REVIEW:

STATUS AND CONSERVATION OF TORTOISES IN GREECE

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ABSTRACT

The present status of tortoises (*Testudo* spp.) in Greece is described, based on studies from 1975 to 1986. The survey includes 79 single species populations at 42 sites throughout the country, at which about 9,600 individuals have been marked and released. Tortoises were still common in Greece in 1986. However, 28 per cent of populations are immediately threatened by catastrophic decline, and 39 per cent have declined in the recent past or are liable to long-term decline. The remaining 33 per cent are not apparently threatened at present. There was no significant difference in these proportions between dense and sparse populations, or between the three species. Most of the highly threatened sites were near the coast; many of the sites under no apparent threat were in mountainous areas. Threats included habitat loss to cultivation or building, fires started for pasture improvement or by accident, herbicide spraying, agricultural machinery, and direct predation of tortoises or nests by rats near rubbish dumps. Most (61 per cent) of the threats to sites were associated with agriculture.

Testudo hermanni is the most widespread and common species, found in woods, scrub, heath, grassland, and farmland. There was substantial variation of body size between populations, which was apparently at least partly genetic; a range of sites would need to be protected to preserve this variability. Populations in the south are in danger, but overall this species is not threatened in Greece. *Testudo marginata* is widespread in Greece, where it is endemic; its typical habitat is thorny scrub. Only one out of 23 populations of this species was found at high density; we recommend protection for this site (at Gytheion). *Testudo marginata* is the largest and latest-maturing species, with the lowest proportion of juveniles in the total marked sample. It is particularly vulnerable to slow decline from occasional loss of adults, such as those killed by machinery while foraging in cultivated areas, or casual collection. *Testudo graeca* is restricted to north eastern Greece, where it usually occupies coastal habitats which are most likely to be disturbed. It is the most threatened species in Greece, but is widely distributed elsewhere.

The reptile faunas associated with tortoises are described, to evaluate the 'biogenetic reserve' concept for reptiles in Greece. Three quarters of the 33 native species of lizards and snakes in mainland Greece have been found with tortoises. In addition, tortoises may be found in very disturbed areas, and they may be affected by factors which affect them but not other reptiles. The presence of tortoises therefore cannot be used as an indication of a particular reptile community, or of an area of high reptile species richness. The herpetofauna of the Alyki coastal heathland is described in detail. We suggest that Alyki merits protection as an unexploited coastal heathland containing almost all the reptile species likely to be found in that habitat. Larger reserves may contain more species, but will not be as effective in conservation if they simply contain the most common species inhabiting many different habitats.

INTRODUCTION

The conservation of tortoises must be based on knowledge of their ecology which can only come from detailed work concentrated at a few sites. Conservation also requires, however, information on the current status of populations and the problems they face (e.g. Honegger, 1982; Andren, Nilson and Podloucky, 1986; Dolmen, 1986). Lambert (1969, 1979, 1981) provided this information for *Testudo graeca* in North Africa, where the major problem was (until 1984) large scale collection for the pet trade. Felix (1983) and Cheylan (1984) have discussed the status of *T. hermanni* in western Europe, where it is threatened by habitat loss. The main object of this review is to summarise data about the current status of populations, resulting from our field studies of tortoise ecology in Greece. We do not discuss the techniques suitable for management of tortoise populations (see Devaux, Pouvreau and Stubbs, 1986). It should be noted that our field work was not designed as a conservation survey of Greek tortoises, but provides the most comprehensive data available at present.

Although studies of status and ecology are essential background to conservation, they will only be effective when applied within a rational strategy. Modern conservation theory and practice has moved away from protecting individual threatened species, towards preserving areas of habitat and the species which live there. The idea for such 'biogenetic reserves' for reptiles and amphibians has been discussed by Corbett (1986). In this review we also consider other species of reptiles found at our sites, and evaluate one well-studied site, the Alyki heath, as a biogenetic reserve for reptiles. Four questions were used as a framework for this analysis:

1) Community. Does the presence of tortoises define a particular assemblage of reptile species?

2) Richness. Does the presence of tortoises define an area with many other species of reptiles?

3) Habitat. Does Alyki provide optimal habitat for a species, or dose the species occur in greater numbers in other natural habitats?

4) Disturbance. Which species are limited to natural habitats, and which may be found in altered or disturbed areas?

We do not analyse the many published works on the distribution of tortoises and other reptiles in Greece and its islands (e.g. the series of papers by Clark, 1967, 1969, 1970, 1972), unless these provide recent information on status, for three reasons. First, such reports are already being collated by full-time conservationists, for a projected atlas of chelonians throughout the Mediterranean area (D. Ballasina, personal communication). Further records of this type should be sent to the addresses in the Appendix. Second, records based on short visits may give an unreliable estimate of the status of populations (see the Discussion). Third, the sites of which we have first-hand experience give an even coverage of the whole of Greece, and are sufficiently numerous for statistical analysis.

It should be stressed that tortoises (and other reptiles) are protected in Greece by national and European Community regulations. They may only be collected under permit from the Ministry of Forestry, Athens.

METHODS

Observations at most sites in north-eastern Greece were made by A.H. between 1980 and 1986. Work at most sites in central and southern Greece was by R.W. on annual visits from 1975 to 1986. The sites were selected as areas having habitat suitable for tortoises; their location is shown in Fig. 1. Some of the sites were selected for marking studies (see Table 2), because of high population density, ease of access and ecological interest. Tortoises were marked in areas of a few tens of hectares, though at most sites the suitable habitat covered a much larger area. Other sites were visited for short periods, and few or no tortoises were marked. We had no preference for studying any particular species of tortoises.

Tortoises were marked by notching the marginal scutes with a file or hacksaw (the coding scheme differed between workers). The number of individuals recorded at marking sites is shown in Table 2; the number of these which were juveniles when first found is shown as an indication of population structure. Juveniles were defined as individuals which could not be sexed by external characters. The size at which tortoises could be sexed varied between the species, (smallest in *T. hermanni* and largest in *T. marginata*) and between populations of *T. hermanni* (because of variation in adult body size). Full details of population size and dynamics at the sites studied in detail will be given elsewhere.

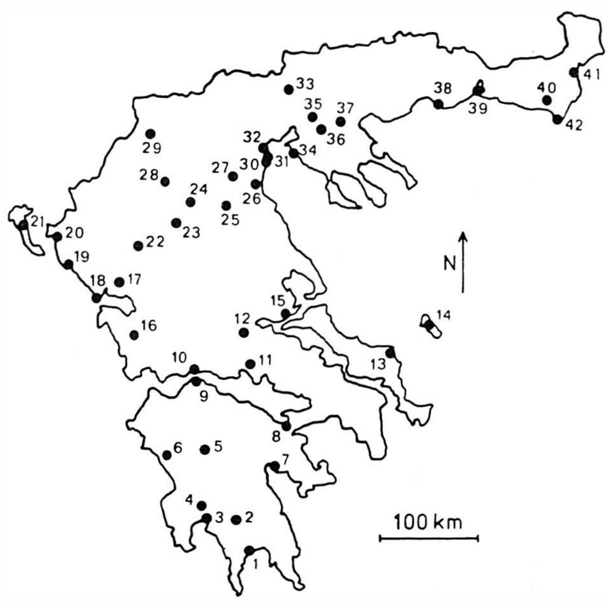

Fig. 1 Location of the study sites, numbered as in Table 1 and in the text.

Vegetation at most sites was described in general terms, not as a result of botanical surveys. The following natural types were recognised:

Coastal Heath. Very open vegetation of herbs, grasses and maritime plants on loose sand. Infrequent cover from *Tamarix* bushes and marram grass (*Ammophilla arenaria*), especially on dunes.

Dry Heath. A few bushes such as *Crataegus* (hawthorn), broom and brambles, and low shrubs (e.g. *Artemisia maritima, Ruscus aculeatus*), with sparse ground cover of grasses and herbs.

Grassland. Dense cover of grasses, height depending on grazing intensity. Asphodels (*Asphodelus microcarpus*) common in overgrazed areas.

Thorny scrub. Dense scrub about 2m high with little ground flora, the dominant species often holly oak. Access usually difficult except along goat tracks.

Woodland. Broadleafed or coniferous woods of various dominant species. Some small single-species woods were apparently plantations for timber or shade cover.

The other species of reptiles seen were noted, but no attempt was made to provide a complete survey at each site. Amphibians and terrapins are not discussed here, as their habitat requirements differ from those of tortoises. In the interests of standardization, the species are considered in the order used by Arnold, Burton and Ovenden (1978).

RESULTS

Status of Tortoises at Specific Sites

The results of the survey take the form of a brief description of each site, its vegetation, tortoise populations, and conservation problems. Sites are numbered as in Fig. 1 and Tables 1 and 2, the name of the nearest village or town is shown, together with a code summarising the status of the tortoise populations present. These codes are:

Species (Hermanni, Marginata, Graeca),

Density (Dense, Sparse),

Status (0 = no apparent threat, 1 = past decline or long-term threat, 2 = immediately threatened).

	Site	*T. hermanni*	*T. marginata*	*T. graeca*	
1	Gytheion	S 1	D 1	—	RW
2	Sparta A	D 1	S 1	—	RW
2	Sparta B	—	S 0	—	RW
3	Kalamata A	D 2	S 1	—	RW
3	Kalamata B	—	S 0	—	RW
4	Arfai	S 2	S 2	—	RW
5	Langadia	D 0	—	—	RW
6	Olympia A	D 2	S 2	—	RW
6	Olympia B	S 1	S 1	—	RW
7	Nauplion	—	S 2	—	RW
8	Korinthos	—	S 0	—	RW
9	Rion	D 2	S 2	—	RW
10	Antirrion	S 2	S 2	—	RW
11	Delphi	—	S 0	—	RW
12	Bralos	S 1	S 1	—	RW
13	Kymi	S 1	—	—	RW
14	Skyros	—	S 0	—	RW
15	Pelasgia A	D 1	S 1	—	AH
15	Pelasgia B	—	S 0	—	AH
16	Fitiae	D 0	—	—	RW
17	Arta	D 1	—	—	RW
18	Preveza	S 2	—	—	RW
19	Parga	D 2	S 1	—	RW
20	Igoumenitsa	D 1	S 1	—	RW
21	Kerkyra	S 1	—	—	RW
22	Mesochoron	S 0	—	—	RW
23	Meteora A	D 1	S 1	—	RW
23	Meteora B	S 0	S 0	—	RW
24	Deskati A	D 0	—	—	RW
24	Deskati B	D 0	—	—	RW
25	Agios Dimitrios	D 0	S 0	—	RW
26	Litochoron	D 1	S 1	—	RW
27	Elassona	S 0	—	—	AH
28	Grevena	S 0	—	—	RW
29	Kastoria	D 0	—	—	RW
30	Korinos	S 2	—	—	AH
31	Alyki A	D 2	—	S 1	AH
31	Alyki B	D 2	—	—	AH
31	Alyki C	S 1	—	—	AH
32	Agathoupolis	S 1	—	—	AH
33	Kilkis	D 1	—	S 1	RW
34	Epanomi	D 0	—	D 0	AH
35	Kolhiko	S 0	—	S 0	AH
36	Langadiki	S 2	—	S 2	AH
37	Mikra Volvi	D 1	—	D 1	RW
38	Keramoti A	D 1	—	D 1	AH
38	Keramoti B	S 0	—	D 0	AH
39	Lagos A	D 2	—	D 2	AH
39	Lagos B	S 1	—	—	AH
40	Avas	S 0	—	S 0	AH
41	Souphli	—	—	S 2	AH
42	Evros	D 2	—	D 2	VG

TABLE 1: Summary of the density and status of *Testudo hermanni, T. marginata* and *T. graeca* populations at all sites. Population density coded as D (dense) or S (sparse). Status coded as 0 (no threat), 1 (long term decline) or 2 (immediately threatened). The author responsible for work at each site is also shown.

1 Gytheion (HS1, MD1)

The vegetation was dense thorny scrub, with patches of grassland and dry heath which were sometimes grazed. This site was unique in that *T. marginata* was the dominant species, and was present at high density. Three *T. hermanni* were also found, all in a wet area near a freshwater canal. Several tortoises were found killed by farmers, but this would have a small effect on the population. A more serious loss was the clearance of large areas of scrub to make new olive groves, during which many tortoises were killed. However, the area used by tortoises was large, so that the site as a whole was not immediately threatened.

2 Sparta A (HD1, MS1)

The plain of Sparta was mostly used for intensive citrus orchards, a habitat which is unsuitable for tortoises. However, a dense population of *T. hermanni* was found in an abandoned orchard near Sparta, together with two juvenile *T. marginata*. No tortoises were found in the surrounding citrus groves or dense scrub of *Sarcopoterium spinosa*. *Testudo hermanni* from the plain of Sparta are characterised by small body size. A high proportion of junveniles was found, despite the presence of many nests destroyed by predators. This population was found over a small area, and would be threatened if the area was reclaimed for cultivation, which seemed likely. However, it would also be threatened by further encroachment of the dense *Sarcopoterium* scrub.

2 Sparta B (MSO)

The hills surrounding the plain of Sparta were covered with thorny scrub. A few *T. marginata* have been found at low density in these areas, which were not threatened.

3 Kalamata A (HD2, MS1)

The site extended from sea level up the slopes of the Taygetas hills, which were terraced, mostly for olive groves, but with some vegetable plots. The scrub vegetation of the low terrace walls was important cover for tortoises. A rotation system was followed up to 1985, in which fields were left fallow for one year. Weeds in these areas provided food for tortoises, which was increased by irrigation in summer. The result was a flourishing population of *T. hermanni*, with many young adults and a very high proportion of juveniles. Most tortoises were found near the terrace walls, and only older animals used the open areas.

No signs of nest predation were seen in the cultivated area, but opened nests were seen in the scrub. Farm machinery killed several tortoises each year, and some were deliberately killed by farmers who believed them to be pests of vegetables, although crop damage must be negligible. In recent years farmers have increasingly sprayed the wall vegetation with the herbicides 2, 4 D and 2, 4, 5 T. Almost no tortoises were subsequently seen in these areas. Citrus trees were planted under the olive trees after 1985; this will cause the population to decline as citrus plantations are unsuitable for

	Site	*T. hermanni*		*T. marginata*		*T. graeca*	
1	Gytheion	3	(1)	227	(8)		
2	Sparta A	385	(48)	2	(2)		
3	Kalamata A	319	(107)	7			
4	Arfai	36	(3)	2			
5	Langadia	54	(1)				
6	Olympia A	879	(117)	7	(3)	1	
9	Rion	38	(2)	2			
10	Antirrion	26	(5)	6			
12	Bralos	30		4			
13	Kymi	24	(1)				
19	Parga	176	(5)	2			
20	Igoumenitsa	329	(44)	5	(2)		
23	Meteora A	1560	(228)	2			
24	Deskati A	181	(2)				
25	Agios Dimitrios	115	(5)	11	(3)		
26	Litochoron	98		9			
29	Kastoria	304	(24)				
30	Korinos	27	(1)				
31	Alyki A,B	3597	(678)			51	(22)
33	Kilkis	91	(3)			13	
34	Epanomi	50	(11)			143	(83)
37	Mikra Volvi	278	(1)			87	(2)
38	Keramoti A,B	92	(9)			152	(34)
39	Lagos A	88	(3)			97	(3)
	Total	8780	(1299)	286	(18)	544	(144)
	Per cent juveniles		14.8		6.3		26.5

TABLE 2: Details of work at sites where more than 10 tortoises were marked. The total number of each species marked at each site is shown (with number of juveniles), and the total for all sites. The percentage of juveniles differs significantly between the three species ($X^2 = 72$, 2 d.f., $P<0.001$).

tortoises. Many parts of the site have also been lost to building in recent years.

The cultivated area was surrounded by dry heath and thorny scrub. Only *T. marginata* were found in this scrub, at lower density than the *T. hermanni* nearby in the cultivated area. There was a sharp distinction between the habitats occupied by the two species.

3 KALAMATA B (MS0)

The mountain slopes around Kalamata were covered in thorny scrub, in which only *T. marginata* was seen at low density. These populations were in no apparent danger.

4 ARFAI (HS2, MS2)

This was an area of grassland with hedges and olive groves, bordered to the east by thorny scrub-covered hills. The grassland was used intensively for agriculture, and the soil under the olive trees was rotavated regularly to clear weeds. The population density of tortoises was low, probably because of this disturbance; high mortality was suggested by many pieces of carapace. Local people indicated that tortoises were very much more common in the past, and blamed modern agricultural practices for the decline.

5 LANGADIA (HD0)

This was the highest site where we have studied tortoises, at 1100-1300 m, close to the altitudinal limit of *T. hermanni* in southern Greece. The vegetation was mainly coniferous wood (*Abies cephalonica*) and patches of grassland. The carapace of a very old female *T. marginata* was found, but local people did not know this species. Several female *T. hermanni* were found in sandy fields in June 1982, and the whole area was littered with pieces of eggshell in August; nest predation was apparently was apparently very high. This population suffered from a high degree of scute irregularities. The area was protected from hunting and there were no human settlements nearby, and the population was apparently not threatened.

6 OLYMPIA A (HD2, MS2)

The site was in a large area of open, park-like vegetation with olive groves, hedges, cypress and pine woods, and patches of thorny scrub. This was one of the first of our sites, and nearby 900 *T. hermanni* have been marked near the village of Flokas since 1975. *Testudo marginata* was much less common, and a single *T. graeca* was also found (Willemsen, 1987), probably moved there by man. Traditional agricultural methods prevailed during the first years of the study, when the tortoise density was about 30 ha^{-1}. Ground vegetation in the olive groves was cleared by scythe and then burnt, activities which caused few tortoise casualties.

Manual clearance of ground vegetation has been replaced by spraying with herbicides in recent years. Very large areas were sprayed with Grammoxone (paraquat) and atrazine in spring, so that many of the hills around Olympia became yellow and brown before summer. There was no obvious effect on tortoises, although these have been seen eating recently sprayed plants and basking on dead vegetation. More seriously, areas of woody vegetation and *Asphodelus microcarpus* were sprayed with 2, 4 D and 2, 4, 5 T. These herbicides apparently affect tortoises directly, rather than indirectly through their food and shelter plants. Tortoises with swollen eyes and fluid discharge from the nose were commonly found in these areas. From 1980, the site was mapped into sectors to study the movements of tortoises; some of these sectors were sprayed, others not. The number of tortoises decreased rapidly in the sprayed sectors (Fig. 2), while remaining constant in unsprayed areas. The widespread use of herbicides also resulted in the start of serious soil erosion.

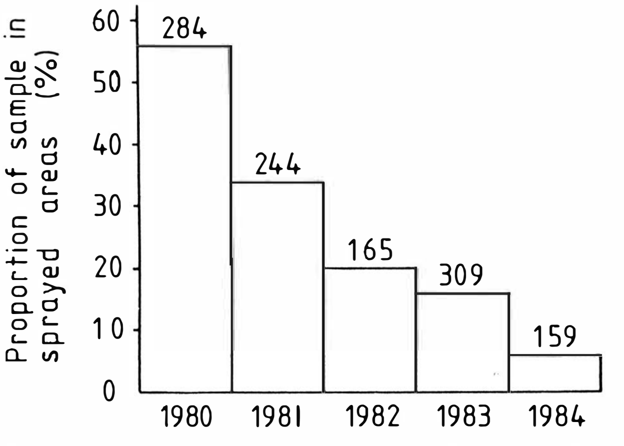

Fig. 2 The effect of spraying with 2, 4 D and 2, 4, 5 T on the relative number of tortoises in sprayed and unsprayed areas of the Olympia A site. Sample sizes shown. Spraying began in 1980, when about half of the tortoises found were in areas which were sprayed. The decline in subsequent years was due to mortality in sprayed areas, and was not caused by migration to unsprayed areas.

Physical disturbance was also a problem. Some hedges and trees were removed for firewood, and the remainder were burnt, killing many tortoises. The area has been increasingly used as a rubbish dump in recent years. The population of rats (*Rattus norvegicus*) increased greatly, and these were seen more frequently every year after 1978. Rats gnaw the forelegs of even adult tortoises to the bone, resulting in loss of limbs or death. These characteristic injuries have been seen at several sites, but nothing like on the scale at Olympia in recent years. This site became so disturbed that research was impossible, and was abandoned after 1984.

6 OLYMPIA B (HS1, MS1)

An area of open pine wood was also investigated near Olympia. This suffered from large forest fires in 1972, 1975 and 1981. Vegetation recovered quickly in burnt areas, but the pine wood was replaced by dense thorny scrub, which was apparently unsuitable for tortoises. A large area of scrub resulting from the fire of 1972 was examined in 1983, and no tortoises, or traces of them, were found. In contrast, five *T. hermanni* and three *T. marginata* were found in a small area of pine wood untouched by the fire.

7 Nauplion (MS2)

The great plain of Argolis was intensively used for citrus orchards. Citrus trees give dense shade so that the ground flora is usually restricted, and many pesticides are used on this crop. Citrus orchards are therefore unsuitable for tortoises, and only two *T. marginata* were found; tortoises in the plain were scarce and threatened. The plain is surrounded by mountains with thorny scrub. This is typical habitat for *T. marginata*, but none have been found during several visits to an area near Nemea, although a few traces of tortoises were seen.

8 Korinthos (MS0)

This area was known years ago for a population of *T. marginata* (Klingelhofer, 1931). Stemmler (1957) could not find any tortoises during a visit in 1957, and suggested that they had been a victim of the pet trade. However, nine *T. marginata* were marked on the east slope of Acrocorinth in 1982. The area was protected, and the population was not threatened.

9 Rion (HD2, MS2)

The vegetation was grassland and cultivated ground, with patches of thorny scrub. Tortoise density was apparently normal for this type of habitat. The area was under threat from agriculture and building. *T. hermanni* was limited to the small cultivated areas, and so was especially vulnerable.

10 Antirrion (HS2, MS2)

The vegetation was grassland with hedges intensively used by farmers, and patches of dry heath. Both *T. hermanni* and *T. marginata* were present at low density. Many tortoises were killed each year by mowing machines. This population appeared to be one of the most susceptible to increased agriculture.

11 Delphi (MS0)

The Parnassos mountains contain large areas of thorny scrub. Six *T. marginata* have been seen, including one juvenile. Local people knew of only this species. Although population density was low, the area is important because of its large extent. The areas immediately around Delphi are well-protected as this is a national monument.

12 Bralos (HS1, MS1)

The vegetation was a patchwork of open oak wood, grassland, cultivated fields and thorny scrub. Both *T. hermanni* and, less often, *T. marginata* have been found. Two visits to the area have both been at periods when tortoise activity was low at other sites, so that the population may be more dense than the numbers marked indicate. Local people reported that tortoises were much more common in the past, and that large forest fires during the civil war (1948) had reduced populations. There seemed to be no other threats to this population.

13 Kymi (HS1)

The habitat was olive groves and patches of pine woods, dry heath and abandoned fields. Only *T. hermanni* was found, at a rather low density for this type of habitat. No tortoises were found at other places on Euboea, including a variety of habitats, although a few traces were seen. The only danger to tortoises was apparently forest fires, which have occurred in recent years.

14 Skyros (MS0)

Watson (1962) recorded *T. marginata* from this island, and five were marked at a site with dry heath and patches of pine wood. Several other traces of tortoises were seen, but the density was apparently low. However, local people recognise *T. marginata*, and know where they can be found. Skyros is a remote island with a small human population and little tourism, and the tortoises seemed in little danger.

15 Pelasgia A (HD1, MS1)

Testudo hermanni and *T. marginata* were found in an area close to National Highway 1, where there were orchards and fields just below a thorny scrub-covered hillside. It is likely that many tortoises in these cultivated areas were making foraging trips from the scrub. The orchards were rotavated to clear weeds, and some carapace bones were seen at the edges of these fields. Several dug-out nets were seen at the edge of the scrub.

15 Pelasgia B (MS0)

Two *T. marginata* were found in small overgrown olive groves among dense thorny scrub in a very rocky area near the village. Several dug out nests were also seen. Access was difficult to this area, and direct human disturbance was not likely.

16 Fitiae (HD0)

This was an area of olive groves and hedges, supporting a dense population of *T. hermanni* typical of this type of habitat. There was no apparent threat to this population.

17 Arta (HD1)

Eight *T. hermanni* were marked in an area of hazel nut orchards, and traces of tortoises were common so that the density was not low. Farmers used many herbicides in this area, and although these had apparently not affected tortoises to date, they would be vulnerable to use of more toxic sprays.

18 Preveza (HS2)

This was an area of grassland and hedges used rather intensively by farmers. The habitat was apparently very suitable for tortoises. However, only a few tortoises were seen, although the site was sampled at a time (May 1982) when high activity was found at other sites. Tortoises were threatened by agricultural machinery.

19 Parga (HD2, MS1)

The vegetation was olive groves and hedges, in which many *T. hermanni* were marked. Two *T. marginata* were found in the theory scrub surrounding the olive groves. Some areas of this scrub were too dense to search for tortoises. Reynolds (1984) has also reported *T. marginata* around Parga. Farmers have destroyed hedges in recent years, resulting in the death of several tortoises and in loss of cover. Killing of tortoises for fun was more common here than elsewhere. The population of *T. hermanni* was vulnerable to cultivation.

20 IGOUMENITSA (HD1, MS1)

This was an area of grassland with rushes (*Juncus*) surrounded by olive groves and mountain slopes with thorny scrub. Both *T. hermanni* and, infrequently, *T. marginata* were found in the grassland, where population density was over 100 animals ha^{-1}. Population density was lower in the olive groves, and only a few *T. hermanni* were found in the thorny scrub. Hoogmoed (personal communication) reports finding *T. graeca* in an olive grove in this area. The presence of all three species of Greek tortoises would be unusual and requires further investigation; possibly the *T. graeca* are a result of translocation by man. The grassland was grazed by cattle, which may benefit tortoises by preventing encroachment by trees. This area is rather small, and so vulnerable to disturbance. About 25 per cent of the area was lost some years ago when a graveyard was constructed.

21 KERKYRA (HS1)

A few *T. hermanni* were seen in olive groves at three locations in 1976. There was a small threat from agricultural machinery. Durrell (1956) observed large numbers of tortoises in the late 1930s, but this island has since been subjected to considerable development for tourism.

22 MESOCHORON (HS0)

This was an area of deciduous woodland with large patches of grassland. Three *T. hermanni* were marked, and there seems to be a low population density. It was amazing to hear that a dealer had been active in this remote part of the central mountains, offering 50 drachmas for tortoises in 1984. Human activities were very limited, and the tortoises were not in danger.

23 METEORA A (HD1, MS1)

This site has been visited many times between 1976 and 1986. There were many habitats in the area: vineyards (some abandoned), grassland with hedges, and patches of thorny scrub and open oak wood. Agriculture has up to now been of traditional forms. Population density of *T. hermanni* was highest near human settlements, and was more than 100 ha^{-1}. Lower population density was found in thorny scrub. Most juveniles were found near settlements, where there were few dug-out nests. Fewer juveniles and more destroyed nests were found further away.

This is one of the few populations where there were predators of adult tortoises. A large colony of Egyptian vultures (*Neophron percnopterus*) live near Meteora. These birds are important predators of tortoises, which may be smashed by dropping them from height, or taken to the nest and eaten there (Obst and Meusel, 1978). Tortoises may sometimes be left alive in unusual places, and have been found by climbers high up in the rocks. Vultures forage through an area more than 20 km from Meteora, but do not come near human settlements, so that tortoises will suffer less predation in these areas. Several species of corvid birds are important predators of juveniles, and again these avoid the area around human settlements. Many carapaces of juveniles were found beneath solitary trees in open areas.

Farmers previously used pesticides which had no obvious effect on tortoise populations in the vineyards. However, hedges have been sprayed with 2, 4 D and 2, 4, 5 T in recent years. Only small areas had been sprayed up to 1986, but their further use is a major cause for concern. Access to the site was restricted to donkey transport up to the summer of 1984, when road construction opened it to cars and tractors. Many hedges were destroyed, causing the death of many tortoises which were sheltering there, out of proportion to the area involved. Improved access also resulted in road deaths, and the use of the area as a rubbish dump (with the risk of rats). Thus although the site was large and losses were still small, there is every indication that losses will increase in future.

23 METEORA B (HS0, MS0)

Another population was studied in a mountainous area about 7 km north of the town, with dense oak wood and some grassland. Both *T. hermanni* and *T. marginata* were found; the former were much less dense than in the cultivated site near the town. The area was protected, and grazing was forbidden, so that the populations were not threatened.

24 DESKATI A (HD0)

This site had an almost complete cover of open oak wood, with some arable fields in lower areas. Only *T. hermanni* were found, with an age distribution dominated by old animals; only 20 tortoises had less than 20 scute annuli. These animals were of large body size compared to other populations in Greece. The herbicides isoproturon and dinoterb were used extensively in spring, but are unlikely to affect tortoises which remain in the woods at this time. Increasing use of the wood by local people for firewood may open up the habitat and make it more suitable for tortoises. There seem to be no threats to this population.

24 DESKATI B (HD0)

Three other places were also examined in the large area of oak wood between Deskati and Meteora. A high density of *T. hermanni* was found in each area, and none of the populations were threatened.

25 AGIOS DIMITRIOS (HD0, MS0)

The vegetation was sparse thorny scrub on rocky soil, and part of the area was grazed grassland. The population density of *T. hermanni* appeared to be rather high for this type of habitat; a few *T. marginata* were also found. The area was protected from hunting, and although several used cartridges have been found, the tortoises do not seem to be under any threat.

26 LITOCHORON (HD1, MS1)

This was an area of thorny scrub on the lower slopes of Mount Olympus, in which there were several cultivated fields, patches of grazed grassland, and orchards. About a hundred *T. hermanni* and several *T. marginata* were marked, and similar numbers were seen during a study of reproduction (Hailey and Loumbourdis, 1988). The habitat in this area was not threatened. The only threat to tortoises was their habit of entering cultivated areas and meadows to feed, as little food was available within the scrub. Agricultural machines killed many tortoises in these areas. One field was visited in May 1986 shortly after the lucerne crop had been cut by tractor, and 10 dead tortoises were found, including three *T. marginata*, in an area of about 1 ha. Annual losses on this scale would be a severe drain on tortoise populations in the surrounding scrub.

27 ELASSONA (HS0)

A low density of *T. hermanni* was seen in deciduous woodland and rocky areas near a small river. The population was apparently not threatened.

28 GREVENA (HS0)

This was an area of open oak woodland. A single tortoise sighting (although the site was not visited at the best time for tortoise activity) and a few traces suggested a low population density. There were no apparent threats to this area.

29 KASTORIA (HD0)

The vegetation was open oak wood and grassland with hedges. Many *T. hermanni* were marked, but no other species was found. Hunting was forbidden, and the tortoises were not threatened at present.

30 KORINOS (HS2)

This area is a continuation of the southern heath at Alyki (below), but was more intensively used. The sand dunes were undisturbed, but behind them the grassland (with *Juncus*) was heavily grazed by cattle. A survey in 1982 found *T. hermanni* at a lower density than on the Alyki main heath. Much of the area was burnt in 1986 for pasture improvement, but few dead tortoises were found. Many more dead tortoises were seen after similar fires in the southern heath and the main heath. The tortoise density at Korinos was thus lower than at Alyki, and declining. The main threat is further fires for pasture improvement.

31 ALYKI A (HD2, GS1)

The areas known as the main heath and the southern heath (Stubbs, Swingland, Hailey and Pulford, 1985) included coastal and dry heath and grassland. These areas held a large population of *T. hermanni*, but were burnt and then rotavated in 1980 (Stubbs, Hailey, Tyler and Pulford, 1981; Stubbs, 1981a, 1981b). This was a deliberate attempt by local people to destroy the wildlife value of the heath, and so to overcome objections to building holiday homes. The tortoise population was reduced by about half (Stubbs *et al.*, 1985). The vegetation regenerated by 1982, apart from large bushes. Recovery of the tortoise population will take much longer, even if the area remains undisturbed.

Many plots for holiday homes, and the path of a new road, were marked out with stakes and concrete posts in 1983, but there was no further development to June 1988. Each year a few tortoises were run over, and one or two were killed by sportsmen with shotguns. Although unsightly, these deaths have negligible effects on the population. Much more serious were deaths from small fires started for pasture improvement. About five per cent of the heath was burnt each year. Most of the area was grazed by sheep between October and May, but this had little if any direct effect on tortoises. The small population of *T. graeca* in coastal heath (Hailey, 1988) would be vulnerable if the beach was improved for bathing by bulldozer; part of the southern heath was destroyed in this way in 1987 (Goutner, personal communication).

31 ALYKI B (HD2)

A high density of *T. hermanni* was found on the isolated salt-works heath (Stubbs *et al.*, 1985). This area was disturbed several times in recent years, by construction of a road to the salt works, small fires, and by improvement of the beach for bathers. This disturbance is expected to increase with modernisation of the salt works.

31 ALYKI C (HS1)

A low density of *T. hermanni* were present in mixed arable farmland, orchards, poplar wood and waste ground around Alyki. These were threatened by mechanised farming, fires to clear fields, and by cutting down woods.

32 AGATHOUPOLIS (HS1)

The Aliakmon river estuary north of Agathoupolis is surrounded by a large area of flat land, most of which must have originally been marsh and heath similar to Alyki. Almost all of the drier parts of this land were intensively cultivated, or used as a rubbish dump. A few *T. hermanni* were found in abandoned fields and waste ground, which were threatened by further slow deterioration of their habitat.

33 KILKIS (HD1, GS1)

Most of the plains of northern Greece were under arable cultivation, and the natural vegetation was only retained on hills. These vegetation islands were the last strongholds of tortoise populations inland in this region. The fields were rendered unsuitable for tortoises by annual fires started to clear up after the harvest; these large fires sometimes spread to the hills.

An isolated tortoise population (mostly *T. hermanni*) was found on a thorny scrub-covered hill near Kilkis. Isoprobuteron and Dinoterbe were used in the surrounding fields, but most tortoises were unlikely to come into contact with these. The main threat was fires spreading from the fields; one part of the hill was burnt years ago, and several carapaces were found in that area. Local people noted that tortoises were much more common in the past, and that changed agriculture had caused the decline.

34 EPANOMI (HD0, GD0)

This was an area of coastal and dry heath and grassland surrounding a lagoon, with both *T. hermanni* and *T. graeca*. These populations had a high proportion of juveniles, and seemed to be flourishing (Hailey *et al.*, 1988). The area was protected, and hunting was banned. There may be some interference with the tortoise population, as two of the *T. graeca* found had been painted white; these were probably pets which had been released.

35 KOLHIKO (HS0, GS0)

This was a large area of thorny scrub-covered hills intersected by small rivers, with areas of close-cropped grassland and bare rocks. It was intensively grazed. A few *T. hermanni* and *T. graeca* were seen in the grassy areas. The population density was low, but the tortoises are not threatened as farming did not involve machinery or spraying.

36 LANGADIKI (HS2, GS2)

The scrub-covered hills typified by sites 35 and 37 gave way to a patchwork of arable fields and grassland with hedges in the low fertile areas around the large lakes. *Testudo hermanni* and *T. graeca* were present at low density in these areas, where they were highly threatened by road traffic and agricultural machinery; only dead animals were found (Stubbs *et al.*, 1981).

37 MIKRA VOLVI (HD1, GD1)

The site was part of a large area of thorny scrub covering the hills to the north of Lake Volvi. Some parts of the scrub were cleared by farmers in recent years, although this affected a small proportion of the total habitat. Both *T. hermanni* and *T. graeca* were common. Tortoises suffered from a high degree of egg predation, judging by the large number of destroyed nests found. The main threat to this population was large fires, of which there have been several in surrounding areas in recent years.

38 KERAMOTI A (HD1, GD1)

The land around the mouth of the Nestos river included damp grassland and cultivated fields, lagoons and marshes, coastal heath and strips of deciduous wood. A dense population of *T. hermanni* and *T. graeca* was found in an area of woods, coastal heath and grassland near the town (Hailey *et al.*, 1988). This population was in a vulnerable position if the town or camping site were further developed. This is a major tourist area, with the ferry port to the popular island of Thasos.

38 KERAMOTI B (HS0, GD0)

Both *T. graeca* and *T. hermanni* were found on a small island west of the town, connected to the land by a small bridge (Hailey *et al.*, 1988). These were apparently under no threat.

39 LAGOS A (HD2, GD2)

A high density of *T. hermanni* and *T. graeca* were found near the town in a coniferous plantation on coastal heath. There were very few juveniles, however, probably because of disturbance from human commensals (Hailey *et al.*, 1988). The population appeared to be declining.

39 LAGOS B (HS1)

A few *T. hermanni* were found in intensively used grassland separated from the Lagos A site by a main road (Area 3 of Wright, Steer and Hailey, 1988). These were apparently threatened by increasing use of the area to dump rubbish.

40 AVAS (HS0, GS0)

The Avas Gorge included steep rocky sides covered in dense thorny scrub, some olive groves, and arable fields in flat areas near the river. A low density of tortoises were found; two *T. hermanni* and five *T. graeca* in several man-days sampling (Stubbs *et al.*, 1981). Tortoises were not apparently threatened.

41 SOUPHLI (GS2)

This site was a patchwork of coniferous woodland, thorny scrub, and grassland and cultivated fields. There was a low density of *T. graeca*, only two being found, one of which had been killed by a tractor. Tortoises in the fields were threatened by mechanised farming.

42 EVROS DELTA (HD2, GD2)

The region with highest tortoise density was the western coastal part of the delta. This was an area of coastal heath, where both *T. graeca* and *T. hermanni* were common. A large part of this area was threatened by the scheduled development of a fish farm (Goutner, personal communication).

HERPETOFAUNA OF TORTOISE SITES

The tortoise populations thus suffered from very varied degrees of disturbance. Many populations in isolated areas were completely undisturbed, and were unlikely to be disturbed in the future (such as Delphi, Skyros, Mesochoron). Other populations had been devastated during our studies, and were in further danger (such as Olympia A, Alyki A). The types of threat were also varied, including fires, building, pesticide spraying and dumping of rubbish. No simple trends are shown by the results, apart from the observation that large numbers of all three species have not been found together (Table 1); *T. marginata* and *T. graeca* have exclusive distributions.

Before presenting a quantitative evaluation of these results (in the Discussion), we consider the other species of reptiles found at the sites, and especially at the Alyki A site. These observations are summarised in Table 3, which excludes sites where few other reptiles were seen. Lizards and snakes were in the same habitat as the tortoises, unless indicated otherwise. The abundance of reptiles at Alyki is shown as the total number of sightings; values above 10 are approximate.

Status of reptiles at Alyki

These notes describe the status of each of the reptiles seen at Alyki A (the main heath) up to June 1988,

Species	31	1	2	3	5	6	13	19	20	23	24	25	26	27	29	32	33	34	35	37	38	40	41	42
Cyrtodactylus kotschyi	+	0								0														0
Agama stellio																			0					
Algyroides moreoticus					0		0																	
Ophisops elegans																							0	
*Lacerta trilineata**	500		0			0	0			0	0		0		0	0			0	0	0	0		0
Lacerta graeca			0																					
Podarcis taurica	2000		0		0	0		0		0	0	0	0			0	0	0		0	0		0	
Podarcus erhardii	+													0										
Podarcis muralis										0			+		0									
Podarcis pelopponesiaca		0	0		0																			
Ophisaurus apodus	100	0		0		0	0	0	0				0							0				
Anguis fragilis					0								0											
Ablepharus kitaibelii	20			0		0					0													
Eryx jaculus	5																	0						0
Malpolon monspessulanus	20			0																0				0
Coluber jugularis	100																	0						
Coluber gemonensis													0											
Elaphe situla										0							0							0
Elaphe quatuorlineata	5												0											
Elaphe longissima						0																		0
Natrix natrix	20												0			0		0	0			0		0
Natrix tessellata	+													0	0					0		+		
Vipera ammodytes	20		0			0					0		0											

TABLE 3: Other reptile species found at tortoise sites. Details of tortoises are given in Tables 1 and 2. Approximate numbers of sightings are given for Alyki (site 31). Presence at the other sites is indicated by: 0 in same habitat as tortoises; + in other habitat. * Not distinguished from *L. viridis* at most sites.

including noteworthy records at other sites. They should be used in conjunction with the maps of the Alyki site given by Stubbs *et al.* (1985).

Emys orbicularis and *Mauremys caspica*

One *Emys* and four *Mauremys* were found in damp areas of the main heath. These had probably dispersed from freshwater dykes in the southern heath and the saltworks heath, where terrapins were common. A few dry carapaces have also been found in the dry pools in sector 12. Terrapins are unlikely to breed on the main heath, but are common in freshwater dykes, pools and streams in the Alyki area and throughout Greece.

Lacerta trilineata

Those green lizards which have been captured at Alyki and at other sites have all proved to be *L. trilineata*. The presence of *L. viridis* at some sites cannot be discounted, as these species are impossible to distinguish unless striped juveniles are seen, or specimens can be examined in the hand. *L. viridis* was identified in orchards at Edessa in Macedonia. Green lizards were quite common at Alyki in dry heath and grassy heath/*Juncus* marsh, foraging in open areas and climbing bushes to escape. Also found in farmland, and often run over as they basked on roads in the evening. The highest density was seen in thorny scrub at Kolhiko, Mikra Volvi and Avas.

Podarcis taurica

Very common in coastal heath and grassland, typically running between low shrubs (*Artemisia*) or patches of grass. High densities also seen in coastal heath at Epanomi and Keramoti. Widely distributed in northern Greece, present in meadows and fields at low density. Another wall lizard, *P. erhardii*, was also present at Alyki and elsewhere in northern Greece. This inhabits rocks and buildings (see Hailey, Gaitanaki and Loumbourdis, 1987), and was not found on the main heath.

Ophisaurus apodus

Most sightings at Alyki were in spring, in dry heath and grassland. Almost all individuals were adults of about 1m total length; only two juveniles have been seen. Some aspects of their biology have been described by Hailey (1984) and Hailey and Theophilidis (1987). A much higher density was found in meadows at Litochoron and Olympia, where several were sometimes seen per day. Glass lizards were often seen dead on roads after rain in spring, in farmland with thick hedgerows.

Ablepharus kitaibelii

Early sightings of this skink at Alyki were of juveniles in drift-line debris in summer (Stubbs *et al.*, 1981). Subsequent sightings have been in the grassy heath of sectors 11 and 12 in spring and autumn. Also seen in farmland at Olympia and more frequently in woods at Deskati. This species is resistant to disturbance; several were seen in roadside verges in the industrial estate at Sindos (near Thessaloniki).

Eryx jaculus

Five seen in dry heath and coastal heath at Alyki, and present in similar habitat at Epanomi (Goutner, personal communication). Two sand boas have been found dead on roads through arable farmland and orchards at Alyki.

Malpolon monspessulanus

This snake was restricted to grassland and *Juncus* marsh in sectors 2, 11 and 12 on the main heath. An adult was seen ingesting a green lizard, and a juvenile was found choked on an adult *P. taurica*. Also seen in dense vegetation around the salt works, and dead on roads in arable farmland and orchards.

Coluber jugularis

The most abundant snake, common in dry heath, and occasionally seen in coastal heath. Also found in similar habitat at Epanomi, and seen dead on roads passing through arable farmland. The only prey recorded was a sand boa.

Elaphe quatuorlineata

Three individuals were sighted from 1980-1986. These were in sectors 9 and 13, and had probably dispersed from the far end of the southern heath where there were permanent livestock shelters (with rats), and tall tamarisk scrub leading to woods. It is unlikely that there was a breeding population on the main heath, as there were few small animals.

Large numbers of small mammals were seen all over the heath in May and June 1988. This population explosion occurred elsewhere in Greece at the same time, following an exceptionally mild winter (Th. Sofianidou, personal communication). Five voles were trapped in dry heath (sectors 1 and 2), grassy heath (sectors 3 and 17) and the coastal dunes (sector 9), all apparently *Microtus guentheri* (van den Brink, 1973; Vohralik and Sofianidou, 1987). Two adult *E. quatuorlineata* were seen in sector 2 in May 1988; these had probably entered the main heath from the southern heath, in response to the vole population explosion.

Natrix natrix

Seen in coastal heath, grassland and *Juncus* marsh, mostly in sectors 2 and 3, usually in the evening. Two melanistic adults with reduced dorso-lateral stripes were found in May 1988. Recorded prey were the toads *Bufo viridis* and *Pelobates syriacus*. A similar heathland population occurred at Epanomi. Grass snakes were more often seen around streams and pools in farmland and natural habitats at several sites, feeding on green frogs.

Natrix tessellata

One seen in sector 2 had probably dispersed from the deep freshwater dykes on the far side of the salt works, and this snake was not thought to breed on the main heath. A few seen in dykes and streams at the other sites: this species is common in Lake Volvi.

Vipera ammodytes

Most vipers were found when basking in spring, in dry heath and coastal heath in sectors 7 and 10. Several juveniles were found in the evening on tracks through arable farmland at Alyki, mostly in October. An adult was seen ingesting *L. trilineata* at Litochoron.

Other species

Four amphibians were found on the main heath. The most abundant was *Bufo viridis*, in dry heath and coastal heath. *Pelobates syriacus* had a similar distribution but was much less common. These toads bred in shallow pools in sector 12 in wet years; these pools dried before tadpoles had developed in the dry year 1985. Four *Hyla arborea* were seen between 1980 and 1986, in dry heath vegetation. Many were heard calling in May and June 1988. Two *Bufo bufo* were found in *Juncus* marsh in 1980, but the common toad has not been seen since at Alyki.

Four other species were seen in the Alyki area, but not on the main heath. These are:

Triturus vulgaris; a single male from a stream,
Rana ridibunda; common in dykes, pools and streams,
Cyrtodactylus kotschyi; on buildings and trees,
Podarcis erhardii; on buildings.

DISCUSSION

Status of Tortoise Populations

The unit of analysis used here is the species-population, that is a population of a single species of tortoise at a single site. This was used because the species sometimes differed in density or status at a single site. The survey included 79 species populations at 42 sites. Overall, 22 populations (28 per cent) were immediately threatened, and 26 (33 per cent) were not apparently threatened at present. The other 31 populations (39 per cent) had declined in the past, or were liable to long-term decline.

The three species differed significantly in the relative numbers of sparse and dense populations. The percentages were:

	Sparse	Dense	(N)
T. hermanni	45	55	44
T. graeca	50	50	12
T. marginata	96	4	23

(X^2 = 16.6, 2 d.f., P = 0.00024). The only dense population of *T. marginata* was found at Gytheion, the other 22 populations of this species being sparse. In contrast, about half of the populations of *T. hermanni* and *T. graeca* were dense; there was no significant difference between these two species (X^2 = 0.0022, 1 d.f., P = 0.96).

There was no significant difference between the three species in the proportion of populations in each threat status category. The percentages were:

	Status 0	Status 1	Status 2
T. hermanni	32	39	29
T. graeca	33	33	33
T. marginata	35	43	22

(X^2 = 0.74, 4 d.f., P= 0.95). The species were therefore pooled, and the status of the 48 sparse and 31 dense populations were compared. There was no significant difference, the percentage in each status category was:

	Status 0	Status 1	Status 2
Sparse	35	40	25
Dense	29	39	32

($X^2 = 0.59$, 2 d.f., P = 0.74). This result was contrary to our expectation that the sparse populations would be less threatened. It is explained as the sparse category includes threatened populations in agricultural land, as well as populations in the large areas of thorny scrub in mountainous regions which are under no threat.

There was a noticeable trend in the location of populations of different threat status. Many of the populations in no apparent danger were in the central mountainous regions (Fig. 3a), or in places where steep hills approached the coast (Pelasgia, Delphi, Korinthos). In contrast, most of the immediately threatened populations were in flat areas at or near the coast (Fig. 3b).

Threats to Tortoise Sites

In total, the 42 sites suffered from 51 identified threats (some sites were subject to several types of threat), which may be grouped into categories. The percentage of the total number of threats made up by the different categories was:

Agricultural development	22
Agricultural machinery	20
General development	10
Agricultural spraying	10
Agricultural burning	8
Forest fires	8
Tourism development	8
Direct slaughter	8
Human commensals	6

Numerically, the most important threats at tortoise sites were agricultural, making up 61 per cent of the total. Threats from urbanisation (general and tourism development, human commensals) made up only 23 per cent of the total. Note that threats from tourism were numerically rather small compared to agriculture, and even compared to other forms of urbanisation. The remaining 16 per cent of threats were more casual; from forest fires and the direct slaughter of tortoises.

Despite these threats to sites, it must be concluded that tortoises are still rather common animals in Greece, where their conservation is a much less serious problem than that of sea turtles, large mammals, or birds of prey. However, about two thirds of Greek tortoise populations are currently threatened by long-term decline or sudden catastrophe. The situation should be monitored, preferably by surveys specifically for this purpose. Such surveys should improve on this review in three respects:

1) Quantitative estimates of population density should be made using short term census techniques such as that described by Hailey (1988).

2) The number of tortoise sites should be found by intensive survey of a few large regions (say 1000 km^2), for use as a calibration. The total number of sites occupied by tortoises in Greece, and the total number of animals, can then be estimated.

3) As much attention should be given to investigating the threats to a site, as to the details of the tortoise population. In our survey, the 46 populations at sites where tortoises were marked were apparently more threatened than the 33 populations at sites visited for shorter periods. The percentages were:

	Status 0	Status 1	Status 2
Marked sites	19	48	33
Short visits	52	27	21

($X^2 = 8.92$, 2 d.f., P = 0.012). One possible reason for this difference is simply that more threats become apparent during a longer study.

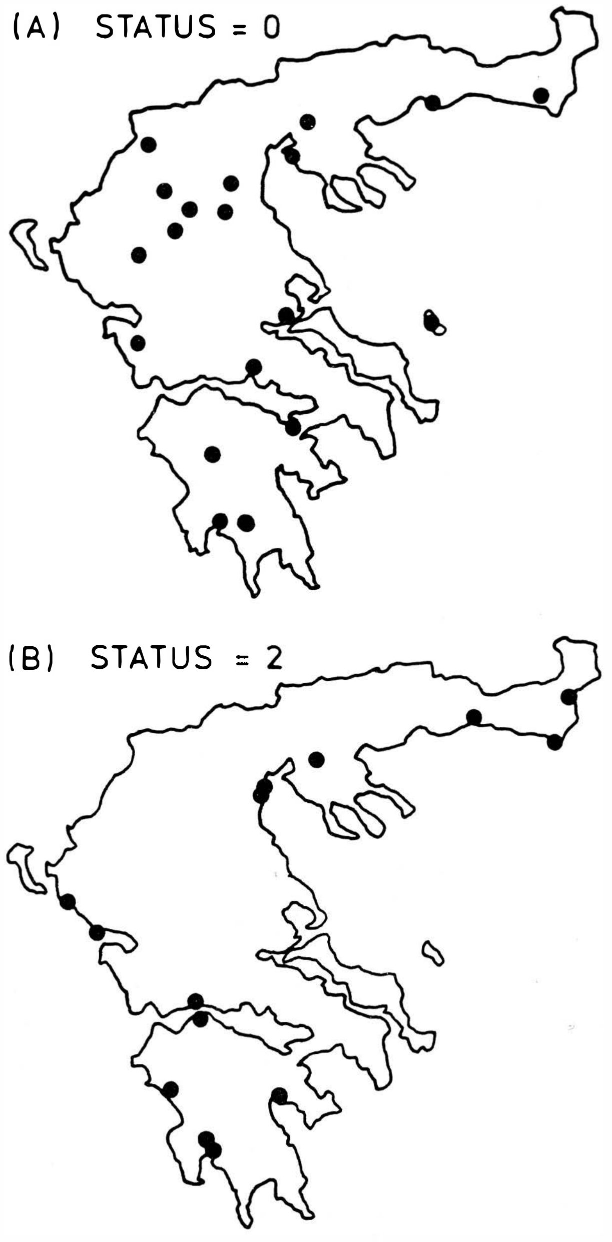

Fig. 3 Location of sites at which populations which were (a) not apparently threatened, and (b) immediately threatened, were found. Note that many of the safe sites are in the central mountainous region, and the majority of the most-threatened sites are near the coast.

Casual collecting is another threat to Greek tortoises, which is hard to quantify but probably widespread (Sofianidou, personal communication). This affects all species (it has been observed twice at Alyki), and is likely to be responsible for translocation of tortoises found well outside the natural range of the species (for example *T. gracea* in western Greece or the Peloponnese). It typically involves Central Europeans touring by car, who see 'the alert, vigorous, herb-scented beasts that plough through the undergrowth' (Arnold *et al.*, 1978) and collect one or two on impulse. The beasts are considerably less attractive after a few days, when they have covered themselves and the boot of the car with their faeces, and are likely to be liberated, perhaps hundreds of kilometres from where they were captured. Translocated animals might persist in the wild for 10 or 20 years, but still represent a loss to the original population.

Status of the Three Species

Testudo hermanni was the most widespread and common species, found throughout Greece, at high density in a variety of natural habitats and at the edge of cultivation, and at low density in thorn scrub and agricultural land. It was unusual in showing wide regional variation of body size (Table 4). The variation is partly explained by climatic and ecological factors; tortoises are larger to the north and in woodland habitat. This is not, however, a simple relationship, because mean adult size may change abruptly between adjacent populations in similar habitat (Willemsen, in preparation). This will be considered in more detail elsewhere; it implies some regional genetic variation, which will be lost if only a few populations remain. *T. hermanni* in southern Greece and the Peloponnese, which are of characteristic small body size, are the most threatened. These populations occupy small areas, usually of cultivated ground liable to disturbance. In general, *T. hermanni* as a species seems to be in no danger at present in Greece.

Type	Site	SCL (mm)	Range
1	Deskati	198 ± 17	NC Greece
2	Volvi	168 ± 10	NE Greece
3	Meteora	159 ± 8	C Greece and coastal sites
4	Olympia	151 ± 7	N & C Peloponnese
5	Sparta	138 ± 9	S Peloponnese and Euboea

TABLE 4: Size variation of *T. hermanni* in different parts of Greece. Measurements are mean straight carapace length (± 1 S.D.) of adult males of five recognisable types. The data are for a typical site for each type, and the geographic range of the type is shown (C = central). Unpublished data of Brinkerink and Willemsen. The range of mean length shown corresponds to a three-fold variation of weight, from about 500 to 1.500g.

Testudo marginata was almost as widespread, but absent from north-east Greece. It was much less abundant as most populations were sparse, whether in natural habitats or in cultivated areas. The site at Gytheion would merit protection as this dense population of *T. marginata* is unique in our experience. Elsewhere, this species was not threatened in the thorn scrub which seems to be its natural habitat; this vegetation is typical of rocky areas which have little value for other uses. The main danger was from a slow loss of animals at the edge of cultivated land. Thorn scrub contains little food, and tortoises often enter fields to feed on herbs and weeds, where they are killed by machinery and pesticides. *Testudo marginata* is especially vulnerable to this slow drain on populations because it is large (adult females weigh about 2 kg) and slow maturing. Only 6 per cent of the animals marked were juveniles, compared to 15 and 26 per cent in *T. hermanni* and *T. graeca*, respectively (Table 2). The slow population turnover also makes *T. marginata* vulnerable to loss of a few adults by casual collecting; this species seems to be more sought after than the other two (Sofianidou, personal communication). In general, we regard the future of this species with more optimism than Keymar and Weissinger (1987), though it is endangered in some regions (around Athens, for example).

Testudo graeca was restricted to north-east Greece, mostly in coastal habitats (see Wright *et al.*, 1988). The populations in Greece were in danger because coastal areas are the most likely to be disturbed. However, the main distribution of this species is in Asia Minor (the subspecies *T. g. ibera*) and North Africa (*T. g. graeca*), so that the Greek populations are of little importance for the future of the species. In contrast, *T. marginata* is endemic to Greece, and *T. hermanni* is largely a Balkan species. Therefore although *T. graeca* is the most threatened tortoise in Greece in national terms, its fate in Greece is of lesser importance in world terms.

Biogenetic Reserves for Reptiles

Most reptiles are difficult to find and will be missed in short surveys. Tortoises, however, are conspicuous, and it would be useful if their presence could be used as an indicator of a particular assemblage of reptile species. There are 33 native species of lizard and snakes in mainland Greece (Arnold *et al.*, 1978), and 23 of these (70 per cent) were found with tortoises. *Testudo hermanni* was associated with 22 species. Many of the remaining species are secretive (*Chalcides ocellatus, Ophiomorus punctatissimus, Typhlops vermicularis, Coronella austriaca*) or nocturnal/crepuscular (*Tarentola mauretanica, Hemidactylus turcicus, Telescopus fallax*), and are likely to be identified by more detailed surveys. Reynolds (1984) has noted two additional species found at tortoise sites in western Greece; *Algyroides nigropunctatus* and *Coluber najadum*. Thus about three quarters of the reptile species of mainland Greece have been found with tortoises. It must be concluded that the presence of tortoises provides little or no information about other species of reptiles likely to be found in an area.

The presence of tortoises might still be a useful indicator of the herpetological potential of a site, by showing an area of high species richness, rather than identifying a particular community. Unfortunately, this also seems to be invalid. Tortoises were found at very disturbed sites such as Lagos, and indeed may be one of the most resistant of reptiles to disturbance over a few years. Ultimately, of course, tortoise populations must die out where recruitment is interrupted (Lambert, 1984).

Another possibility is using the population structure of tortoises to show whether a site is disturbed and has a low richness of other reptiles. The population structure at disturbed sites is often adult-dominated, with few juveniles (Hailey *et al.*, 1988). However, population structure may be affected by factors specific to tortoises, such as predation on nest aggregations (Stubbs and Swingland, 1985). For example, the declining tortoise population in the Massif des Maures in southern France is in an area with many other reptile species (Stubbs, personal communication).

The herpetofauna of the main heath at Alyki is substantially less rich than the 39 species which have been identified in the proposed biogenetic reserve in Thrace, north-eastern Greece (Anonymous, 1987). However, simple numbers of species, or numbers of threatened species, should not be used as the main criterion for selecting a reserve. It is important to distinguish the contributions of within-habitat and between-habitat richness to the number of species present. Reptiles are often rather habitat-specific (Heatwole, 1976), so that an area containing many types of habitat will have a large number of species. For example Kitchener, Chapman, Dell, Muir and Palmer (1980) examined the lizard faunas of 23 reserves in the wheatbelt of Australia, to see the effects of area, isolation and habitat diversity. Their main conclusion was that:

> 'Multiple regression analysis shows that 75 per cent of the variation observed in lizard species richness between reserves is accounted for by the logarithm of the number of vegetation associations in these reserves; addition of other reserve variables examined (including area) does not significantly increase this explained variation.'

It is suggested below that Alyki merits protection as an undisturbed coastal heathland containing most or all of the reptile species likely to be found in that habitat. Larger areas may hold a greater number of species, but will not be as effective for conservation if they simply contain the most common species from many different habitats.

Alyki as a Reserve for Reptiles

The reptile most deserving of attention at Alyki is *T. hermanni*, of which there is a large population in an apparently optimum habitat for the species. Conservation of the site would also benefit the other species of reptile which breed there. After *T. hermanni*, the snakes *E. jaculus* and *V. ammodytes* are of most interest. These are not abundant anywhere, and coastal and dry heath seem to be their typical habitat. These snakes also occur in traditionally farmed land, but would be vulnerable to intensive land use; *Eryx* to mechanised farming, and *Vipera* to direct persecution.

Three further groups of reptile species present at Alyki may be recognised.

a) Those for which the main heath provides typical natural habitat, but which are abundant in disturbed areas and of low priority for conservation: *P. taurica*, *M. monspessulanus*, *C. jugularis*.

b) Those which are abundant at Alyki, but are even more abundant in other natural habitats: *L. trilineata* (scrub), *O. apodus* (meadow), *A. kitaibelii* (woods), *N. natrix* (marsh).

c) Those present in small numbers for which Alyki is at the edge of the geographic range (*T. graeca*) or which do not breed on the heath (*E. orbicularis*, *M. caspica*, *E. quatuorlineata*, *N. tessellata*).

Alyki contains almost all the reptiles which occur in coastal heathland in northern Greece. We have not seen any other reptiles in coastal heathland in this area which are not present at Alyki. Three other species might occur (Arnold *et al.*, 1978), but their habitat preferences are not known in detail. *Chalcides ocellatus* and *Typhlops vermicularis* may require ground cover of rocks, which is not present at Alyki. These two species are otherwise common; *Chalcides* has a wide geographic range in the Middle East, and *Typhlops* also inhabits disturbed areas such as the suburbs of Thessaloniki. Another possibility is *Telescopus fallax*, although the typical habitat of this snake seems to be fields with dry stone walls and rocky areas; it has been found in Chalkidiki around farms.

In conclusion, it must be admitted that there are no reptiles at Alyki which do not occur elsewhere at similar or greater densities. The site is worth conserving, however, as an example of a little disturbed coastal heathland; it is also important for bird and plant life (D. Stubbs, V. Goutner, personal communications). The survey of tortoise sites showed that coastal areas were the most threatened. There are rather few good coastal sites in Greece, as steep hills come down to the sea in most places; coastal heathlands are restricted to the areas around lagoons and estuaries. The Alyki heath is at present one of the best remaining examples of this habitat in Greece, and should be protected.

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APPENDIX

Further records of the distribution and status of tortoises and other reptiles in Europe are always useful. These should be sent direct to:

DR BRIAN GROOMBRIDGE: IUCN Monitoring Centre, 219c Huntingdon Road, Cambridge CB3 0DL, UK.

and

DONATO BALLASINA: R.A.N.A. – Belgium vzw' Populierenlaan 17'B – 1980 Tervuren, Belgium.

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IMMUNOCYTOCHEMICAL AND QUANTITATIVE STUDY OF INTERSTITIAL CELLS IN THE HIGH MOUNTAIN TOAD *BUFO BUFO GREDOSICOLA* DURING THE SPERMATOGENETIC CYCLE

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ABSTRACT

The interstitial cells of the toad *Bufo Bufo gredosicola* were studied throughout the seasonal period of spermatogenesis (from April to October) by means of immunocytochemical detection of testosterone and quantitative histological studies. The total number of interstitial cells per testis did not vary during the spermatogenetic period. However, in April, May and October, there were many interstitial cells showing an abundant testosterone content, whereas from June to September poorly-differentiated interstitial cells with a scanty testosterone content are the most abundant interstitial cell type. Since the interstitial cells with abundant testosterone content are larger than the interstitial cells with scanty testosterone content, the volume occupied by interstitial cells decreased in June-September. The development of thumb pads coincides with that of testosterone-containing interstitial cells.

INTRODUCTION

It is generally accepted that, as in other vertebrates, the interstitial cells or Leydig cells represent the major source of testicular steroid hormones in anuran amphibia. This ideas has been supported by direct evidence from cytochemical (presence of cholesterol-rich cytoplasmic droplets and $\Delta^5$3ß-hydroxysteroid dehydrogenase activity), and ultrastructural studies (Lofts, 1974; Unsicker, 1975; Rastogi and Iela, 1980). However, unlike in higher vertebrates, no tissue cultures and incubation experiments with dissociated cell populations of the anuran testes have been performed and it cannot be excluded that other cells such as the Sertoli cells, which also show Δ^5-3ß-hydroxysteroid dehydrogenase activity, might be involved in steroid biosynthesis (Lofts and Bern, 1972).