THE DADIA–LEFKIMI–SOUFLI FOREST NATIONAL PARK, GREECE: BIODIVERSITY, MANAGEMENT AND CONSERVATION

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Spatial and temporal variation of reptiles

Dimitrios E. Bakaloudis

Reptiles play an important role in complex ecosystems, especially when they constitute the major prey for most of the breeding raptorial birds, as is the case in the Dadia–Lefkimi–Soufli Forest National Park (DNP). Understanding the way reptiles respond to land use and factors that influence their spatial and temporal variation are crucial for any management plan. The patchwork of different habitats that occurs in the area supports both a diverse assemblage and high numbers of reptile species. I studied the diversity and numbers of reptiles in different kinds of habitat within the DNP. Forested areas had relatively high reptile counts but low diversities. In contrast, high reptile diversities were found in grasslands, non-intensively cultivated areas and shrublands. These open habitats were also used by foraging raptors. Most of the raptors that breed in the area rely on different reptile species and adjust their foraging activities according to the reptiles' temporal patterns of activity. Thus, in heterogeneous landscapes, such as in DNP, conservation measures should aim both to maximize vegetation heterogeneity at the landscape scale and to maintain microhabitat complexity at the scale of the forest stand.

Keywords: Snakes, lizards, diversity, habitat types, prey, conservation

Introduction

Dadia forest is well known for its diverse avifauna and especially for the assemblage of birds of prey it supports (Bakaloudis 2000). However, the area supports other valuable groups of animals, such as mammals, reptiles, amphibians, fish and insects. Most of the studies carried out in the region have concentrated mainly on the ecology of raptorial birds, and little information is available on the remaining groups.

Ecologists recognise that reptiles play an important role in a complex ecosystem (Zug et al. 2001) and constitute a vital link in food chains (Vlachos 1989, Bakaloudis et al. 1998a) as predators on a variety of small animals ranging from arthropods to amphibians, small mammals and birds, and as prey for higher order predators such as shrikes, falcons, buzzards and a few eagle species. In addition, many studies have suggested that both amphibian and reptile communities might be affected by land use changes that have occurred worldwide during recent decades (Greenberg 2001, Maisonneuve and Rioux 2001, Loehle et al. 2005). Alterations of habitat regimes as a consequence of land use exploitation (particularly forestry, agriculture and reafforestation of non-intensively cultivated land) are a potential threat to most animal species that occur in the Dadia forest. We need to understand the processes sustaining animal diversity in Dadia forest if we wish to protect the local biodiversity and to manage land use and other activities impinging on this unique ecosystem (Holloway and Bakaloudis 1998). Consequently, it is important to know how reptiles respond to any changes in land use so as to predict how these may affect the abundance and diversity of reptiles, and any knock-on effects on other animals, including raptors.

Information on the diversity of the herpetofauna in the Dadia forest reserve has been obtained mainly from a few works (Helmer and Scholte 1985, Bakaloudis et al. 1998, Capper 1998, Taylor 1998, Kati et al. 2007), but there is no information on the abundance and seasonal variation in activity patterns of this group of animals.

In order to gather information on how reptile populations vary according to the different habitat types and land uses, as well as to understand the factors that influence the spatial and temporal variation of reptiles in the area, and to assess if the reptilian community affects the distribution and abundance of raptorial birds, I examined: (a) the pattern of spatial distribution, abundance and community structure of reptiles, and (b) their pattern of temporal variation in Dadia–Lefkimi–Soufli Forest National Park (DNP).

Methods and habitat classification

Habitat classification

Although the area is characterised by a mosaic of habitats, woodland is the dominant habitat type. Nine different habitat types were identified, according to plant species composition and land cover, following the CORINE land cover nomenclature with some modifications (Commission of the European Communities 1994):

(1) Flat, intensively cultivated areas. These are situated close to the Evros River and its tributaries, mostly <40 m asl. The cultivated areas generally have limited lengths of vertical structures (e.g. natural hedgerows) separating the fields. However, in some cases natural riparian vegetation (poplars *Populus alba* and *P. tremula*, willows *Salix* spp. and alders *Alnus glutinosa*) occur along irrigation channels and drainage networks. Annual crops are dominated by cotton, corn and sugar-beet that are irrigated during the dry summer months. Irrigation involves redirecting water from the Evros River into dammed reservoirs and then across the cultivated areas in channels.

(2) Non-intensively cultivated areas. Situated by the small villages and generally 40–100 m asl these areas are hilly and used to grow cereals, sunflowers, grapes and almond trees. They contain many hedges and coppice strips. The fields are smaller than on intensively cultivated land, and they are often left fallow, sometimes for considerable periods of time so that rough patches of grass occur between some of the fields.

(3) Shrublands. Mainly situated in the south-western part of the area where the grazing pressure is relatively low. The maquis vegetation is dominated by *Phillyrea media, Arbutus andrachne, Carpinus orientalis, Ostrya carpinifolia, Paliurus spina-christi, Cistus* spp., *Erica arborea*, and covers >40% of the ground.

(4) Pine forest (canopy >40% closed). Situated in the central part of the study area, approximately 100–300 m asl and characterised by mature stands of Turkish Pine *Pinus brutia* and Black Pine *P. nigra*. Usually, these grow over shrub-layer vegetation such as *Erica arborea, Phillyrea media* and *Cistus* spp.

(5) Mixed pine-oak forest (canopy >40% closed). Principally found in the north-western part of the area, approximately 300–700 m asl and dominated by *P. brutia* and *Quercus* sp. associations. As with pine forests, shrub vegetation occurs in the understorey.

(6) Oak forest (canopy >40% closed). Mainly found in the north-western part of the area, approximately 500–700 m asl and dominated by *Quercus fraineto, Q. pubescens, Q. sessiliflora, Sorbus torminalis, Fraxinus ornus* and *Colutea arborescens*.

(7) Degraded oak forest (canopy <40% closed). Mainly found in the western part of the area, approximately 400–600 m asl and dominated by old oak trees in the upper layer and *Cistus* sp. in the herb layer. This habitat is heavily grazed by cattle, goats and sheep.

(8) Grasslands with sparse shrubs and trees (shrub and tree coverage < 40%). These areas are generally between 0.05–1.5 ha with a patchy, but sparse, distribution of shrubs or trees (e.g. *Paliurus spina-christi, Juniperus oxycedrus, Carpinus orientalis, Phillyrea media* and *Pinus brutia*). Grasslands are used mainly for grazing livestock, which probably helps to maintain an open structure. Recently burnt areas, where most trees were felled while some were left, belong to this category. Grazing is, however, excluded for ten years after a fire.

(9) Rocky areas. Mainly found on the steep south facing slopes in the southern part of the area and on mountain tops where the soil has been eroded away. Rocks cover up to 40% of this habitat.

Reptile sampling plots and surveys

Reptile data were collected between the beginning of April and the end of September in 1996. For each habitat type (see above), five randomly selected plots were established (45 plots in all). Each plot measured 10 m by 100 m (0.1 ha) and was at least 200 m away from the boundaries of any other habitat to avoid edge effects. The shape of each plot facilitated sampling. Two people walked the length of each plot approximately 5 m apart, enabling each reptile to be easily spotted and scored. Identification was carried out following Arnold and Ovenden (2002). All 45 plots were sampled once each week during the study period. Sampling was carried out between 8:00 am and 7:00 pm, but the order in which the plots were visited was randomised to avoid time of day effects.

Statistical analysis

In order to compare mean number of sightings of each reptile species in each habitat and mean numbers of lizards and snakes recorded per plot per sample period (data for two-week periods were pooled), one-way ANOVA was used, but to normalise variances, the data were first log transformed (Bartlett 1947, Zar 1996). To measure diversity, Shannon-Weiner indices (H') were calculated (Shannon and Weaver 1949).

All statistical analyses were carried out using Minitab statistical software (version 13.2), and SPSS (version 12.0) and differences were considered significant with $\alpha \leq 0.05$.

Spatial distribution of reptiles

A total of 1,703 sightings of reptiles were made during the study period, represented by eight lizard and ten snake species. Table 1 shows the mean numbers of sightings of each species in each habitat type. There was a 10-fold variation in the numbers of records made in each habitat ($F_{8,1026} = 34.9$, $P < 0.001$), with rocky areas (habitat 9) being least favoured and mixed pine-oak forest (habitat 5) having the highest number of sightings. All forest types containing oak trees had relatively high reptile counts (habitats 5, 6 and 7), but the numbers were dominated by the Green Lizard *Lacerta viridis* and the Snake-eyed Skink *Ablepharus kitaibelii*. Intensively cultivated areas (habitat 1) also had a high count, but interestingly in this case, the numbers were dominated by two snake species, the Grass Snake *Natrix natrix* and the Dice Snake *Natrix tessellata*, which accounted for nearly 80% of the records. Furthermore, deciduous forest habitats (oak and degraded oak forest) and shrublands had high counts but mainly of Green Lizard and Snake-eyed Skink in the deciduous oak habitat types, and the Green Lizard and Snake-eyed Lizard *Ophisops elegans* across shrublands.

Although intensively cultivated areas contained high numbers of reptiles, only nine species were recorded and, as mentioned above, nearly 80% of the records referred to the two *Natrix* species. Consequently, the diversity (H') of the habitat was low (1.44). Only one habitat, rocky areas, was less diverse and was associated with fewer species than in the intensive cultivations. Only seven species were recorded, giving a diversity estimate of just 1.3. Between 11 and 16 species of reptile were recorded in the other habitats, with the highest number being recorded in oak forest. The highest diversity estimates came from grasslands (habitat 8), non-intensively cultivated areas (habitat 2) and shrublands (habitat 3), all of which produced relatively low counts but were associated with a high number of different species.

Diversity indices were similarly produced to indicate the degree of specialisation of each species (see Pianka 1986). The Green Lizard was by far the commonest species of reptile recorded. Generally, between 30% and 50% of the sightings in each habitat were of this species, the exception being in intensively cultivated areas where it constituted only 6% of records. Consequently, this species had a high diversity score (0.865) indicating that it is a generalist in the study area. The Balkan Green Lizard *Lacerta trilineata* and the Glass Lizard *Pseudopus apodus* had the highest diversity scores (0.87) among the lizards. They were recorded in all habitat types but their numbers were lower than those of the Green Lizard. Two other lizard species were found to require special habitat features. The Snake-eyed Skink with a distinct distribution in the study area, preferred wooded habitats, while the Common Wall Lizard *Podarcis muralis* was mainly concentrated in deciduous forest types. Both had low diversity scores (0.64 and 0.47, respectively) indicating they are specialists in the Dadia forest.

Among the snakes, Grass Snake and Dice Snake, comprised 65% of the observations, but nearly all of these came from just one habitat, intensively cultivated areas. As a result, these species were scored as specialists. Three snake species were noted in all habitat types: Large Whip Snake *Coluber caspius*, Nose-horned Viper *Vipera ammodytes* and Montpellier Snake *Malpolon monspessulanus* and all scored as generalists with high diversity values (0.90, 0.88 and 0.87, respectively). Smooth Snake *Coronella austriaca* was found only in two habitat types of deciduous oak associations. Furthermore, two snake species, the Four-lined Snake *Elaphe quatuorlineata* and the Cat Snake *Telescopus fallax* were recorded once, in just one habitat type (non-intensively cultivated area).

Seasonal abundance of reptiles

Table 2 shows the mean numbers of lizards and snakes noted per 0.1 ha plot per sample period. There was considerable variation in the mean numbers of lizards recorded per plot per two-week period ($F_{11,1023} = 20.67$, $P < 0.001$). However, lizard abundance did not change in a random way throughout the year. The mean numbers of lizards recorded increased steadily through April and May, but dropped off during June and July to its lowest point during August, before rising again in September

Table 1. Mean numbers of lizard and snake species/visit/hectare in nine habitat types (1 = intensively cultivated areas, 2 = non-intensively cultivated areas, 3 = shrublands, 4 = pine forest, 5 = mixed oak/pine forest, 6 = oak forest, 7 = degradated oak forest, 8 = grasslands, 9 = rocky areas) in the region of Dadia Forest in North-eastern Greece in 1996. The species involved include Green Lizard *Lacerta viridis*, Balkan Green Lizard *L. trilineata*, Snake-eyed Lizard *Ophisops elegans*, Snake-eyed Skink *Ablepharus kitaibelii*, Erhard's Wall Lizard *Podarcis erhardii*, Balkan Wall Lizard *P. taurica*, Common Wall Lizard *P. muralis*, European Glass Lizard *Pseudopus apodus*, Grass Snake *Natrix natrix*, Dice Snake *N. tessellata*, Montpellier Snake *Malpolon mospessulanus*, Large Whip Snake *Coluber caspius*, Dahl's Whip Snake *C. najadum*, Aesculapian Snake *Elaphe longissima*, Four-lined Snake *E. quatuorlineata*, Smooth Snake *Coronella austriaca*, Cat Snake *Telescopus fallax* and Nose-horned Viper *Vipera ammodytes* (Bakaloudis 2000).

	HABITAT										
SPECIES	1	2	3	4	5	6	7	8	9	Grand mean	H′
Lizards											
L. viridis	7.5	16.2	25	30	52.1	55.4	36.7	9.6	9.6	**26.9**	**0.86**
L. trilineata	9.2	7.1	4.2	2.9	1.7	2.5	7.9	10	1.2	**5.2**	**0.87**
O. elegans	0	7.5	12.9	2.5	22.5	2.1	0	2.5	1.7	**5.7**	**0.66**
A. kitaibelii	0	0	2.1	9.2	43.3	35.8	31.2	5	0.4	**14.1**	**0.64**
P. erhardii	0	2.1	1.7	2.5	23	8	2.5	0	0	**4.4**	**0.68**
P. taurica	0	4.2	2.9	0	6.7	0.4	4.6	0	0	**2.1**	**0.62**
P. muralis	0	0	0	0	2.1	2.1	1.2	0	0	**0.6**	**0.47**
P. apodus	1.2	3.7	2.1	1.2	2.1	1.2	2.1	1.7	0	**1.7**	**0.87**
Snakes											
N. natrix	47.9	5.4	1.7	0	2.1	1.7	1.2	0.8	0	**6.8**	**0.37**
N. tesselata	51.7	0	0	0.8	1.2	1.2	0	0	0	**6.1**	**0.13**
M. monspes.	2.5	1.2	2.9	1.2	1.2	2.5	3.3	2.1	0	**1.9**	**0.87**
C. caspius	4.6	1.2	3.3	1.7	1.7	0.8	2.1	2.5	1.2	**2.1**	**0.90**
C. najadum	0	0	0.8	0.4	0.8	1.2	0.8	0.8	0.4	**0.6**	**0.82**
E. longissima	1.2	0.8	0.4	0.8	0.4	0.4	0	1.7	0	**0.6**	**0.78**
E. quatuorlin.	0	0.4	0	0	0	0	0	0	0	**0.04**	**–**
C. austriaca	0	0	0	0	0	0.4	0.4	0	0	**0.09**	**0.30**
T. fallax	0	0.4	0	0	0	0	0	0	0	**0.04**	**–**
V. ammodytes	1.7	0.4	1.7	1.7	1.7	2.5	1.7	3.3	0.8	**1.6**	**0.88**
Habitat means	**7.1**	**2.8**	**3.4**	**3.0**	**9.0**	**6.6**	**5.5**	**2.2**	**0.8**		
Species number	**9**	**13**	**13**	**12**	**15**	**16**	**13**	**11**	**7**		
H′	**1.44**	**2.06**	**1.94**	**1.61**	**1.78**	**1.52**	**1.71**	**2.08**	**1.30**		

(Fig. 1). Closer examination of Table 2 shows that this trend was generally seen across all habitat types.

There was also significant variation in the mean numbers of snakes recorded during each two-week period throughout the year ($F_{11,1023} = 2.95$, $P < 0.002$). The numbers generally increased as the year progressed, although this observation was heavily influenced by the high numbers of snakes recorded in habitat 1 (intensively cultivated land) (Fig. 1).

Reptile responses to land uses

This study shows that the patchwork of different habitat types occurring in DNP supports a valuable assemblage of reptile species. Twelve amphibian and 29 reptile species were observed during the study (Appendix), but only eight of 11 lizard and 10 of 14 snake species were counted on the established plots. With the exception of Montpellier Snake, all observed species are listed under

Table 2. Mean numbers of (a) lizards and (b) snakes recorded per 0.1 ha plot in each of the nine habitat types (see text) every two weeks from the beginning of April to the end of September in the region of Dadia–Lefkimi–Soufli forest complex, North-eastern Greece in 1996 (Bakaloudis 2000).

(a) Lizards

	Two-week periods												
Habitat	1	2	3	4	5	6	7	8	9	10	11	12	Habitat mean
1	0.3	0.4	0.0	0.5	0.4	0.4	0.2	0.3	0.3	0.2	0.6	0.7	0.37
2	0.8	1.2	1.0	1.3	0.7	0.4	0.3	0.7	0.5	0.9	0.9	0.9	0.79
3	2.3	2.9	2.2	2.1	1.1	0.3	0.4	0.4	0.2	0.0	0.5	0.6	1.03
4	0.9	1.3	2.2	2.7	1.8	0.5	0.1	0.7	0.0	0.2	1.0	1.5	1.03
5	2.6	2.7	4.8	4.7	5.8	4.0	1.9	1.0	0.6	1.4	1.9	3.4	2.82
6	3.0	3.8	3.2	3.6	2.1	1.2	0.7	1.7	0.9	0.8	1.9	2.9	2.10
7	1.6	2.7	4.2	5.4	3.9	1.7	1.4	0.8	0.1	0.2	0.1	0.4	1.77
8	0.6	1.2	1.4	2.1	0.4	0.1	0.1	0.1	0.0	0.2	0.1	1.1	0.58
9	0.2	0.4	1.0	0.6	0.1	0.0	0.1	0.0	0.0	0.2	0.2	0.7	0.26
Period mean	1.37	1.84	2.22	2.56	1.81	0.96	0.58	0.63	0.29	0.46	0.80	1.36	1.20

(b) Snakes

	Two-week periods												
Habitat	1	2	3	4	5	6	7	8	9	10	11	12	Habitat mean
1	0.9	0.8	0.0	1.0	1.8	2.2	3.0	2.4	2.9	3.5	5.1	2.0	2.23
2	0.3	0.2	0.0	0.0	0.3	0.1	0.1	0.2	0.4	0.2	0.1	0.2	0.19
3	0.2	0.2	0.2	0.2	0.3	0.0	0.1	0.1	0.3	0.3	0.3	0.1	0.16
4	0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.4	0.1	0.09
5	0.1	0.2	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.1	0.5	0.6	0.18
6	0.1	0.3	0.4	0.1	0.2	0.0	0.0	0.0	0.1	0.4	0.8	0.1	0.20
7	0.0	0.0	0.0	0.2	0.3	0.2	0.1	0.0	0.1	0.0	0.6	0.4	0.16
8	0.2	0.3	0.0	0.1	0.4	0.2	0.1	0.0	0.3	0.4	0.1	0.3	0.21
9	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.3	0.05
Period mean	0.20	0.23	0.07	0.23	0.42	0.31	0.37	0.31	0.44	0.56	0.88	0.46	0.39

Appendix II of Bern Convention (Council of Europe 1979) and therefore merit strict protection.

Forested habitat types were characterised by high reptile counts, greater species numbers and relatively high diversity scores. This was true, especially for deciduous forest habitats (both pure oak and mixed pine-oak) which consisted mainly of various oak species as well as exhibiting a more complex vertical structure. This type of habitat permits increased light levels to reach the forest floor especially during early spring which subsequently leads to changes in vegetation structure and microclimate (Begon et al. 1996). In addition, during recent decades, such stands underwent increased timber extraction, which created clearings. This happened in the study area and was mainly a response to high prices of oak timber. These conditions, of increased light and associated microclimate and microhabitat changes which appear to favour reptile abundance and diversity are also supported by other studies (Adams et al. 1996, Greenberg 2001). In contrast, coniferous forest habitats

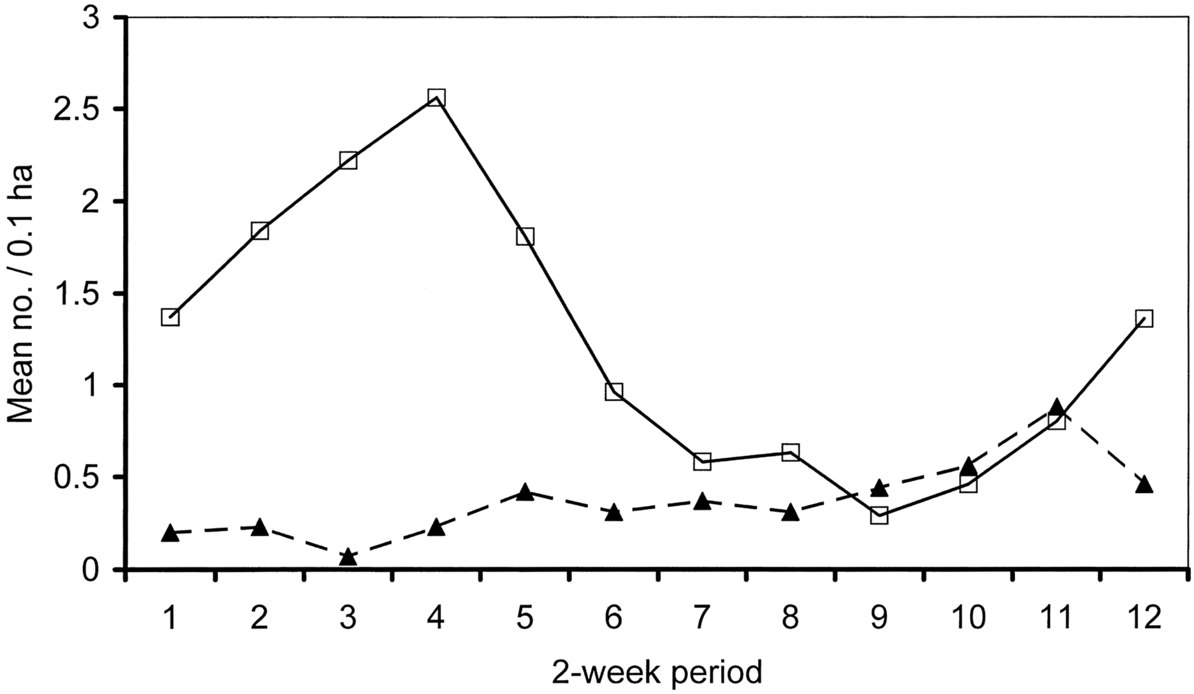

Fig. 1. Total mean number of reptiles recorded per 0.1 ha plot every two weeks from the beginning of April (1) to the end of September (12) in the Dadia forest in 1996. Continuous line and open squares = lizards, broken line and filled triangles = snakes.

supported fewer reptile species and had lower diversity scores than deciduous habitats in the study area. Others have also reported lower abundances of reptiles in coniferous stands than in deciduous ones. For example, De Graaf and Rudis (1990) reported that conifer stands consisting of *Abies* spp. supported half as many reptile species as deciduous forests. They also found that reptile diversity was correlated with litter depth and associated soil pH. The thinner litter layer and the lower soil pH under coniferous stands affected the whole herpetofauna negatively, resulting in lower diversity scores than in deciduous stands. Loehle et al. (2005) found that hardwood forests had more species of reptiles and amphibians than pine or mixed pine-hardwood forests. Furthermore, they reported that other site-specific abiotic factors, such as north-facing slopes and presence of water, might be related to differences in moisture availability, which in turn affects the abundance of species occurring in more mesic forest types (e.g. amphibians and snakes) positively. The south-facing slopes in DNP forest are drier than the northern ones, and they typically support pine stands with a relatively open canopy structure (Bakaloudis 2000). Such a canopy structure in southern exposures creates more xeric microclimates and may have been responsible for the lower number of animals seen and the lower species number than those recorded for the more mesic deciduous forests. Similar findings are reported by Helmer and Scholte (1985) for the same area. They found that all lizard and snake species occurred in low densities in pine stands on south-facing slopes, whereas the Spur-thighed Tortoise *Testudo graeca* occurs in large numbers and spawns there. They also found that the northern exposures covered by pine forest had lower densities and species variety of reptiles than other habitat types. They suggested that the shade and unfavourable light conditions produced by the evergreen foliage of the conifers caused the decrease in reptile numbers in this habitat type after mid-April.

Rocky areas supported the lowest number of species and had the lowest diversity score among the habitat types in the region. Most of the rocky survey plots were established in the southern part of the National Park, mainly on south exposures without or with very small patches of vegetation. Thus, the conditions for reptiles were unfavourable, and explains the low counts in this type of habitat.

The remaining habitat types lie in-between the above two situations. Intensively cultivated land in the study area had a quite low diversity score as well as a low number of species. However, this habitat type supported high mean reptile numbers, especially for snakes, but these numbers were mainly for two species, the Grass Snake and the Dice Snake, which both require aquatic environments. The Dice Snake is generally considered an aquatic species (Arnold and Ovenden 2002), which spends much of its time foraging in water. Along the drainage network on the border of fields and small streams, riparian vegetation may contribute to the maintenance of few reptile species but in higher concentrations than in other habitat types. Other studies have also reported the importance of riparian vegetation for reptiles within agricultural landscapes (Taylor 1998, Maisonneuve and Rioux 2001). Furthermore, Helmer and Scholte (1985) observed high densities not only for reptiles, such as Grass Snake, Dice Snake and terrapins, but for many amphibians, including the Marsh Frog *Pelophylax ridibundus*, Agile Frog *Rana dalmatina* and the Yellow-bellied Toad *Bombina variegata*. In contrast to what was observed in intensively cultivated areas, species richness and diversity were high in non-intensively cultivated land. This habitat type is characterised by small cultivated fields bordered by natural hedgerow vegetation and trees. In addition, no irrigation was practiced and, generally, less fertilisers and pesticides are used.

Interestingly, both shrublands and grasslands had the highest diversity scores and contained relatively high numbers of different reptile species, but they had relatively low mean counts. Both habitat types were grazed but the relatively high grazing pressure in grasslands, in conjunction with the dry-Mediterranean climate, may reduce the vegetation cover, resulting in fewer species and lower numbers than in the shrublands.

Reptiles as raptor prey

Timing of raptor breeding is closely linked with the period of maximum food supply (Newton 1979) and most birds of prey start to breed when their main prey become available and sufficiently abundant. Food availability may influence gonad development and body condition in females prior to the breeding season and can also affect overall breeding success. In addition, in temperate regions, species that feed mainly on ectotherms such as reptiles and amphibians, tend to change their feeding preferences during periods of low food scarcity or they migrate when their prey becomes unavailable.

There is some evidence in the study area that raptor populations are related to the temporal and spatial availability of reptiles. In DNP, the breeding period for most raptors begins in early spring when the reptiles emerge from hibernation (Alivizatos and Goutner 1997, Bakaloudis et al. 2005). After this period, reptiles become less available as the summer progresses by restricting their daytime activity to early morning and late afternoon, probably to avoid exposure to high temperatures (Zug et al. 2001). As a result, raptors adjust their foraging activities in relation to these reptile behaviour changes. For example, Short-toed Eagles *Circaetus gallicus* tended to hunt during midday in early spring and during autumn, but from May to August their foraging became more or less bimodal (Taylor 1998, Bakaloudis 2000).

Table 3 shows that in DNP reptiles constitute a high proportion in the diet of some of the birds of prey that have been studied intensively. Although there was some variation between the methods applied to investigate food habits of the different species, reptiles appeared to comprise a high proportion in the diets of Short-toed Eagle (Bakaloudis 2000), Lesser Spotted Eagle *Aquila pomarina* (Vlachos 1989), Long-legged Buzzard *Buteo rufinus* (Alivizatos and Goutner 1997) and Egyptian Vulture *Neophron percnopterus* (Vlachos et al. 1998). However, other birds of prey, such as Golden Eagle *Aquila chrysaetos*, Common Buzzard *Buteo buteo* and Booted Eagle *Hieraaetus pennatus* as well as the White Stork *Ciconia ciconia* and the Black Stork *C. nigra*, feed more or less on different reptile groups, from tortoises and snakes to large and small lizards, but detailed information on the diet of these species in the study area is limited. In general, there was considerably greater variation between the different prey groups found in pellets than recorded by direct observation. For example, snakes formed a much higher proportion of the diet of adult raptors, as analysed through pellet examination, while amphibians were not found in pellets. It is possible that raptors digest amphibians thoroughly so that very little remains to be regurgitated. Among the snakes, Grass Snake was the most important prey species for two eagle species and the Long-legged Buzzard. Grass Snakes made up over 43% of the Short-toed Eagle diet (Bakaloudis 2000), 30% of that of the Lesser Spotted Eagle (Vlachos 1989) and about 12% of that of the Long-legged Buzzard (Alivizatos and Goutner 1997). Other snake species included in raptor diets have been the Montpellier Snake and the Large Whip Snake, both of which were very common across different habitat types in the area (Petrov 2004). The next most important category included lizards, namely the Glass Lizard and *Lacerta* spp. Interestingly, Egyptian Vulture feeds largely on the two terrestrial tortoise species (26.1%):

Table 3. Different prey types (%) in the diets of four diurnal and one nocturnal bird of prey in Dadia forest as determined by (a) analyses of pellets and/or prey remains and (b) direct observations at the nest.

(a)

	Sample size*	Reptiles	Amphibians	Birds	Mammals	Insects	Other
Circaetus gallicus [1]	167	92.3	–	0.9	5.6	1.3	–
Aquila pomarina [2]	101	72.1	–	5.0	15.0	7.9	–
Buteo rufinus [3]	89	21.0	–	16.0	34.0	37.0	–
Neophron percnopterus [4]	394	45.6	2.8	10.7	10.8	–	29.7
Bubo bubo [5]	185	1.2	0.5	44.1	48.6	4.8	0.7

(b)

	Observation days	Reptiles	Amphibians	Birds	Mammals	Insects	Other
Circaetus gallicus [1]	98	98.3	0.9	–	0.9	–	–
Aquila pomarina [2]	**	43.4	34.8	8.6	13.0	–	–
Buteo rufinus [3]	**	41.0	3.0	3.0	31.0	–	–

Source: 1 = Bakaloudis 2000, 2 = Vlachos 1989, 3 = Alivizatos and Goutner 1997, 4 = Vlachos et al. 1998, 5 = Papageorgiou et al. 1993.
* Number of pellets examined.
** Data not available.

Hermann's Tortoise *Testudo hermanni* and Spur-thighed Tortoise.

In addition to reptiles' temporal availability, their spatial distribution may affect the foraging activities of raptorial birds in the area. The foraging distribution of seven birds of prey in DNP (Bakaloudis et al. 1998b) indicated that their hunting activities were a response to environmental factors such as habitat characteristics. In general, most birds of prey that breed in the DNP rely on open areas for hunting. Some of the studied species used cultivated areas (Lesser Spotted Eagle, Booted Eagle, Common Buzzard and Long-legged Buzzard); one species used cultivated areas and grasslands (Short-toed Eagle), while two species preferred to hunt in grasslands only (Golden Eagle and Egyptian Vulture). This could explain the high proportion of tortoises in Golden Eagle and Egyptian Vulture diets. Tortoises reach very high densities in cultivated land and in grasslands (Helmer and Scholte 1985, Capper 1998), where the two raptors were frequently observed searching for food.

Conclusions

This study clearly shows the importance of maintaining a diversity of habitat types in order to maintain high wildlife diversity within natural and/or semi-natural ecosystems.

The presence of strong faunal associations ranging from top-predators (many birds of prey with large populations) to reptiles, small mammals, small birds and insects implies that species in different groups are affected by similar processes and may even depend on each other (Grill and Cleary 2003, Chen et al. 2005, Kati and Sekercioglu, 2006). Sustaining regions with high species concentrations and their environmental conditions, including vegetation types, are necessary for the continuing existence of healthy wildlife populations, as well as for maintaining the DNP ecosystem integrity.

In heterogeneous landscapes, such as the DNP, no single conservation measure will benefit all species. Two general conservation strategies may be feasible in the case of a complex and heterogeneous ecosystem. The first one is to maximise landscape heterogeneity in order to ensure that a wide variety of environmental conditions is available. The second may require the maintenance of microhabitat complexity in order to help the reptiles of the area. Both of these approaches need a prior understanding of those factors that contributed to the creation and/or maintenance of the heterogeneity of the Dadia landscape. Anthropogenic factors such as diversity-friendly forestry operations and non-intensive agricultural practices should be enhanced for the preservation of the current mosaic of different habitat types in which different environmental conditions prevail. Therefore, moderate timber harvesting creating a greater range of forest age classes, canopy structures and microclimate conditions may help to maintain reptile species diversity (Shipman et al. 2004, Loehle et al. 2005), but may also promote a higher avifauna diversity, including many birds of prey (Bakaloudis 2000). In addition, diversification of crops in intensively and non-intensively cultivated areas, along with maintenance of riparian vegetation on irrigation channels and drainage network and hedgerows, respectively, may be especially valuable (Bowers et al. 2000, Maisonneuve and Rioux 2001) for enhancing reptile abundance and thus availability of prey for higher level predators.

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Appendix. List of amphibian and reptilian species present in the region of Dadia–Lefkimi–Soufli Forest National Park.

AMPHIBIA	**Common name**
Urodela	
Fam. Salamandridae	
Salamandra salamandra	Fire Salamander
Triturus vulgaris	Smooth Newt
Anura	
Fam. Bufonidae	
Bufo bufo	Common Toad
Bufo viridis	Green Toad
Fam. Bombinatoridae	
Bombina bombina	Fire-bellied Toad
Bombina variegata	Yellow-bellied Toad
Fam. Hylidae	
Hyla arborea	Common Tree Frog
Fam. Ranidae	
Rana dalmatina	Agile Frog
Rana graeca	Stream Frog
Pelophylax ridibundus	Marsh Frog
Rana temporaria	Grass Frog

REPTILIA	**Common name**
Chelonia	
Fam. Emydidae	
Emys orbicularis	European Pond Terrapin
Mauremys rivulata	Balkan Terrapin
Fam. Testudinidae	
Testudo hermanni	Hermann's Tortoise
Testudo graeca	Spur-thighed Tortoise
Squamata	
Lacertilia	
Fam. Gekkonidae	
Cyrtopodion kotschyi	Kotschy's Gecko
Fam. Anguidae	
Anguis fragilis	Slow Worm
Pseudopus apodus	European Glass Lizard
Fam. Scincidae	
Ablepharus kitaibelii	Snake-eyed Skink
Fam. Lacertidae	
Lacerta praticola	Meadow Lizard
Lacerta trilineata	Balkan Green Lizard
Lacerta viridis	Green Lizard

	Ophisops elegans	Snake-eyed Lizard
	Podarcis erhardii	Erhard's Wall Lizard
	Podarcis muralis	Common Wall Lizard
	Podarcis taurica	Balkan Wall Lizard
Ophidia		
Fam. Typhlopidae		
	Typhlops vermicularis	Worm Snake
Fam. Boidae		
	Eryx jaculus	Sand Boa
Fam. Colubridae		
	Coluber caspius	Large Whip Snake
	Coluber najadum	Dahl's Whip Snake
	Coronella austriaca	Smooth Snake
	Elaphe longissima	Aesculapian Snake
	Elaphe quatuorlineata	Four-lined Snake
	Elaphe situla	Leopard Snake
	Malpolon monspessulanus	Montpellier Snake
	Natrix natrix	Grass Snake
	Natrix tessellata	Dice Snake
	Telescopus fallax	Cat Snake
Fam. Viperidae		
	Vipera ammodytes	Nose-horned Viper
	Vipera xanthina	Ottoman Viper