cause of low juvenile frequencies should be investigated more closely to tease apart the respective influences of population structure and behavioural biases.

Population density and individual catchability

The population size estimate in our study area was of 192 adults and sub-adults. This corresponds roughly to a population density of 6 individuals per hectare. The vegetal cover is strongly degraded by over-grazing (*pers obs*). Nevertheless, the estimated tortoise's density is greater than what has been reported in the other part of the distribution range (2 ind/ha in Greece, Hailey 2000, 1.7 to 4.2 ind/ha in Spain, Braza *et al.* 1981, Andreu 1987, Andreu *et al*. 2000). Longer-time scale investigations are necessary to better assess the current status of our population. It would be very interesting to determine if the population is declining or stable. In the first case this would indicate that even a high population density cannot be considered as an index of the health of the population, and that great caution is required in short term surveys that are based on simplistic indexes (transects for instance). In the second case, this would rather indicate that the tortoises can afford the degradation of their habitat, as documented for *Gopherus berlandieri* (Kazmaier *et al*. 2000) and consequently that other factors, such as harvesting for pet-trade, are responsible of the general declines observed in other areas. Below we briefly address these two issues.

Capture/recapture methods are logistically complicated and time consuming, they were often considered as too difficult to set up on a large geographical scale (Krzysik 2002, Lambert *et al.* 1981, 1982) and alternative sampling methods have been developed (*Testudo graeca*: Lambert *et al*. 2001, *Gopherus agassizii*: Krzysik 2002). For example, population estimates available for *T. graeca* in North Africa are based on the number of tortoises counted over time (Lambert 1981, 1982). The results obtained with such methodology may be strongly biased with respect to the time-period, the age, the sex of the tortoises, climatic conditions or the ability of the observers to detect the tortoises (Diaz-Paniagua *et al*. 1995, Kazmaier *et al*. 2001, Lagarde *et al*. 2002, Lambert 1981, Perez *et al.* 2001). The sampling protocol developed for *Gopherus agassizii* based on Distance Sampling Method (Krzysik 2002) offer a mean to limit such biases by taking into account the detection function of tortoises at x distance from a centreline transect. Such method assumes that the probability to detect a tortoise at a null distance of the transect-line is 1. Such requisite is not applicable for *Testudo graeca graeca* as this tortoise is often hidden (i.e. half buried) under thick spiny shrubs (*Acacia* or *Ziziphus*) and hence is very difficult to found. The transect-line method proposed by Hailey (1988) could provide satisfactory results of population estimates if the proportion of active animals was known at that time. However, such proportion of active animals is strongly influenced by sex, season and daily climatic conditions in terrestrial tortoises and cannot lead to accurate population estimates. There is yet no satisfactory alternative method to the classical recapture techniques to assess precisely changes in population size and demographics characteristics of *T. graeca*.

During the three months of the current study, two researchers caught 60% of the adults and subadults estimated population. Our sampling effort should be considered as moderate comparative to the hunting pressure exerted on traditional harvesting areas. Notably local collectors employ many kids to find the animals whilst the recapture procedure entail long-time interval between captures to identify, measure etc. each individual. *Testudo graeca graeca* may be highly sensitive to repeated illegal harvesting. Although, in certain situations (i.e. high female fecundity in a poorly degraded landscape), a moderate level of harvesting maybe sustainable (Hailey 2000). Nonetheless, Lambert (1981) found that in North Africa, the population sizes and structures are affected by the intensive harvesting of the sixties. Overall, the conservation of the main populations of *Testudo graeca* requires the extension of recapture studies in a set of different areas.

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