Monitoring breeding raptor populations - a proposed methodology using repeatable methods and GIS

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Abstract – Monitoring raptor populations is a difficult task, because birds of prey are wide-ranging, many are secretive and in some places very difficult to detect. In this paper, a systematic methodology for the monitoring of raptor populations is presented. This methodology was developed and implemented in Dadia National Park, north-eastern Greece, which hosts a diverse community of birds of prey in high abundance. It was applied by WWF - Greece in the framework of the monitoring plan established in the area, aiming at the evaluation of the raptor population trends in order to promote conservation measures. From 2001 until 2005, all species of diurnal raptors, except the large vultures *Aegypius monachus* and *Gyps fulvus*, were surveyed in 34 permanent plots, and a total of 4000-6000 annual observations of 22-24 species (17-18 breeding species) were collected during March to July. The observations were used to estimate raptor species' relative abundances and the numbers of territories. All the observations were entered in ArcGIS and the digitized observations were labelled, showing the number of individuals, age, sex, and bird behaviour under different symbols. For each species a spatially explicit territory analysis was performed, based on pre-defined criteria and the resulting breeding territories were classified in two categories: *confirmed* or *possible*. During the study period, the total number of territories was almost stable with an average value of 350 territories. Common Buzzard was the most abundant raptor having at average 120 territories and other nine species were found to have more than 10 territories.

INTRODUCTION

The decline of most bird of prey species has been relatively well investigated in Europe (Newton 1979, Cramp and Simmons 1980, Birdlife International 2004), but the estimation of their population status and trends pose special problems as raptors are usually dispersed, several are secretive, and in some places they are very difficult to detect due to the topography of the land (Fuller and Mosher 1987). Additionally, their population may strongly fluctuate (Kirk and Hyslop 1998) and the monitoring of populations and the interpretation of their fluctuations requires specific and long-term studies (Catsadorakis 1994).

The assessment of population trends and the identification of the causes of population fluctuations could help in taking proper management measures (Vos *et al.* 2000), but comprehensive censuses and data collection on population dynamics have high requirements in personnel, time and cost (Noll West 1998). To overcome this problem, WWF Greece formulated a systematic monitoring plan for birds of prey in Dadia-Lefkimi-Soufli National Park (hereafter Dadia NP), northeastern Greece (Poirazidis *et al*. 2002) under the framework of Ecological Monitoring for Nature Management (Vos *et al.* 2000). Dadia NP holds one of the most diversified communities of raptor species across Europe, including endangered species such as the black vulture *Aegypius monachus*, the imperial eagle *Aquila heliaca*, and the white-tailed eagle *Haliaeetus albicilla,* and in fact 90% of European raptor species assemblage has been observed in this region (Hallmann 1979, Dennis 1989).

The main goal of the raptor monitoring was to estimate each year a relative abundance index of the breeding territorial raptor species through consistently repeatable methods, permitting data comparison throughout years. Relative abundance is used when it is difficult to overcome factors that impede the estimation of absolute densities.

It is useful when comparing raptor populations against time, among sites or between species (Fuller and Mosher 1987). The aim of this paper is to provide an overview of the methodology implemented in Dadia NP from 2001 to 2005 and to present the main findings of the five-year raptor monitoring.

METHODS

Study Area

The Dadia NP is located in the centre of the Evros Prefecture, (E 260 20', N 410 15), and is part of the south-eastern tip of the Rhodope mountain range, with altitudes lying between 10 and 654 m, close to the border of Greece with Turkey (Fig. 1). Declared as a Protected Area in 1980, it includes now two strictly protected core areas, together covering 7290 ha, and a buffer zone covering 35170 ha. The landscape of the area is characterized by the sudden interchange of small and large valleys, by steep and shallow slopes, as well as an intricate hydrological network, composed of small and large streams. Seventy six percent (76%) of the area of Dadia NP is covered by forest vegetation, in which pine, mixed and oak forests are dominant while other vegetation types, such as broadleaf forests and maquis scrublands, participate with smaller proportions. The commonest pine forests are those dominated by calabrian pine *Pinus halepensis subsp. brutia*, while the corsican pine *Pinus nigra* develops smaller stands, usually close to streams. Four species of oak *Quercus* spp. are found in the oak and mixed forests of the area. In vegetation formations close to streams common alder *Alnus glutinosa* is dominant, and in some riparian places other species such as willow *Salix sp.*, black poplar *Populus nigra* and tamarisk *Tamarix spp*. The remaining area of Dadia NP is covered by grazing lands, fields and villages that interrupt the forested areas, creating characteristic mosaics of habitats and high landscape diversity (Schindler *et al.* 2008).

Monitoring the populations of birds of prey

We conducted a systematic monitoring of raptor territories each year within the same area and for this reason the use of permanent plots was preferred to random plots (Millsap and Le Franc 1988). Several sampling methods exist to census breeding raptors. The three main ones are: a) line transects (surveys in a small area on either side along a line transect), b) point counts (surveys in specified areas around fixed points) and c) territory mapping (Fuller and Mosher 1987). In this study we combined all three methods in the following way:

1. Surveillance of a fixed area from permanent view points with mapping of observations (*view points*).
2. Surveillance from a vehicle in predetermined transects with mapping of observations (*road transects*).

All territorial species of diurnal raptors were included in the systematic monitoring. These species were: white-tailed eagle, golden eagle *Aquila chrysaetos*, imperial eagle, lesser spotted eagle *Aquila pomarina*, short-toed eagle *Circaetus gallicus*, booted eagle *Hieraaetus pennatus*, egyptian vulture *Neophron percnopterus*, common buzzard *Buteo buteo*, long-legged buzzard *Buteo rufinus*, honey buzzard *Pernis apivorus*, black kite *Milvus migrans*, marsh harrier *Circus aeruginosus*, goshawk *Accipiter gentilis*, levant sparrowhawk *Accipiter brevipes*, sparrowhawk *Accipiter nisus*, peregrine falcon *Falco peregrinus*, lanner falcon *Falco biarmicus*, hobby *Falco subbuteo* and eurasian kestrel *Falco tinnunculus*. Furthermore, one non-raptorial species, the black stork *Ciconia nigra*, was included in this monitoring, as it shares the same ecosystem and has similar nesting and foraging requirements; additionally the local population is of national conservation importance (Handrinos and Akriotis 1997).

Since the reproductive periods of the species differ, it had to be ensured that the monitoring included the period in which each species emitted most cues of presence and reproductive behaviour (courting and pair formation displays, calls, clutches, etc). Furthermore, monitoring raptors presents difficulties due to their small population size and wide home-range. Thus, to increase both the sample size and the probability of key observations of all species, five surveys were carried out from March until July (one survey per month), covering each time all view points and road transects.

Twenty-four view points and 10 road transects were selected throughout the entire study area to monitor as much as possible of the raptor population (Fig. 1). Each survey was completed by two observers that alternated at sampling units, in order to reduce observer bias. Each observation was recorded in a field sheet and mapped on a field map with a scale of 1:10000 or 1:15000, and the following data were recorded:

1) the species and the number of individuals
2) the age and the sex of the individuals if feasible
3) the time of the observation
4) the type of activity of the individuals
5) the classification in migrating and local birds and
6) simultaneous observations with other individuals of the same species.

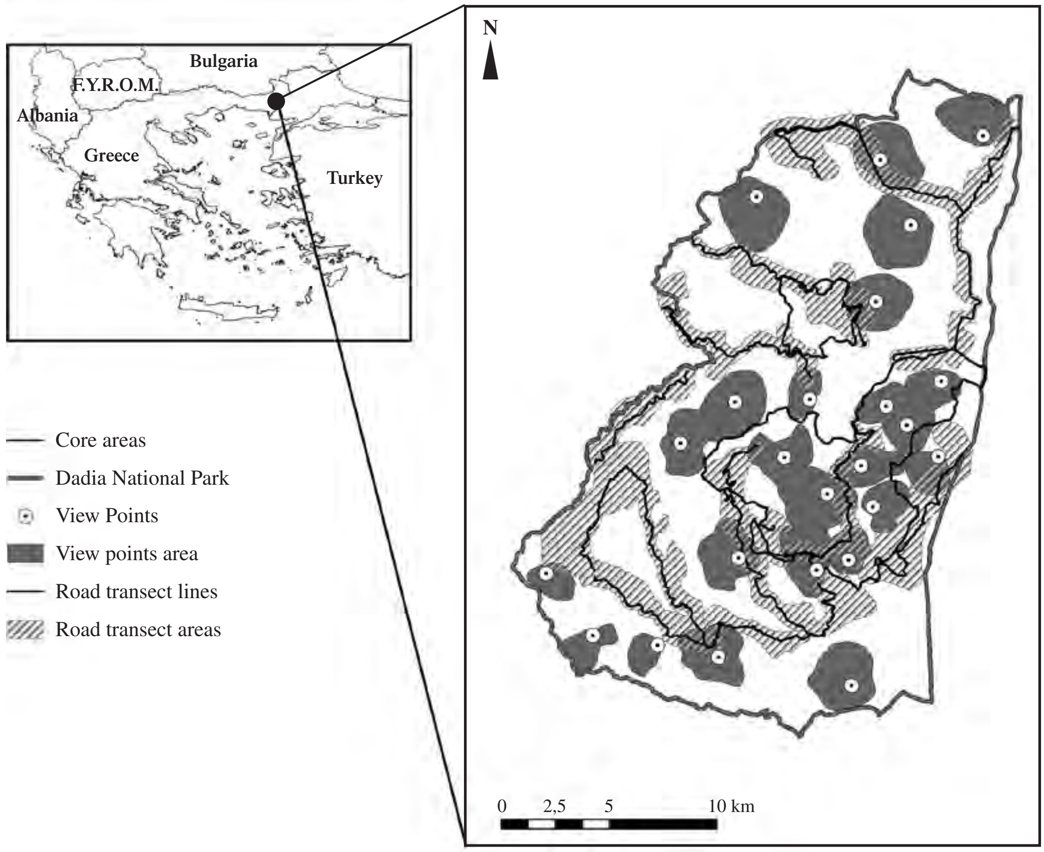

Figure 1. Sampling areas for the raptor monitoring in Dadia-Lefkimi-Soufli National Park.

Selection of the permanent plots

Due to the topography of the area, the number of good vantage points was rather limited, and the definitive view points were selected using the following criteria:

- the point ensured the best and widest view of the neighbouring hillsides,
- the total area surveyed from all view points included all main habitat types in proportion to their availability,
- the points were distributed equally all over the expanse of the area without a bias towards habitats with already known high raptor presence,
- the access time to the view point from the nearest road should be short,
- the black vulture colonies were avoided to reduce disturbance.

The selection of road transects was based on the following criteria:

- their complementarities with view points and especially for covering raptor surveys within valleys where the positioning of good view points was impossible,
- the maximum coverage of the reserve jointly by the two methods.

The area covered by the established sampling plots was estimated as 66% of the total study area (12,668 ha covered by the 24 view points and 15,497 ha covered by the 10 road transects with an overall length of 149.6 km). Censuses from fixed view points offered great potential for detection of raptors in a radius of 1-1.5 km around the observation point; as the sampling plots were scattered all over the reserve, the uncovered area between them was small (Fig. 1), and most of the raptors (especially the bigger ones) that centered their territories in these intermediate zones could be detected from the neighboring sampling plots.

Territory estimation

The territory estimation processing followed a sequence of standard steps to permit comparison among the years:

1. The observation data were entered in seven different ArcGIS layers: general flights, territorial observations,

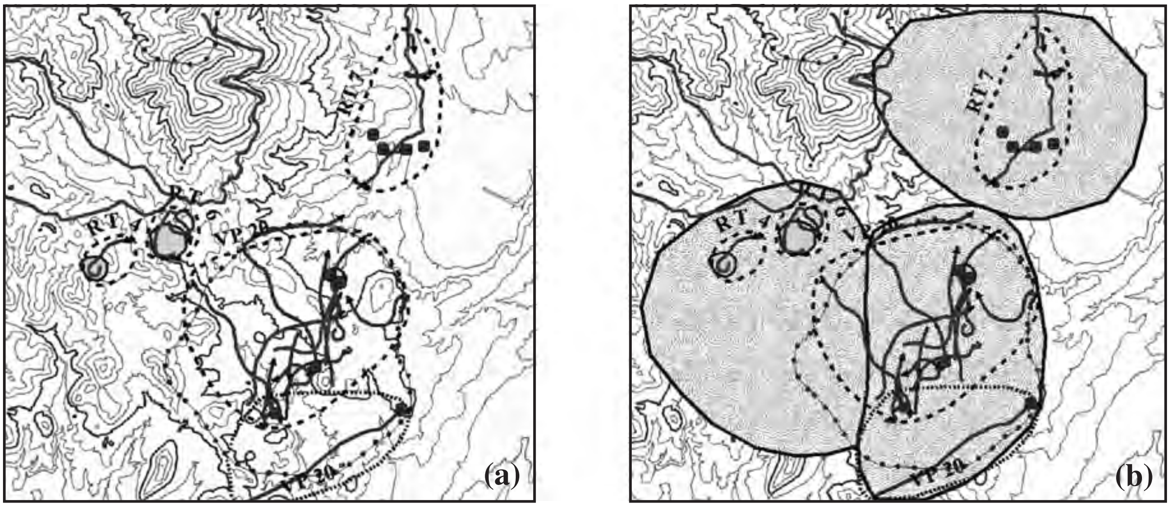

Figure 2. Example of territory estimation per sampling unit and overall estimation (lesser spotted eagle in the south-eastern part of Dadia NP in the year 2003, for details see text).

landings, synchronous observations, nest areas, meeting points, meeting point flights. Each observation was represented as arrow and symbolized the movement of the observed birds. The labels showed the number of individuals, age, sex, and different activities under different symbols, as well as comments obtained during the field work. The GIS files were connected with the ACCESS database (where all the field data were initially entered and stored) to obtain all the available information in the GIS. Simultaneous observations were labelled as the maximum number of birds of the same species that had been seen at the moment of the observation. Characteristic symbols were used for Landmarks and Meeting Points and the important territorial observations were highlighted using thicker coloured lines.

2. The territory estimation was done progressively per season based on the following criteria: a) possible nest sites, b) landings and take offs, c) territorial observations, d) simultaneous observations, e) non-intersection of bird flight lines, f) special circumstances per species, g) mean distance between nesting sites for species with marginal observations, and h) types of land cover and topography.

3. At the first stage, the estimation of each territory was done independently for each view point and each road transect, namely for 34 sampling plots. An example is given in Figure 2a, where five territories of lesser spotted eagle were detected in the south-eastern part of Dadia NP in 2003. As territories extend beyond the boundaries of sampling plots and often the same territory continues onto the area of a neighbouring observation point, the results of the initial processing were used for further analysis combining and interpreting the territory polygons obtained by the estimations per view point and road transect. Based on this new interpretation, new polygons were created for the entire study area, representing the final result of the territory assessment per species. These polygons don't necessarily cover the entire size of each territory, but include only the area confirmed by the raw data. In the previous example, the two territories identified by RT 4 and RT 6 were merged into one. In the area covered by VP 20 two territories were identified at the first stage (one confirmed and one possible) but at the overall analysis all the observations were consider to belong to the confirmed territories already identified (RT4-RT6 & VP20) and the possible territory was rejected (Fig. 2b).

We classified breeding territories as *confirmed* and *possible*, using *possible* when it could not be confirmed that the observations were obtained from separate individuals maintaining a separate territory. Considering the overall raptor population survey from 1999-2000 (Poirazidis 2003a), we made the assumption that the estimated number of confirmed territories was too conservative and that approximately 50% of the possible territories could be real territories. Therefore we estimated the total number of territories per species as the sum of confirmed territories plus 50% of the possible territories (Palma *et al.* 2004). An overview of the territory estimation is presented in figure 3.

The investigation of the fluctuation of the raptor pop-

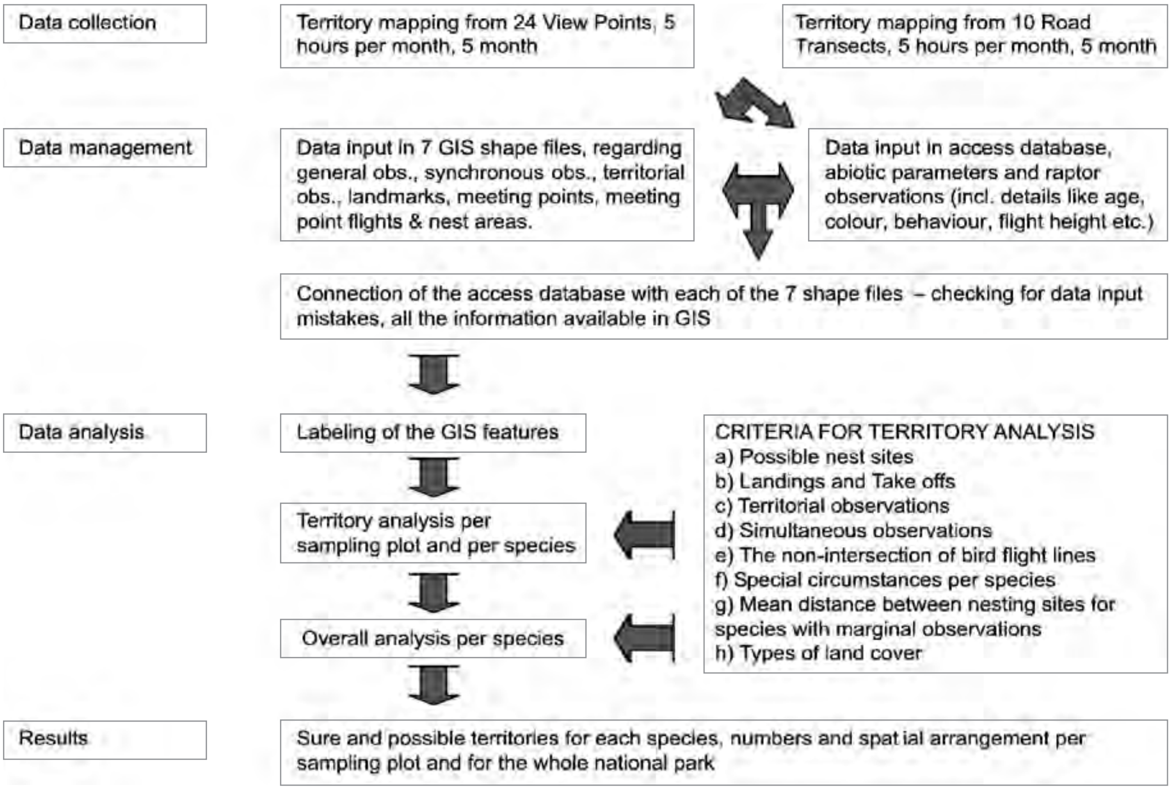

Figure 3. Methodological steps of the GIS based raptor territory analysis.

ulation was done using a simple linear regression, with the total number of territories as the dependent variable and the five years of monitoring as the independent variable. Each data set was tested for normality with the Kolmogorov-Smirnov test. We report means ± S.D. for all measures of number of species and territories. Statistical tests were considered significant at $p < 0.05$.

RESULTS

Total number of observations

By applying the sampling scheme of the systematic monitoring, several thousands of raptor records were collected each year. Most of the observations referred to the common buzzard; together with the observations regarding black storks and short-toed eagles, they comprised on average 74.9% of the total observations from view points and 75.1% from road transects. The egyptian vulture, lesser-spotted eagle and booted eagle formed a next group of species with an average, together, of 13.2% of the total observations for both kinds of sampling plots. The rest of the species obtained less than 12% of the observations. The proportions of the observations per species are presented analytically for each year in table 1 and table 2.

Number of species and territories

The total number of species observed in Dadia NP was 23-26 during the period 2001-2005 (March to July) and it reached 27-29 species, if black vulture and griffon vulture *Gyps fulvus* (species not included in the annual systematic raptor monitoring) and other raptor species observed by chance were included. The number of the observed species during the systematic monitoring was stable among the years having an average value of 24.8 ± 1.3 ($F_{1,3} = 0.045$, $p = 0.846$). Among these species 19 to 20 bred in the area. The remaining species included raptors that used the area as a wintering place until March such as the spotted eagle *Aquila clanga*, or passage raptors like osprey *Pandion haliaetus*, bonelli's eagle *Hieraaetus fasciatus*, steppe eagle *Aquila nipalensis*, hen harrier *Circus cyneus*, montagu's harrier *Cyrcus pygargus*, pallid harrier *Circus macrourus* and the red-footed falcon *Falco vespertinus*. Finally the eleonora's falcon *Falco eleonorae* used the area late spring - early summer.

Table 1. Proportion of observations per species in view points during 2001-2005.

Species	**2001** (%)	**2002** (%)	**2003** (%)	**2004** (%)	**2005** (%)
Common buzzard	39.56	26.57	26.94	25.45	29.27
Short-toed eagle	21.12	24.54	24.39	23.68	23.88
Black stork	12.17	19.37	27.62	26.31	23.43
Egyptian vulture	4.38	5.28	4.10	5.96	5.47
Lesser spotted eagle	4.43	5.99	3.99	5.12	4.23
Booted eagle	3.92	3.37	3.69	3.29	2.80
Honey buzzard	3.09	3.26	2.23	1.30	2.16
Sparrowhawk	2.44	3.34	2.43	1.20	1.49
Goshawk	1.89	2.57	1.26	0.88	1.63
Eurasian kestrel	2.07	1.78	0.91	2.22	0.96
others	4.93	3.94	2.43	4.58	4.69

Table 2. Proportion of observations per species in road transects during 2001-2005.

Species	**2001** (%)	**2002** (%)	**2003** (%)	**2004** (%)	**2005** (%)
Common buzzard	42.26	31.84	25.34	31.15	29.70
Short-toed eagle	18.45	27.14	31.72	25.02	20.33
Black stork	11.90	16.99	20.13	19.93	23.78
Lesser spotted eagle	4.76	5.02	4.76	7.30	6.33
Egyptian vulture	3.57	3.31	3.14	5.66	3.81
Booted eagle	4.17	3.95	4.04	2.95	3.50
Honey buzzard	3.97	4.38	3.86	0.84	2.01
Sparrowhawk	3.97	1.82	2.34	1.22	1.60
Golden eagle	1.98	1.50	0.99	1.64	2.16
Black kite	0.99	0.75	0.63	0.28	1.18
others	3.97	2.88	3.05	4.02	5.59

Table 3. Total number of estimated territories of the raptor species during 2001-2005.

Territories	**2001**	**2002**	**2003**	**2004**	**2005**
Confirmed	305	331	325	311	352
Possible	58	53	43	50	42
Total *	**334**	**357,5**	**346,5**	**336**	**373**

***** *The total numbers are the sum of the confirmed and the half of the possible territories*

Number of territories per species

The number of territories of all the species ranged from 334 to 373 (Table 3) and the average number was 349.4 ± 16.2, corresponding to a density of 82.4 terr/100km^2. Overall for all species, no statistical changes of the total number of territories was observed during the survey period ($F_{1,3}$ = 1.315, p = 0.335).

The number of territories was stable for most of the species and actually the eurasian kestrel was the only raptor species that showed a significant but marginal increase during the study period ($F_{1,3}$ = 10.208, p = 0.049). The average number of the territories was 17.4 ± 3.5 (4.1 terr/100km^2) and reached 22 territories in 2005 following an annual increase of 1.95 terr/year (Fig. 4). The commonest species in Dadia NP was the common buzzard with a density of 28.2 terr/100 km², representing 34% of the total number of breeding raptors in the area. The buzzard nested almost everywhere in Dadia NP with a nearest neighbour

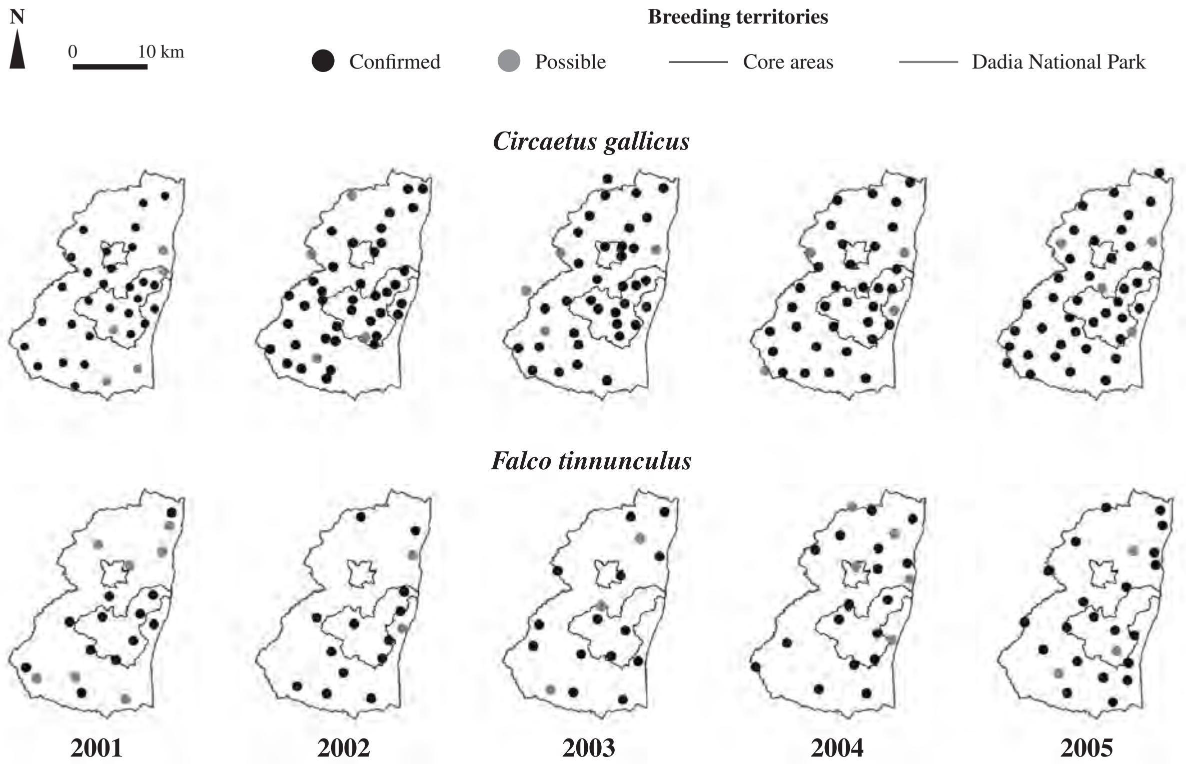

Figure 4. Centers of confirmed and possible territories of short-toed eagle and eurasian kestrel for the breeding seasons 2001-2005.

distance between nests of 1452 ± 358 m (Poirazidis 2003b). The density of the short-toed eagle was 8.7 terr/100 km^2; it showed no significant population changes during the five years with an average number of 36.9 ± 3.8 territories ($F_{1,3} = 1.485$, $p = 0.31$). The small fluctuation during the five years of monitoring reached high values of 40-41 pairs in 2002 and 2005 and a low value of 31 pairs in 2001 (Fig. 4). Other common species in descending order were the sparrowhawk, the black stork, the honey buzzard and the booted eagle (Table 4).

Spatial distribution of territories

One advantage of the applied methodology based on the use of GIS in all stages is that the spatial distribution of the territories can be obtained as a direct result of the overall estimations per species. The spatial explicit output was stored in GIS (as example see figure 5 for the year 2005) and is therefore easily available for further analyses.

DISCUSSION

Raptors are supposed to be good indicators of overall biodiversity (Sergio *et al.* 2006), but their monitoring is a time-intensive and difficult task. The monitoring of raptor populations has historically focussed on nests (Fuller and Mosher 1987). But searching, observing and climbing of nests can include a high amount of disturbance and searching success can suffer from observer bias. On the other hand, the monitoring of territory occupancy has proved useful to trace the population trends of raptors in a feasible way (Katzner *et al.* 2007) and it was used to predict the implications of conservation measures (Carrete *et al.* 2002). Cost effectiveness is a key issue of assessments based on quantitative indicators (Atauri *et al*. 2005). In order to detect long term population changes of a diverse assemblage of birds of prey, a large amount of data is needed. and the integrated use of GIS based methods was found to be an effective tool for ecological monitoring (e.g. Joselyn 2003). Raptor populations can fluctuate considerably and if the monitoring is focusing only on rare species it is difficult to distinguish a directional trend due to external factors from “noise” o random elements (Palmer 1993). To distinguish chance fluctuation from actual trend, a long-term monitoring program is needed (Catsadorakis 1994). The methodology applied in this study permits cost effective overall surveys of raptor populations. Monitoring should not be viewed as a stand-alone activity, but instead as a compo-

Table 4. Numbers of estimated territories per raptor species during 2001-2005.

	2001	**2002**	**2003**	**2004**	**2005**
Vultures					
Egyptian Vulture	11	11.5	9.5	12	9.5
Eagles					
Golden Eagle	4	4.5	3.5	5	5.5
Imperial Eagle	1	0	1	1	0
Lesser spotted Eagle	17	20.5	18.5	20.5	22
Short-toed Eagle	31.5	40	37	35	41
Booted Eagle	20.5	20	18	21	20.5
Buzzards-Harriers-Kites					
Common Buzzard	110	128.5	125.5	112	122
Long-legged Buzzard	3.5	3	3	3	4
Honey Buzzard	28.5	27	23	18.5	24.5
Black Kite	0	0	0.5	0	0
Marsh Harrier	0	0.5	0.5	0	1
Hawks					
Goshawk	19	18.5	16.5	19.5	22.5
Sparrowhawk	36	29	31	27.5	32.5
Levant Sparrowhawk	2.5	6	4	1	3
Falcons					
Hobby	6.5	9	3.5	8.5	7
Eurasian Kestrel	15.5	14	15.5	19.5	22.5
Peregrine Falcon	2	0.5	3	3	3
Lanner Falcon	1	0	0	0	0
Storks					
Black Stork	24.5	25	33	29	30.5
Total	**334**	**357.5**	**346.5**	**336**	**373**

nent of a larger process of either conservation-oriented science or management (Nichols and Williams 2006) and the output of the implemented raptor monitoring (e.g. the spatial distribution of the territories) can be used effectively for management decisions and conservation. Due to the spatially explicit output, different years can be compared easily to evaluate stability and changes of the spatial distribution of the territories (Fig. 4). This latter aspect is very important especially in the case where one species could suffer from habitat degradation without showing any notable population decline. This has been observed for the lesser-spotted eagle in our study area as the breeding population of this species was stable during the last 25 years, but the spatial distribution of its territories has changed. The eagles abandoned their breeding sites in the interior of the forest, recorded by Hallmann (1979) in 1978, and nowadays all the pairs of this species have established their territories in the periphery of the National Park where the forest-meadow mosaic is still existing (Poirazidis *et al*. 2007), thus making the population very sensitive to further reduction of suitable habitats (Väli *et al*. 2004).

Differences regarding the usefulness of the method presented here could be due to the biological characteristics of the raptor species. The GIS approach of the analysis of raptor territories was very precise for typical territorial and relatively obvious species like most of the eagles, buzzards (*Buteo* spp.), and falcons (*Falco* spp.), but large amount of data is needed to increase the precision of the estimates for species that nest in high densities like the common buzzard. Some other species, like the hawks (*Accipiter* spp.), are very secretive and only few observations were obtained per sampling plot. For less territorial species, like the short-toed eagle, the black stork or the egyptian vulture, difficulties could arise. These species have a great overlap between neighbouring home-ranges, making the delineation of the different territories a difficult task.

Figure 5. Confirmed and possible territories of 14 territorial raptor species, estimated for the breeding season 2005 in the framework of the systematic raptor monitoring. (These polygons don't necessarily cover the entire size of each territory, but include only the area confirmed by the raw data.)

However, this problem was minimized by recoding about one thousand observations for both short-toed eagle and black stork every year. The territory estimation for the egyptian vulture were less problematic, because this species uses obvious nest sites in the rocks of Dadia NP, often easily detectable from view points or road transects and thus facilitating the overall territory estimation. The key issue for all the difficult estimations is to obtain more and good-quality data (like territorial observations, landings, etc.). An overview of the evaluation of the methodology per species is presented in the Appendix 1.

The Dadia NP is one of the most important European forests for birds of prey. The integrated monitoring of their population trends combined with conservation-oriented management will contribute to safeguard their future (Poirazidis *et al.* 2010). The proposed procedure can be applied to any ecosystem, region or country regardless of the raptor species being studied or their densities.

Acknowledgements – This paper is based upon work conducted under the WWF Greece projects for the conservation of the Dadia Forest Reserve. We are grateful to Elefterios Kakalis, Dimitris Bakaloudis, Chris Eastham, Hristo Hristov, Giorgos Catsadorakis and Javier Elorriaga for their participation in the field work and to Beatriz Cárcamo, Lise Pomarède, Myriam Serrano, Raquel Rodríguez, Reyes Martínez, Arturo Guitierrez, Victoria Saravía, Andreas Porss, Nicolas Dagens, Soraya Ouldji, Sara Blanco, and Jana Glaser for their help regarding the input of field data in the ACCESS and ArcGIS databases. Lorenzo Fornasari and an anonymous reviewer provided very useful comments on a previous version of the manuscript.

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Appendix 1. Summary of the specific problems and advantages of the application of the methodology described in this paper for the estimation of the raptor territories.

	Problems due to small territoriality	***Problems with few data due to secretiveness or late arrival***	***Raised accuracy due to often records of important data***	***Total usefulness of the GIS based methodology***
White-tailed Eagle	*medium*	*very few*	*medium*	*medium*
Golden Eagle	*not any*	*very few*	*medium*	*very high*
Imperial Eagle	*very few*	*high*	*medium*	*medium*
Lesser spotted Eagle	*few*	*very few*	*high*	*very high*
Short-toed Eagle	*high*	*not any*	*medium*	*medium*
Booted Eagle	*very few*	*few*	*medium*	*high*
Egyptian Vulture	*very high*	*few*	*very high*	*high*
Common Buzzard	*very few*	*not any*	*high*	*very high*
Long-legged Buzzard	*very few*	*few*	*high*	*very high*
Honey Buzzard	*very few*	*high*	*medium*	*medium*
Black Kite	*very high*	*few*	*very few*	*low*
Marsh Harrier	*high*	*very few*	*very few*	*low*
Goshawk	*not any*	*medium*	*few*	*medium*
Levant Sparrowhawk	*very few*	*very high*	*few*	*low*
Sparrowhawk	*very few*	*medium*	*few*	*medium*
Peregrine Falcon	*few*	*very few*	*high*	*very high*
Lanner Falcon	*very few*	*very few*	*high*	*very high*
Hobby	*not any*	*high*	*few*	*medium*
Eurasian Kestrel	*not any*	*very few*	*medium*	*very high*
Black Stork	*very high*	*not any*	*medium*	*medium*


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