Distribution of the Endangered Hermann's tortoise *Testudo hermanni hermanni* in Var, France, and recommendations for its conservation

Barbara Livoreil

Abstract Censuses of population fragments of the Endangered, endemic Hermann's tortoise *Testudo hermanni hermanni* were carried out during 2001–2005 in mainland France to reassess their status and provide guidelines for conservation management. Comparisons with previous censuses suggest a decline in abundance since 1992, although the total area of distribution remains unchanged. If conservation and management decisions only consider sites where there is a high encounter rate of tortoises, 19 sites would be protected. If indicators of effective reproduction (presence of both sexes, juveniles and subadults) are taken into account, 31 sites would deserve attention, of which only 10 have high encounter rates. Discarding sites with low encounter rates omits c. 70% of sites where the species appears to be reproducing. I provide a new map that includes demographic parameters, and thus describe 16 reproductive fragments plus four where reproduction is suspected. In the long-term the major conservation goal should be to protect these fragments and facilitate their reconnection. The global population of Hermann's tortoise could thus be largely contained in eight large fragments, enhancing the persistence of this species in mainland France.

Keywords Census, chelonian, distribution, *Testudo hermanni hermanni*, tortoise, Var.

Introduction

Many species of turtles and tortoises are considered to be so-called living dead populations (Klemens, 2000) because they cannot cope with the increased mortality of adults, young and eggs caused by human activities. Terrestrial turtles (tortoises) are threatened by direct exploitation (for food, medicine and the pet trade), habitat loss and degradation, and diseases (McDougal, 2000).

The endemic western Hermann's tortoise *Testudo hermanni hermanni*, recently renamed *Eurotestudo hermanni* (de Lapparent de Broin et al., 2006), is the only terrestrial chelonian in mainland France. It is a small chelonian (maximum carapace length 154 mm for males, 191 mm for females; Stubbs & Swingland, 1985) with a yellow and black shell (Bour, 1986). During the Neolithic Age it was present along the entire Mediterranean shore and on the Mediterranean islands (Cheylan, 1981). It now occurs only in France, where its decline has been reported since the early 1910s (Chabanaud, 1919; Petit & Knoepffler, 1959). Its habitat has been fragmented and lost due to urbanization and agricultural development, forest fires affect the populations, adults are illegally collected, and individuals are killed by machinery used for land clearing and forestry. The species also has a low fecundity, and there is a high rate of natural predation on eggs and young (Madec, 1999). Hermann's tortoise has been categorized as Endangered on the IUCN Red List since 1990 (IUCN, 2007).

The preferred habitat of *T. h. hermanni* is a shrub-grassland mosaic that provides locations for both foraging and nesting (Nougarède, 1998; Cheylan, 2001). Since the early 1980s its range has been restricted to c. 750 km^2, mostly comprising the areas of the Plaine and Massif des Maures, in the department of Var, in south-east France (Cheylan, 1981, 2001; Stubbs et al., 1991). However, densities high enough to indicate supposedly viable populations occur in only 260 km^2 (Cheylan, 1981; Stubbs et al., 1991). The total population size of *T. h. hermanni* in Var is unknown but the species is restricted to 10 distinct areas (Cheylan, 2001).

The areas that have so far benefited from the greatest conservation efforts for *T. h. hermanni* (Natura 2000 sites, land acquisition by NGOs, and National or Regional Reserves) have been selected based on a high encounter rate (number of tortoises observed per searching hour per unit area) and a large area of available habitat. However, there has been only one study of the population dynamics of the species (Guyot, 1996) and therefore most conservation decisions currently rely only on presence/absence or encounter rate data, as reported in maps drawn by Stubbs et al. (1991) and M. Cheylan (unpubl. data).

Capture-mark-recapture studies of chelonians are time-consuming to implement and therefore encounter rates have generally been employed for assessing *T. h. hermanni* populations. However, analyses based on encounter rates are incomplete because there can be a high encounter rate even if a site only has adults, and a smaller but reproductive population may have a temporarily low encounter rate although young individuals are present (e.g. in a post-fire recovery situation). In the first example, the population may be functionally extinct and persists only because of adult longevity (Gibbs & Amato, 2000; McDougal, 2000). In the

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second example, a site with reproducing individuals may inadvertently be neglected. The occurrence of an equilibrated sex-ratio and presence of subadults and juveniles must therefore be considered when considering protection of a site for *T. h. hermanni*.

Given that censuses of *T. h. hermanni* were >10 years old I undertook a new census of the population in Var during 2001–2005, obtaining data on encounter rates and sex ratios and the presence of subadults and juveniles. I aimed to update knowledge of the species in southern France while taking into account demographic variables often neglected in conservation decisions. The study provides a baseline for future surveys of this species using a standardized protocol. I thus hope to promote evidence-based decisions by stakeholders and facilitate the dialogue between scientists and managers/practitioners for the conservation of this species (Bibby, 1995; Sutherland, 2003, 2006).

Methods

Survey sites

The 5,970 km^2 department of Var, southern France, borders the Mediterranean. Each of the 187 survey sites was a rectangle of 1.0×1.5 km positioned on a 1:5,000 National Geographical Institute map (IGN-Top 25) partitioned into a grid of 50×50 m cells. Sites were chosen according to whether there had been a prior census by SOPTOM (Stubbs et al., 1991), reports of presence of tortoises by the public or by naturalists, and presence of a large proportion of natural habitat. To cover as much of the area potentially favourable for *T. h. hermanni* (semi-open vegetation, low degree of urbanization, presence of water) as possible, some extra sites were also surveyed even if there was no previous indication that *T. h. hermanni* was present. We did not survey locations with steep slopes, dense forest, short grassland or bare ground because these habitats are rarely occupied by *T. h. hermanni* (Cheylan, 1981, 2001). We did not sample urban areas because they often contain feral captive-bred tortoises (including hybrids with *T. h. hermanni* that are difficult to identify without genetic analysis), except when they neighboured large natural places.

Sampling

Our method aimed to (1) facilitate comparison between sites and long-term monitoring, (2) minimize the training period required for observers, (3), maximize motivation and efficiency of observers, and (4) minimize biases between observers. The method was designed and tested over 1998–2000.

As detectability of males and females varies seasonally (males are more easily detected in April, females in June while nesting), each site was visited 1 day per month, i.e. three times during 15 April–15 June, over 2001–2005. Censuses only took place when the temperature was 17–27°C in the shade at ground level, on vegetation. Subadults (carapace length, CL, < 100 mm) and juveniles (CL < 70–80 mm) were defined based on Guyot (1996) and Stubbs & Swingland (1985). Sex was identifiable only for individuals with CL >100 mm.

Three teams of 3–4 people worked each year, and to minimize differences in ability to detect tortoises the three visits to a site per year were by different teams so that each individual observer surveyed all the sites in a given year. Thus, c. 40 sites were visited each year for all teams combined. Observers spent 30 minutes searching each 50 × 50 m cell. When a tortoise was found and examined handling time was discarded from search time. Each observer looked for tortoises by wandering randomly within a cell, alternating sight-sampling whilst walking with detection of tortoises by movements whilst stationary (the latter for at least 2 minutes each time the observer stopped in a cell). This method aimed to minimize the effect of habitat structure and composition on detection rate and to avoid bias due to differential skills of observers (Stubbs et al., 1984). We sampled at least 60 cells per site (10% of the surface), each cell being chosen randomly. Each surveyed cell was visited only once during the whole census. Each located tortoise with a CL > 90 mm was fitted with a numbered tag inserted on the anterior first marginal scale (Madec, 1995), and the position of each tortoise was recorded with a global positioning system to a precision of 4–8 m.

Data analysis

Comparisons between sites were based on categories of encounter rate, population structure and categories of observed sex ratio (Table 1). I compared the survey results with those of M. Cheylan (unpubl. data, 1992 & 2001) to assess changes in encounter rate over time. M. Cheylan's data were collected for restricted-use reports to Ministries or administrative agencies as preliminary maps reporting variation in abundance of tortoises in Var (1992) or in Plaine des Maures only (2001). They were based on several years of transects surveyed by his teams before 1992 or before 2001, respectively. M. Cheylan (unpubl. data, 1992) used data from transect surveys to define areas of high, medium and low abundance (average encounter rates of 3.5, 2.5 and 1.0 tortoises h^{-1}, respectively). A superimposition of our survey sites on Cheylan's 1992 classification using the geographical information system *Mapinfo* (Pitney Bowes, Troy, USA) showed that 20 of our 187 sites were totally included in the areas surveyed by Cheylan. I used this superimposition to estimate an average 1992 encounter rate for each of our sites based on the proportion of the site included in the high, medium or low density areas of

TABLE 1 Number of sites (of a total of 187) with low, medium and high encounter rates (number of *T. h. hermanni* per hour), by population structure and sex-ratio. Some sites are not reported because either one sex was not observed (n = 37), no adults were recorded (n = 3) or no *T. h. hermanni* were located (n = 34).

		Sex-ratio				
Encounter rate (h^{-1})	Population structure[1]	> 75% of one sex	65–75% of one sex	55–65% of one sex	45–55% of each sex	Total
Low (0 > 0.5)	No immatures	1	14	7	10	32
	No subadults	1	6	2	2	11
	No juveniles	1	3	5	1	10
	All	1	3	6		10
Medium (0.5 > 1.0)	No immatures			2	1	3
	No subadults	1	2	2	2	7
	No juveniles	1		5	4	10
	All	1	2	5	3	11
High (1.0 > 2.5)	No immatures		1	1		2
	No subadults			4	2	6
	No juveniles		1			1
	All			6	4	10
	Total	7	32	45	29	113

[1]No immatures, neither juveniles nor subadults observed; no subadults, subadults not observed; no juveniles, subadults but no juveniles detected; all, both juveniles and subadults observed

M. Cheylan's survey. A Wilcoxon's signed rank test was used to detect any differences between these estimated 1992 encounter rates and those I recorded in 2001–2005, and a Spearman correlation between the two data sets was used to describe any general trend in observed changes. A similar protocol was used to generate a second comparative analysis using M. Cheylan's 2001 data for Plaine des Maures, the richest area for tortoises in mainland France. For this second comparison 22 of our 187 sites coincided with M. Cheylan's data.

Collection of *T. h. hermanni* (for the pet trade or by contractors wishing to avoid the mitigation measures that are compulsory when *T. h. hermanni* are detected in an area) is a cause of decline of wild populations. The map figures have therefore been distorted to hide the exact location of our surveyed sites. Precise locations are available upon request to the author.

Results

Total search time was c. 4,776 hours in a total of 2,388 km^2. We recorded 2,049 live individuals and collected 21 dead individuals. No *T. h. hermanni* were observed in 34 (18%) of the 187 sites. These sites were along the western edge of the area of distribution, in the most north-easterly areas and in places heavily urbanized near the coast. In the remaining 153 sites three had juveniles but no adults and 150 sites had an encounter rate of 0.01–2.43 individuals per hour (mean 0.47 ± SD 0.44, median 0.33). Only six sites (13%) had an encounter rate > 1.0 (Fig. 1).

Comparing our data with theoretical data obtained for the sites of M. Cheylan for 20 sites in 1992 (14 of which were in Plaine des Maures), the encounter rate in our survey differed significantly from that of 1992 ($T = 2$, $P = 0.00012$), with an average decline of 52.7 ± SD 26.8% and with the highest decline being 89%. The only sites that did not undergo such a dramatic decline were one in le Cannet des Maures (6.8% increase in encounter rate), one in Callas (7% decline) and one in Vidauban (15.7% decline). The correlation between the two data sets is significant ($r = 0.577$, $P = 0.0078$; Fig. 2).

There was no significant difference in a comparison of encounter rates between our survey and M. Cheylan's 2001 data ($T = 96$, $P = 0.322$; mean difference 19 ± SD 23%) and the two data sets were positively correlated ($r = 0.83$, $P < 0.0001$). Both data sets describe a decreasing gradient from north to south in the Plaine des Maures and a lower abundance in highly urbanized areas.

Of 31 sites with both juveniles and subadults there was a high encounter rate in only 10 (Table 1). Thus if only sites with a high encounter rate were to be protected this would omit 74% of sites with reproduction. Protecting only such sites would also mean including two sites where no reproduction has been observed at all, and six sites without subadults. Protecting sites with both juveniles and subadults and with an equilibrated (45–55% of each sex) or slightly unbalanced sex ratio (55–65% of one sex) would include 24 sites (and 39 sites if sites with no juveniles were to be included). Protecting these sites would allow the preservation of 58.8% of sites with a high encounter rate and 33.0% of sites with a medium encounter rate (and up to 70.8% if sites with no juveniles were to be included).

I produced a new map of the distribution of *T. h. hermanni* in France based on both encounter rates and the composition of the observed individuals (Fig. 3). In terms of

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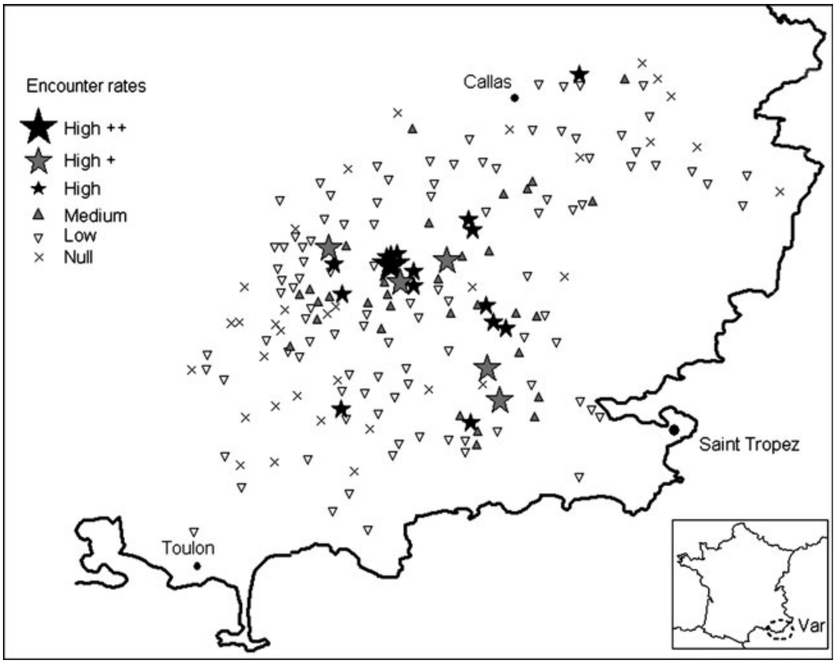

FIG. 1 Classification of the 187 sites in Var surveyed for *T. h. hermanni* according to encounter rates (ER) with individuals. High++, ER $> 2\ h^{-1}$; High+, $1.5 < ER \leq 2$; High, $1 < ER \leq 1.5$; Medium, $0.5 < ER \leq 1$; Low, $0 < ER \leq 0.5$; Null, ER = 0. The inset indicates the location of the main figure in south-east France.

protection I assign priority to sites with both juveniles and subadults and take into account their distribution and possible connections with each other. When two sites are separated by natural habitats, with no major barrier such as a road or houses, I pool them into a single population fragment. I also include, wherever possible, sites with a high or medium encounter rate and an equilibrated or slightly unbalanced sex ratio, and sites where no juveniles were observed but subadults were present, as the population fragment may be reproducing (although egg and juvenile survival needs to be examined). These 16 areas I describe as reproductive fragments, with three levels of abundance. Four sites without juveniles can be attached to these fragments, which thus encompass 28 of our surveyed sites. Six sites compose four new fragments that I refer to as potentially reproductive fragments because adults and subadults have been observed, suggesting functional reproduction, but juveniles were not observed, suggesting a recent problem with their survival or an especially low detectability of juveniles.

Starting with these fragments I drew a map to illustrate what the potential distribution of *T. h. hermanni* could be if the population fragments expanded and if fragments reconnected with each other. This map addresses the need to preserve putative corridors between fragments and to make sure the habitat is or becomes suitable for tortoises in the future. These areas include as many reproductive fragments as possible, avoiding the largest barriers and covering as much natural habitat as possible. I thus obtained eight areas that could be a long-term target for conservation programmes of *T. h. hermanni* and its habitat (Fig. 3).

Discussion

Although our study has shown that the general distribution of *T. h. hermanni* has not changed greatly compared to previous studies (Cheylan, 1981; Stubbs et al., 1991; Cheylan et al., 1993; M. Cheylan, unpubl. data, 1992 & 2001), there are three points of note. Firstly, population fragments that

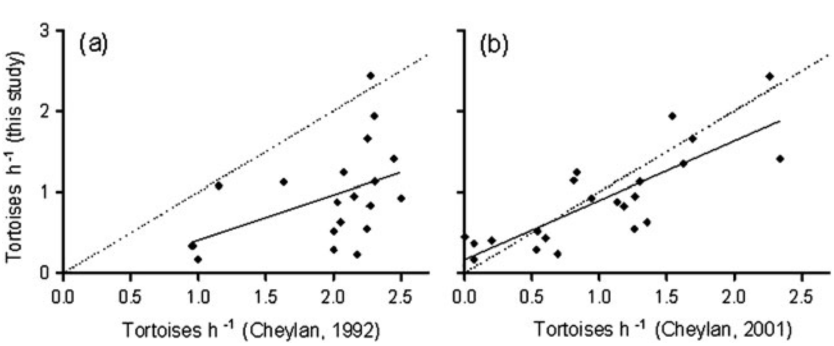

FIG. 2 Correlations between the estimated encounter rates of *T. h. hermanni* in 20 and 22 sites, respectively, in 1992 and 2001 (based on data from this 2001–2005 survey; see text for details) and the encounter rates at the sites surveyed by Cheylan (a) in 1992 (unpubl. data) and (b) in 2001 (unpubl. data). The dotted lines show the regression line for a perfect correlation (r = 1).

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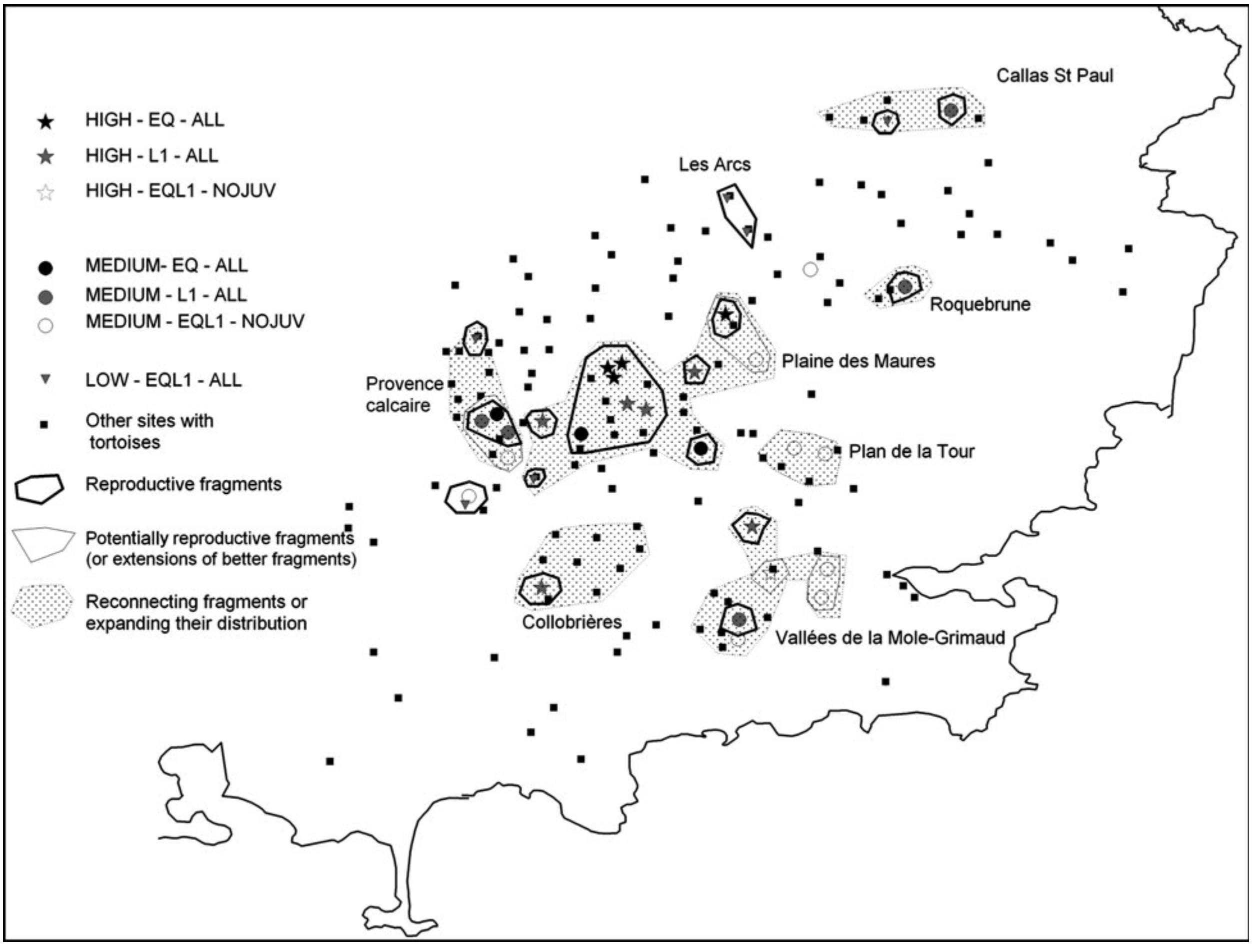

FIG. 3 Population fragments (reproductive and potentially reproductive, see text for details) delimited based on the characteristics of the surveyed sites (encounter rate, presence of young and sex ratio). HIGH, MEDIUM and LOW are levels of encounter rate; EQ and L1 are observed sex-ratio (EQ, 45–55%, L1, slightly unbalanced with 55–65% of one sex); ALL, juveniles and subadults present; NO JUV, absence of juveniles but presence of subadults.

disappeared in the recent past (Estérel, Albères; Cheylan et al., 2001) have so far not re-established.

Secondly, the global population is now highly fragmented; c. 16 areas in which reproduction is occurring are more or less disconnected from each other, and are interspersed with low numbers of individuals in areas where natural habitat still exists. Past and current conservation actions (increasing area of protected land, connectivity within and between population fragments, decrease of direct threats to individuals), focused on the largest fragments (Plaine des Maures, Callas), need to be continued and should be extended. However, smaller population fragments should also be conserved, especially if the population is highly fragmented (Longepierre et al., 2001). Hailey (1988, 2000) and Hailey & Willemsen (2003) noted that because tortoises can persist in small areas in situ protection of small fragments can be an effective conservation action. The size of the larger natural areas harbouring tortoises does not prevent forest fires, which destroyed up to 80% of the population in 1991 in Plaine des Maures (Cheylan et al., 1993). Thus conserving a set of smaller sites, especially where reproduction is successful, would increase the long-term preservation of *T. h. hermanni*. However, > 80% of the fragments in which reproduction is occurring do not have any protection, and some of them are threatened by urbanization or agriculture.

Thirdly, comparisons with M. Cheylan's data (1992, 2001, unpubl.) suggest a strong decline in abundance since 1992, even within the fragments with a high encounter rate. Differences between our results and the 1992 data could be due to differences in sampling methods (transects vs quadrats), observer skills, or to a strong decline in detectability and/or population size. The comparisons show, however, that differences in sampling methods or teams cannot explain the results and thus the decrease in abundance, implied by fewer encounters, between 1992 and 2001–2005 appears to be real. At some sites no major disaster (e.g. fires) has occurred that could explain the decline since 1992, and therefore other threats should be alleviated as soon as possible, whether they impact adults (effect of machinery, illegal collection) or juveniles (predation). This implies providing solutions at a local level (manual land-clearing, pastoralism, controlled winter burning, training and restraint of domestic dogs, control of game fauna and of collection for pets).

Currently the Natura 2000 network only covers c. 49% of one reproductive fragment (Plaine des Maures). Other than this, c. 360 ha of the same population fragment was protected in 2006 by an Arrêté de Protection de Biotope. Up to 20% of two other reproductive fragments benefit from protection by land ownership: Callas (by CEEP, a local environmental NGO) and La Môle (Conseil General, state office). The National Office of Forestry owns and manages some habitats suitable for expansion in Massif des Maures. However, most of the fragments with reproductive individuals remain threatened and unless conservation action is taken the future of the species in mainland France will be compromised. The National Action Plan for this species is expected in early 2009. It will contain a map describing the distribution of population fragments and will include the data presented here. I plan, together with the NGO CEEP and M. Cheylan (of EPHE-CNRS), to design new maps for the conservation of *T. h. hermanni*, in which our proposal (Fig. 3) will be taken into account. Since the census described here we have also designed more detailed maps for the area of Cogolin-Grimaud, in which some areas with reproductive *T. h. hermanni* have been observed. This area, located near St Tropez, is undergoing rapid development. Under the leadership of the Ministry of Ecology, a FEDER and a LIFE project have been submitted to the European authorities. Such financial help would allow us to implement both management, education and scientific programmes for this Endangered tortoise.

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Biographical sketch

Barbara Livoreil helps establish conservation and management guidelines by enhancing the scientific understanding of the relationship between individuals and their environment. Her other research interests are conservation genetics, ethology, foraging ecology and socio-economics. She is currently developing research programmes on the use of microhabitats, based on the age, sex and body condition of *T. h. hermanni*, to develop guidelines for habitat management and restoration.