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Observations on Ecological Changes Threatening a Population of *Testudo graeca graeca* in the Souss Valley, Southern Morocco

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ABSTRACT. – **The dominant natural habitat of *Testudo graeca graeca* in the Souss Valley in southern Morocco is argan (*Argania spinosa*) forest. This unique ecosystem is undergoing considerable modification as a result of agricultural intensification, overgrazing, deforestation, hydrological change, and the introduction of non-endemic species. Recent changes in the pattern of distribution of *T. g. graeca* are recognized. Tortoises are now rarely encountered in natural forest areas where high density populations were reported previously; instead, the highest density populations are now found in irrigated, intensively farmed areas. The interrelationships of *T. g. graeca* with these agricultural systems, together with the geology, climate, soils, and vegetation of the Souss Valley are discussed. Population structure is described, and observations on the annual activity cycle are reported. The implications of dietary modifications imposed by the ecological changes noted are discussed.**

KEY WORDS. – **Reptilia; Testudines; Testudinidae; *Testudo graeca*; tortoise; ecology; habitat; diet; status; conservation; Morocco**

Mediterranean spur-thighed tortoises, *Testudo graeca graeca* (Fig. 1), have been recorded in the Souss Valley of southern Morocco (Lambert, 1983). During the export trade era they were reported to be common, and populations were dense enough for trade collection centers to be established in the vicinity of the Admine Forest (Lambert, 1969). In 1992 we initiated a study of these populations of tortoises. The purpose of this investigation was to assess the effects of environmental change on the tortoise populations in the area, especially since 1960. The study aimed to record the behavioral responses of tortoises to different ecological and weather conditions, with several sites in the Admine Forest as the main focus of research.

METHODS

Four visits to the Souss Valley were made from 1992 to 1995. The first visit (September 1992) followed 18 months of drought in the region. The second visit (December 1993) occurred two weeks after a substantial rainstorm. The third visit (December 1994) took place 3 months after a 16 mm episode of rainfall and the final visit (April 1995) took place 3 weeks after a 56 mm episode. General aspects of the physical environment of the Souss Valley were documented.

The carapace length, carapace width, weight, sex, and estimated age of each tortoise was recorded, as well as any evidence of injury. Carapace length (SCL) was measured in a straight line from the nuchal to the supracaudal scute. Weights were taken by means of a calibrated spring balance. Age was recorded by analyzing scute growth rings; in addition, in fully grown specimens, the degree of carapace wear was taken into account, based on our experience with known-age animals.

RESULTS

Physical Environment

Location and Topography. — The Souss Valley lies at about latitude 30°20'N, 9°30'W in southern Morocco (Fig. 2). It is a major valley 160 km long and up to 38 km wide, draining the High Atlas in the east and northeast and the Anti Atlas in the south. The Admine Forest is a region of low relief bordering the Chtouka Plain and located some 30 km southeast of Agadir near the mouth of the Souss Valley at 40–140 m above sea level.

Geology. — The Souss Valley developed during the Tertiary period when a variety of sedimentary rocks of predominantly calcareous lithologies was laid down. In some areas of the valley, such as the Admine Forest, these limestones together with conglomerates form important aquifers (Geanah et al., 1988) that have made possible the development of intensive agriculture by providing a perennial source of irrigation water (Popp, 1987).

During the Quaternary the most widespread deposit was of aeolian sands, for which the field evidence is clear; remnants of the subsequently stabilized fossil dunes still occur as mounds within cultivated fields where vegetation such as *Ziziphus lotus* remains.

Vegetation. — The major natural vegetation of the region is forest dominated by the argan tree, *Argania spinosa*, a species endemic to southwest Morocco. The extent and quality of the argan forest has been seriously reduced,

Figure 1. Adult female *Testudo graeca graeca* photographed in the Souss Valley in mid-December. Tortoises do not hibernate in this region.

particularly since the 1960s, largely as a result of intensification of agriculture, which has led to a reduction in the extent of rangelands and therefore increased grazing pressure in the forest (Mellado, 1989). This is a matter of concern, not only because of habitat loss but also because the argan tree produces a fruit that yields an oil important in the local human diet.

In the process of agricultural intensification many of the fossil dunes have been destabilized through removal of the binding vegetation, while others have remained and support a variety of drought-resistant shrubs, such as *Ziziphus lotus*, the wild jujube (Tanji et al., 1988), prized for its thorny branches which are cut to make goat- and sheep-proof hedging. These thorny thickets form an important habitat for tortoises.

Climate. — Bons (1967) argues that biogeographical regions should be used as the basis for herpetological study because reptiles are so dependent upon their environment. This region of southern Morocco falls within the Xerothermo-mediterranean bioclimatic zone as defined by UNESCO-FAO (1963) and the Mediterranean steppe zone as defined by Emberger (1930). Lambert (1983) presents a climagram using the Emberger quotient to illustrate that the range of *T. g. graeca* in Morocco may extend into more arid climates, such as that of the Souss Valley, by the existence of a broad-leaved woodland that provides a moderating microclimate.

The Souss Valley experiences a transitional climate, lying at the southernmost limit of the Mediterranean zone close to the boundary with the sub-tropical semi-arid zone; and, hence, temperatures tend to be higher, precipitation lower, and sunshine hours higher than in most other areas where *T. graeca* is found. In Agadir, which lies close to the mouth of the Souss River, the mean annual temperature is 18.2°C, the mean annual precipitation is 239 mm, and the mean annual total sunshine is 3168 hours (Fig. 3). Corresponding figures for inland sites in the Souss Valley around Taroudannt reveal a slightly higher temperature range and reduced precipitation totals because of the declining influence of the Atlantic Ocean (Oliva, 1972).

The seasonal pattern of precipitation is distinctive, with a marked dry season in the summer months; mean totals for Agadir for June and July are less than 1 mm and for August, 1 mm. Combined with the effects of high temperatures — maxima of 40.8, 48.6, and 47.2°C for June, July, and August, respectively — the very low precipitation in the summer months results in food shortages to which tortoises respond by estivation.

The wide valley of the Souss is open to the influence of the Atlantic Ocean. The region does, nonetheless, experience the unreliable pattern of precipitation associated with

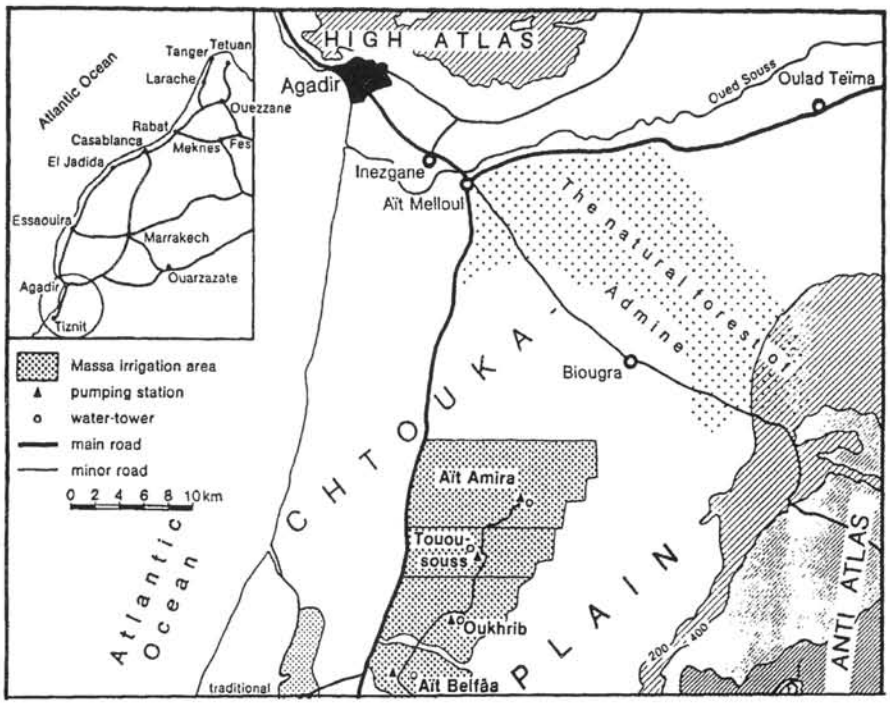

Figure 2. Map of the study area in the Souss Valley of southern Morocco.

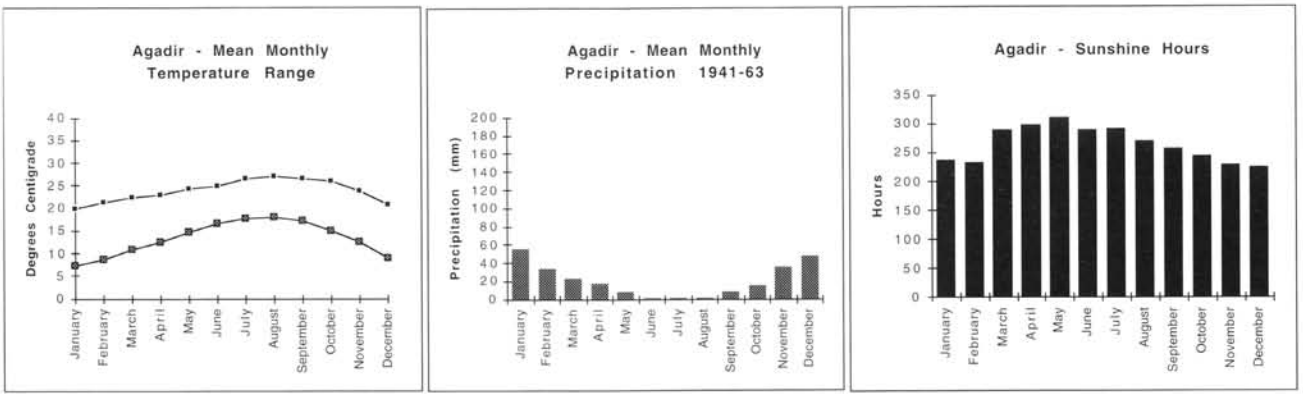

Figure 3. Climatological statistics for Agadir in the Souss Valley, showing temperature, precipitation, and sunshine hours (Meteorological Office, 1983).

these latitudes, partly because the predominant winds are offshore and also because the Anti Atlas provides a substantial barrier to the influx of air from the Sahara. The last five years (1989–94) have seen a succession of droughts. In the Admine Forest in 1994, for example, there was only a total of 16 mm precipitation. As a consequence even introduced, highly drought resistant plants, such as *Opuntia ficus indica,* the prickly pear, demonstrated wilting in December 1994.

This pattern is not atypical, as verified by climatic records provided by the Meteorologie Nationale de Paris for the period from 1923 onward; and, although it might be tempting to suggest a correlation with the droughts of the Sahel region, no clear patterns are obvious (Till and Guiot, 1990).

Soils. — The predominant soil type of the region is a structureless, fine, sandy soil, although pockets of clayey soils are also to be found, for example at a site 7 km SSW of Taroudannt. Bedrock was typically observed at depths of 30–70 cm in cultivated areas where erosion had reduced soil thickness. In some parts of the Admine Forest a calcareous pan was observed, as mapped by Oliva (1972); the presence of calcareous overgrowths on sand grains was confirmed by application of dilute hydrochloric acid. At every site where *T. g. graeca* was observed in the region, with the exception of the site near Taroudannt, the combination of a calcareous bedrock overlain by sandy soils was observed. The need for adequate levels of calcium in tortoise diets is widely recognized (Highfield,1989). Examination of tortoise fecal pellets revealed fragments of gastropod valves, which would provide a further source of dietary calcium.

Although the sandy soils displayed very limited cohesiveness where cultivated, the binding effects of roots in hedgerows were sufficient to support permanent scrapes and burrows (see below) that were utilized by tortoises for overnight shelter and during estivation.

Hydrology. — The hydrologic cycle has been substantially modified in this region by the major irrigation projects, instituted by the government, beginning in the 1960s (Geanah et al., 1988). Between 1956 and 1986 the area irrigated by large-scale projects in the Souss-Massa region grew from 0 to 25,700 ha, and by the year 2000 it is planned that the irrigated area will increase considerably again (Swearingen, 1988).

The environmental effects of this program are substantial. Of particular relevance to tortoises is the fact that the valley has become much drier outside the irrigated areas. There are two reasons for this change: first, groups of springs that previously issued into the vicinity of the Souss River have almost disappeared because of the rapid fall of the water table, in some areas at a rate of 2 m per year; and second, the building of two major dams in the upper reaches of the Souss River has considerably reduced the volume and frequency of flows in the main channel (Geanah and Meilhac, 1988; Geanah et al., 1988). Thus the areas closer to the river which are not currently irrigated, suffer from extreme aridity, support few living plants, and provide little potential tortoise food. Tortoises have responded by migrating into the irrigated areas; the highest density populations observed on all four field visits were in these areas.

Habitat Degradation and Agriculture

The Souss Valley is one of the most productive agricultural regions of Morocco, having been developed originally by the French, largely for arboriculture, predominantly citrus, and more recently also for a variety of intensively produced horticultural crops (El Khyari, 1987). The latter encompass substantial areas under plastic greenhouses, which can provide an attractive environment for many reptiles, especially during times of food shortage. We have heard reports of visitors collecting numerous reptiles, particularly snakes, from these highly artificial habitats.

The main period of irrigation for vegetables is during the winter season (November–February). Hence, an abundance of food is available at this time of year. This is the wetter season of the year and therefore coincides with the period when a greater abundance of food would also be found in the natural habitat.

In the Admine Forest, once one of the best preserved forests in the region, the rate of degradation has been rapid (Mellado, 1989); in areas that Lambert (1981) cites as good collecting areas for *T. g. graeca* for export, the trees now rarely have any basal branch growth due to overgrazing by

Figure 4. Degraded argan forest. Overgrazing is a major problem; goats and camels are the most common livestock.

sheep and goats. These ground level branches provided an important tortoise habitat. Local villagers recall the ease of locating tortoises for collection 40 years ago, when collection for the export trade was at its peak (Lambert, 1984); they also recall the difficulty of walking through parts of the forest even 25 years ago. Figure 4, taken in December 1994 after a five-year dry period, testifies to the current state of the forest, showing the very open habitat, the browse line, and the loss of shrubs and climbing plants that once characterized this ecosystem. However, it should be noted that the appearance of the forest is highly variable depending on whether there has been recent rain; after rain, a carpet of annuals, including grain crops sown between the trees, is evident.

A further threat to the forest is illegal felling of trees for firewood or construction purposes. This is usually carried out at night to escape the attention of forest guards.

Within the Admine Forest there are pockets of agricultural land surrounding the villages, predominantly small fields of 0.1 to 2 ha surrounded by thorny hedges. The most widespread hedging material is *Opuntia ficus indica,* a cactus species introduced from the Americas, while the endemic species *Ziziphus lotus* is the next most abundant. Both species provide the major present day habitat for tortoises: *Opuntia* (Fig. 5) has created an important new habitat, providing good protection from predators and humans, a food source, and good nesting, basking, estivation, and scrape sites (the use of individual sites depending on the aspect of the bank and season of the year). It is interesting to note that this introduced cactus, much maligned in Australia for its effect upon indigenous species, should now be such an important refuge for tortoises in Morocco.

In areas of the Admine Forest that are not irrigated, it is common practice to plow between the trees in autumn and sow grain in the hope that winter rains will support a crop. Using traditional methods it is not possible to begin plowing until after the first rains have softened the soil by which time tortoises would have emerged from estivation. The spread of mechanized plowing now poses a threat to tortoises, especially if the estivation period has extended into the plowing season. When tractors are used, the plowing can begin earlier, at a time when tortoises are more vulnerable in their estivation sites. Furthermore, the use of tractors allows patches of *Ziziphus lotus* to be cleared (Swearingen, 1988) and thus acts as a further hazard because of these plants' importance as tortoise habitat.

Characteristics of Tortoise Populations

Morphometrics. — Between 14–21 December 1994, 40 *T. g. graeca* were located in the irrigated fields bordering the Admine Forest, of which 35 were live and 5 dead. Between 22–27 April 1995 a further 23 live specimens were located in the Admine Forest itself.

The mean SCL of adult males was 144.9 mm with a standard deviation of 13.1 mm. The mean SCL of adult females was 184.9 mm with a standard deviation of 20.2 mm. The mean mass of males was 672 g with a standard deviation of 149 g, and the mean mass of females was 1426 g with a standard deviation of 424 g. The largest male had a SCL of 169 mm and weighed 980 g, while the largest female measured 206 mm and weighed 1840 g. Several hatchlings and juveniles of various ages were recorded. The hatchlings, which emerge in September, measured 35–39 mm SCL and weighed 11–12 g by mid-December.

These figures contrast markedly with *T. graeca* complex specimens elsewhere in North Africa. In Tunisia 93 tortoises were located and measured, and the mean SCL of adult males was 112 mm and that of adult females 143 mm (Highfield, 1990a). Certain Algerian tortoise populations diverge further from the Moroccan populations in that adult males have a mean SCL of 220 mm and adult females 282 mm SCL ($n = 200$, unpublished data). The maximum SCL of tortoises from these three localities is also disparate, with the largest specimen recorded from Morocco not exceeding 222 mm, those of Tunisia 161 mm, and the largest Algerian specimen was 305 mm and weighed 5.4 kg. It should be noted that in each case, the largest recorded specimen was a

Figure 5. *Opuntia ficus indica* hedging is now an important habitat of *Testudo graeca graeca* in the region.

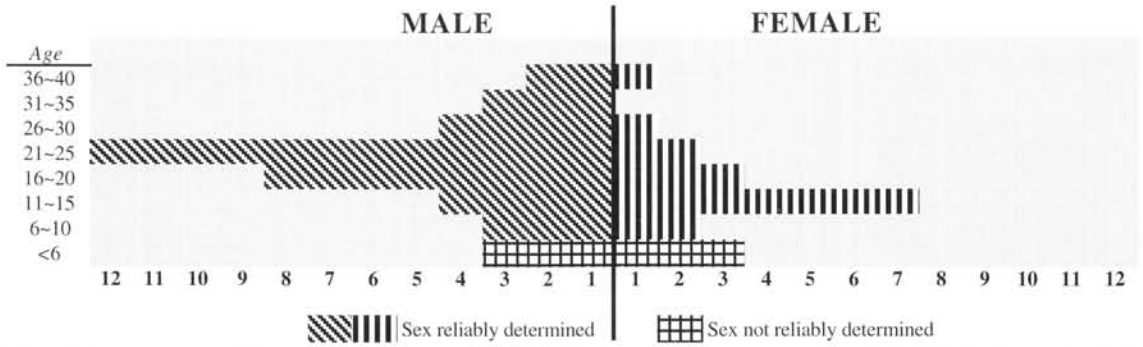

Figure 6. Population structure of *Testudo graeca graeca* specimens located in and on the margins of the Admine Forest (n = 36 males, 16 females, 6 juveniles).

female. Each country's populations are, furthermore, distinguished by a range of characteristics which include, in addition to size, scute, head and limb markings and coloration, thigh tubercle morphology, and a range of osteological features (Highfield, 1990b).

Population Structure. — Age-sex graphs were plotted in order to determine adult population structure (Fig. 6). The six juveniles were included in order to produce a complete population pyramid; these are indicated separately on the graph. The results show a substantial imbalance between the sexes, with totals of 36 live males and 16 live females. Only 16 specimens (27.6%) were estimated to be immature. A predominance of young males was encountered in the available sample; 24 of 36 (66% of the males or 41.4% of the total population) were in the 11–25 year category compared with 12 of 16 females (75% of the females or 20.7% of the total population). The sample size is too small and the variables involved too complex to draw valid conclusions, but the underlying causes of the observed population structure are worthy of further investigation.

Two of the five dead specimens located had been crushed, evidently by vehicles. Increased agricultural mechanization in the region and an increase in road traffic represent growing threats. In addition, illegal exploitation of *T. g. graeca* for the tourist souvenir trade continues to drain the population in some areas. Although not currently widespread in the Admine Forest, it is undoubtedly a serious drain on populations elsewhere in this region (Highfield, 1994; Highfield and Bayley, 1996).

Annual Activity Cycle. — Hibernation does not occur in the study area, where average monthly mean temperatures in the coolest months of the year (December and January) do not fall below 14.8 and 13.6°C, respectively. Average daily temperatures in winter are typically 23.8°C in November, 20.8°C in December, and 31.1°C in January. Air temperatures at sites where active tortoises were observed in mid-December 1994 ranged from 24–27°C between 1000 and 1400 hrs. The temperature recorded in scrapes and shallow burrows occupied by tortoises was typically 24–26°C and the relative humidity there ranged from 48–60% compared to 20% or less in exposed areas.

Estivation typically begins in June and ends in September. The precise timing is affected by prevailing temperature and, especially, by precipitation. In drought years estivation may be considerably extended. Tortoises are invariably estivating during July and August where average mean monthly temperatures are 22.2 and 22.5°C, respectively. Peak daily temperatures during these months can exceed 48°C.

It should be stressed that tortoises in northern Morocco have a reversed annual activity cycle compared to these in the south, with up to 5 months hibernation during the cold, wet winter and peak activity during the spring and early summer.

Reproduction. — Mating activity in the Souss Valley occurs bimodally, in the early spring and in September, immediately following emergence from estivation. Nesting occurs in May and June. Clutch size is typically from 5 to 7 eggs which measure about 27.5 x 30 mm. Nesting sites are usually located in sandy banks on the periphery of cultivated fields and at the base of *Opuntia* hedging. Emergence occurs in September. Common predators of hatchlings observed in this region include hedgehogs, rats, and birds of prey.

Tortoise Scrapes and Burrows. — Tortoises in southern Morocco utilize scrapes and burrows to avoid the mid-day heat, for shelter at night, and for prolonged periods during estivation. Scrapes and burrows vary considerably in opening size and depth of excavation. Some are consistent with having been produced by tortoises, but others are clearly beyond their excavating capabilities and bear signs of previous occupation by mammals such as *Mellivora capensis* (honey badger) and *Xerus erythropus* (Geoffroy's ground squirrel). Shallow scrapes are often found at the base of *Opuntia* hedging, where the presence of roots stabilizes the otherwise loose and structureless sand. Larger burrows are also found in these hedges, but are more frequently located in fossilized sand dunes and in the banks of dry rivers. Burrow depth at these sites ranged from 40 cm to more than 1.5 m. In September 1992 several estivating tortoises were located in a series of deep burrows in a fossil sand dune and one was located partly covered by sand and spider webs in a shallow excavation in the bank of a dry river bed.

Dietary Modifications. — Cobo and Andreu (1988) give useful data on the dietary preferences of *T. g. graeca* in Spain. The dietary constituents in southern Morocco are not dissimilar, but additionally include several cultivated species. A list of plant species observed in their habitats and which are known to be palatable to tortoises (through observation of grazing wild specimens and captive specimens in

Table 1. Plant species in the diet of *T. g. graeca* in the Souss Valley.

Wild Food Plants	Cultivated Food Plants
Brassica spp.	*Brassica* spp.
Calendula spp.	*Convolvulus* spp.
Chenopodium spp.	*Cucimus sativu*
Chrysanthemum spp.	*Cucurbita pepo*
Fumaria agraria	*Lactuca sativa*
Launaea residifolia	*Lycopersicon lycopersicon* (fruit)
Leotodon spp.	*Medicago sativa*
Linaria incarta	*Opuntia* spp.
Malva spp.	*Phaseolus vulgaris*
Medicago lupulina	*Solanum tuberocum* (leaves)
Mesembryanthemum crystallinum	*Vicia faba*
Plantago spp.	
Sonchus oleraceus	

Morocco) is given in Table 1. In the study area displacement of tortoises from the argan forest as a result of overgrazing, loss of ground cover, and drought, has led to their concentration along the margins of cultivated fields. In these situations a high proportion of their diet now consists of *Opuntia* cacti and agricultural crops. Local farmers report that tortoises frequently consume French and broad beans, lucerne, potato leaves, tomatoes, lettuce, zucchini, cauliflower, and cabbage. These habits were confirmed by observing several tortoises grazing in fields and by numerous tortoise tracks in the sand leading to and from damaged crops. As a consequence tortoises are not always popular with farmers. The standard practice is to pick the intruding reptile up and throw it away as far as possible outside the boundary of the field. In the study region adult tortoises are rarely harmed deliberately, but some farmers destroy tortoise nests whenever they find them. Many tortoises do, however, bear the scars of numerous impacts; and, on one occasion, a farm worker was observed to pick up two tortoises feeding on crops and throw them forcefully onto a nearby pile of rocks. The tortoises did not appear unduly disturbed by this incident and quickly disappeared into the nearest *Opuntia* hedge.

Inadequate use of crop rotation and the naturally poor soils predispose certain crops to pests; these are typically treated by the routine application of pesticides. In this region of low precipitation, pesticide residues tend to remain on the foliage and their ingestion by grazing tortoises is inevitable. It should be noted that several of the most common crops under cultivation in the region are likely to represent a particular hazard in this respect due to their susceptibility to pests and consequent requirement for multiple applications of a number of different pesticides, yielding a high number of pesticide residues (Steinmann, 1990). Among the pesticides in common use is Kelthane which is manufactured from DDT and thus contains DDT residues (Highfield and Bayley, in press). The possible long-term consequences of such ingestion by tortoises is a matter of concern and requires further investigation.

SUMMARY

The combination of pressures of export trade collection, agricultural modifications, hydrological change, and environmental degradation, in addition to the natural vagaries of climate in this region, has affected the microgeographical distribution and size of this tortoise population to a considerable extent over the past 100 years. The migration of tortoises from degraded forest habitat to intensively farmed areas has exposed the population to a different group of threats and has dramatically changed the quality and pattern of food availability. It is significant that, despite very intensive searches, not one tortoise was observed within the bounds of the remaining Admine Forest during the course of the first three field trips; specimens were located exclusively within cultivated zones. On the fourth trip, when there had been sufficient rainfall to sustain plants beneath tree canopies, tortoises were observed in the natural forest, but only within 500 m of the margins of the irrigated land, suggesting that they had migrated from hedgerows surrounding cultivated land in search of food.

Certain specific forest habitat modifications, such as the loss of basal branch growth from the argan trees and drastic reductions in ground cover as a consequence of overgrazing and water shortages, are almost certainly key factors in this population shift. These changes have accelerated dramatically over the last 35 years, and the trend continues. This suggests that the current pattern of agriculture is not sustainable in the long term; if wildlife and humans alike are to secure a future, present practices must be reformed and some positive steps taken to manage the region in a sustainable manner. Such steps might include cultivating fast-growing alternative forage plants for domestic livestock that could serve other useful functions, such as providing mulching material and acting as a windbreak, both of which would reduce wind erosion, as well as providing firewood and a sustainable source of timber (Bayley, in press).

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