

Testudo hermanni (Gmelin 1789) – Hermann's Tortoise

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SUMMARY. – Hermann's Tortoise, *Testudo hermanni* (Family Testudinidae), is a medium-sized terrestrial species (average carapace length ca. 130 to 180 mm), widespread in the European Mediterranean region. Currently two subspecies are distinguished: *T. h. hermanni* in Western Europe and *T. h. boettgeri* in Eastern Europe, the border between them being the Po Valley in northeastern Italy. The species inhabits most Mediterranean vegetation habitats, but typically semi-open formations of stony, sun-drenched hills with low and sparse vegetation and grass. Some East European populations are found at up to 1300 m of elevation, but most populations are below 500 m. Sexual dimorphism is moderate, with females on average 12% larger than males. A morphological distinction from most other tortoise species is the presence of a horny claw-like scale at the tip of the tail that is more developed in males than in females. The maximum number of clutches laid annually is 3, but most frequent are 1 to 2 clutches per year. Maximum clutch size is 7 eggs for *T. h. hermanni* and 9 eggs for *T. h. boettgeri*, with a mean clutch size of 3.3 and 4.3 eggs, respectively. Annual survival of adults is estimated to range from 85 to 97%. Most western populations of the species are in strong decline and have very restricted distributions. Eastern populations appear to be more stable, though some populations also show a strong decline. Primary threats are destruction and alteration of habitats (mostly by forest fires, expansion of human settlements and infrastructure, and changes to traditional use of forest, pastoral practices, and agriculture), harvesting for the pet trade, and increases in the population size of native predators (mainly mammal carnivores and wild boars). Proposed conservation measures include habitat restoration and improvement, creation of reserves to protect the species, and environmental education. Captive breeding and reintroduction programs are necessary only for the most threatened populations.

DISTRIBUTION. – Albania, Bosnia and Herzegovina, Bulgaria, Croatia, France, Greece, Italy, Kosovo, Macedonia, Montenegro, Romania, Serbia, Slovenia, Spain, Turkey. Fragmented distribution in southern Europe from northeastern coastal Spain and southern coastal France through much of Italy, and more continuous in the Balkan Peninsula, extending eastward to European Turkey. Distributed also in most western Mediterranean islands (Balearics, Corsica, Tuscan Archipelago, Sardinia, and Sicily) as well as some eastern islands (Ionian and Euboea).

SYNONYMY. – *Testudo hermanni* Gmelin 1789, *Testudo hermanni hermanni*, *Protestudo hermanni*, *Agrionemys hermanni*, *Eurotestudo hermanni*, *Testudo graeca bettai* Lataste 1881, *Testudo hermanni robertmertensi* Wermuth 1952.

SUBSPECIES. – Two currently recognized: 1) *Testudo hermanni hermanni* (Western Hermann's Tortoise) (synonymy: *Testudo hermanni robertmertensi*, *Eurotestudo hermanni*) (distribution: Western Europe from Spain through western and southern Italy); and 2) *Testudo hermanni boettgeri* (Eastern Hermann's Tortoise) (synonymy: *Testudo graeca boettgeri* Mojsisovics 1889, *Testudo boettgeri*, *Eurotestudo boettgeri*, *Testudo graeca hercegovinensis* Werner 1899, *Testudo hercegovinensis*, *Testudo hermanni hercegovinensis*, *Eurotestudo hercegovinensis*, *Testudo enriquesi* Parenzan 1932, *Testudo hermanni hermanni* [in error]) (distribution: Eastern Europe from northeastern Italy to European Turkey).

STATUS. – IUCN 2011 Red List: Lower Risk/near threatened (LR/nt) (assessed 1996, needs updating); CITES: Appendix II, as Testudinidae spp., and Appendix A (European Community); Habitat Directive: Annexes II and IV; Berne Convention: Annex II.



Figure 1. Adult male *Testudo hermanni hermanni* (CL = 141 mm) from Albera, Catalonia, Spain. Photo by Albert Bertolero.

Taxonomy. — The taxonomy of the species has been complicated and confusing above the species level (van der Kuyl et al. 2002; Lapparent de Broin et al. 2006a, b; Parham et al. 2006; Fritz and Bininda-Emonds 2007) as well as within the species (Bour 2004a, b; Perälä 2002a, 2004; Fritz et al. 2006). Regarding its classification above the species level, *Testudo hermanni* has succes-

sively been placed in the genera *Protestudo* (Chkhikvadze 1970), *Agrionemys* (Gmira 1993, 1995), and *Eurotestudo* (Lapparent de Broin et al. 2006a, b) essentially on the basis of paleontological, anatomical, and morphological characters. Recent molecular-based phylogenies have invalidated these classifications, except the grouping of *T. hermanni* and *T. horsfieldii* which could be considered as a distinct subgenus (Fritz and Bininda-Emonds 2007). Within the existing taxon *T. hermanni*, Bour (2004b) and Perälä (2002b, 2004) recognized three distinct species: *Testudo hermanni* (Gmelin 1789) for the western populations (subspecies *T. h. hermanni*), *Testudo boettgeri* (Mojsisovics 1889) for most eastern populations (subspecies *T. h. boettgeri*), and *Testudo hercegovinensis* (Werner 1899) for the populations along the Adriatic coast of northern Albania (subspecies *T. h. boettgeri*). These propositions, based only on external morphology, are not sustained by recent molecular phylogenies which acknowledge only one species in the taxon *T. hermanni* (Fritz et al. 2006).



Figure 2. Adult *Testudo hermanni hermanni* from north Minorca, Spain; **top and bottom left:** male, **bottom right:** female. Photos by Albert Bertolero.



Figure 3. Ventral view of the tail of an adult male *Testudo hermanni hermanni* from Ebro Delta, Spain, showing the terminal horny claw-like scale. Photo by Albert Bertolero.

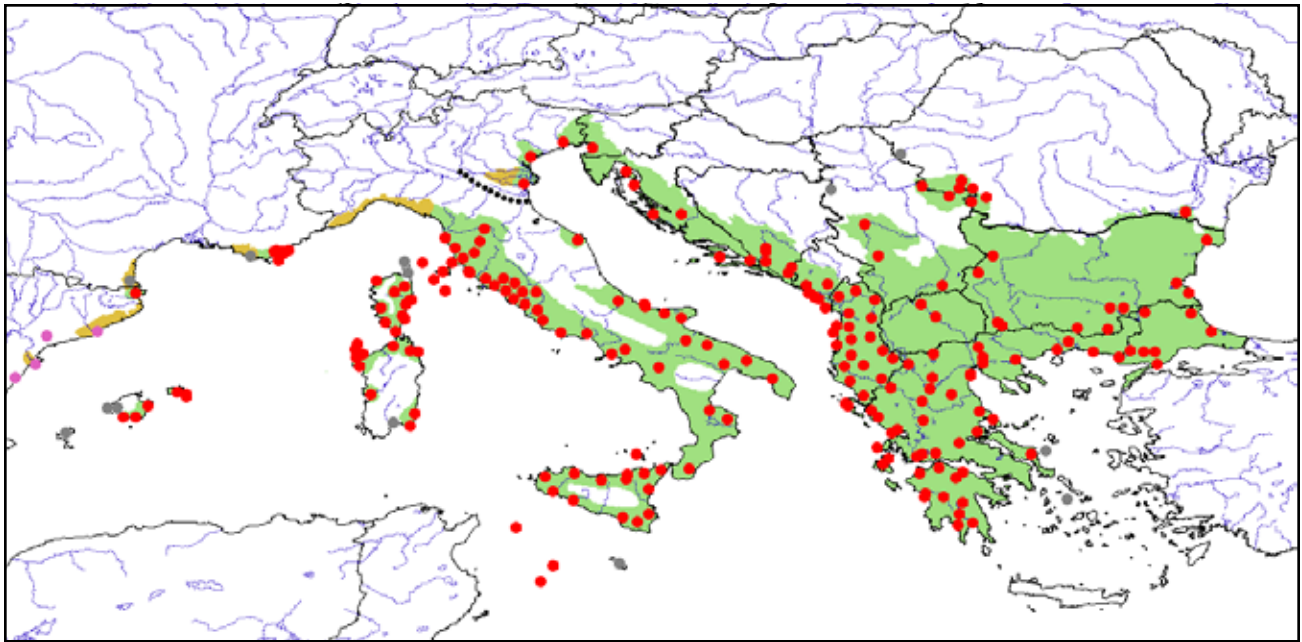


Figure 4. Distribution of *Testudo hermanni* in the Mediterranean Region; dotted line delimits the distribution of subspecies *T. h. hermanni* to the west and *T. h. boettgeri* to the east. Red dots = museum and literature occurrence records of native populations based on Iverson (1992), plus more recent and authors' data; gray dots = extralimital occurrences reflecting escaped pets and/or erroneous or prehistoric records, or extirpated populations (e.g., southern France); purple dots = recently introduced populations; green shading = projected native distribution based on GIS-defined hydrologic unit compartments (HUCs) constructed around verified localities and then adding HUCs that connect known point localities in the same watershed or physiographic region, and similar habitats and elevations as verified HUCs (Buhlmann et al. 2009), and adjusted based on authors' data; olive shading = native range extirpated in modern times.

At the present time, most scientists recognize the existence of only one species and two subspecies, matching the classical systematics.

Two subspecies were first established by Wermuth (1952): *Testudo hermanni hermanni* (as his new subspecies *T. hermanni robertmertensi*) west of the plain of the Po River, northeast Italy, and *Testudo hermanni boettgeri* in the east (erroneously referred to as *T. h. hermanni* by Wermuth and some subsequent authors). Distinguishing between these two subspecies based only on morphology is difficult due to the variations observed in morphology and color within the distribution area of the species (Guyot and Devaux 1997; Willemsen and Hailey 1999a; Cheylan 2001). Recent studies based on mtDNA (Fritz et al. 2006) have confirmed the existence of two major groups within the species, confirming the validity of these two subspecies. These studies highlighted four distinct Evolutionarily Significant Units (ESUs): one grouping all the western

populations (Italy, France, Spain and the Balearic Islands, Corsica, Sardinia, Sicily), a second grouping the populations in the east of the Balkans (Greece, Bulgaria, Macedonia, Romania) to the Taygetos Mountains in the Peloponnese; a third grouping the populations of the Adriatic coast to the Pindos Mountains in Greece (Croatia, Adriatic coast of Greece, Corfu Island), and a fourth very localized in the extreme south of Greece, on the western slope of the Taygetos Mountains in the Peloponnese.

Recent studies on phylogeography and population genetics have clarified the status of most populations in Europe. The first analysis of mitochondrial DNA reported the existence of two major clusters of sequences for 12S ribosomal RNA (van der Kuyl et al. 2002). Each group could be easily attributed to one of the two subspecies, and the low genetic divergence between them argued against the hypothesis that *hermanni* and *boettgeri* should be classified as full species (Bour 2004a; de Lapparent de Broin et al. 2006a, b). The cytochrome *b* gene additionally suggested the existence of three major groups of mtDNA sequences (also called haplogroups) in *T. h. boettgeri*, approximately located in three different geographic areas (Fritz et al. 2006). This study also suggested that Hermann's Tortoises from Corsica were more closely related to Italian tortoises than to tortoises from Var in southeastern France. Microsatellite DNA has been examined recently together with mtDNA, and also suggests a clear differentiation between *T. h. hermanni* and *T. h. boettgeri*. Populations in Var appear to be highly homozygotic, and clearly differentiated from those of Italy and Spain (Bertorelle et al. 2007). The area of distribution of



Figure 5. Hatchling and juvenile *Testudo hermanni hermanni* from south Minorca, Spain. Photos by Albert Bertolero.



Figure 6. Adult *Testudo hermanni boettgeri* from Greece. Photo by Adrian Hailey.

T. h. hermanni and *T. h. boettgeri* does not overlap and the two subspecies are allopatric, the borderline being near the Po River, in northeastern Italy. Hybrids have been recorded but it is difficult to assess their true origin, as releases from captivity may have occurred in some areas. Perälä (2002b) resurrected the taxon *T. hercegovinensis*, based on the absence of inguinal scutes, but this proposal has not been supported by genetic analysis (Fritz et al. 2006).

Description. — Hermann's Tortoises are yellow and black, sometimes uniformly yellow or greenish yellow in specimens from Greece or some islands (e.g., Corsica). The plastron has two large black stripes, separated by a lighter median line of variable width. In some cases (mainly in the eastern subspecies), these black stripes are reduced to disjointed spots more or less spread out, or almost absent (specimens with very light color, especially in northern populations; Willemsen and Hailey 1999a).

The carapace is high, with an oval form in females and a sub-trapezoidal form in males. Growth rings are well marked, except for old specimens which can in extreme cases present an entirely smooth carapace. The plastron is rigid, flat in females and slightly concave in males. Sexual



Figure 8. Adult *Testudo hermanni boettgeri* from Sparta, Greece. This specific pigmentation is only characteristic in the Peloponnese area. Photo by Ronald E. Willemsen.



Figure 7. Hatchling *Testudo hermanni boettgeri* from Greece. Photo by Adrian Hailey.

dimorphism starts to appear when the carapace reaches a length of about 10 cm, corresponding to 6–7 yrs of age. Males are smaller than the females (by approximately 12%), with a more trapezoidal form (seen from above) due to an increased width of marginals 9–10 (Willemsen and Hailey 2003). Males possess a longer tail (26% of the length of the carapace compared to 14% in females) that is also thicker at the base, the supracaudal scute is strongly incurved, and the rear part of the plastron has a wider opening than in females. In both sexes the tail has a well-developed terminal horny claw-like scale. The young cannot be distinguished from adult females, except from a paler coloration in the early life stages. Hatchlings are on an average 30 to 36 mm long for a weight ranging between 9.6 and 12.7 g.

The main diagnostic characteristics of *T. hermanni* are the following: supracaudal scute almost always divided, a narrow vertebral scute, a horny claw-like scale at the tip of the tail, no real corneous tubercles on the inner side of the thigh, large scales on the anterior external part of the foreleg in at least 5 transverse rows. Typically, the species has a nuchal (cervical), 5 vertebral scutes, 4 costals, 2 supracaudals, and 11 marginals. The plastron has 2 gulars, 2 humerals, 2 pectorals, 2 abdominals, 2 femorals, 2 anals, 2 axillary, and 2 inguinal scutes. In the east (in the southern Balkans) Hermann's tortoise coexists with two other *Testudo* species (*T. marginata* and *T. graeca*) with which it can occasionally be confused, especially when young. No cases of hybridization are known in the wild but some hybrids have been obtained in captivity with *T. graeca iberica*, *T. g. graeca*, and *T. horsfieldii* (Cheylan 2001).

Across their range, adults show a large variation in size (Willemsen and Hailey 1999b; Cheylan 2001). The western populations (Spain, France, Italy) are mainly of small size, with straight carapace length (CL) ranging on average between 150–179 mm in females and 130–149 mm in males; the eastern populations (in the Balkans) are of larger size, CL on average > 180 mm in females and > 155 mm in males. The largest known specimens have been found in Bulgaria (CL 346 mm, Beshkov 1997), the smallest in the south of the Peloponnese in Greece (average CL 153 mm in females;



Figure 9. *Testudo hermanni hermanni* habitats. **Top left:** agricultural landscape of Minorca, Spain; **top right:** Albera, Spain; **bottom left:** Ebro Delta, Spain; **bottom right:** Corsica, France. Photos by Albert Bertolero.

Willemsen and Hailey 1999b) and in northern Catalonia in Spain (average CL 150 mm in females).

Distribution. — Hermann's Tortoise inhabits the Mediterranean and submediterranean regions of Europe, from Catalonia (northeast Spain) in the west to the Bosphorus Strait in the east (Cheylan 2001). In the north, it reaches 45°N in Romania, at the Iron Gates along the Danube River. The plain of the Po River, in northeastern Italy, constitutes an important border between the western European subspecies (*T. h. hermanni*) and the eastern subspecies in the Balkans (*T. h. boettgeri*).

The western European subspecies is scattered. In Spain, the species inhabits only a reduced area (134 km²) in the north of Catalonia (the Albera Massif) (Bertolero 2008). It can also be found on the Balearic Islands (Minorca and Mallorca) where it was introduced by the first inhabitants perhaps 3000 years ago (Mayol 1985). It has been successfully reintroduced in the Ebro Delta Natural Park (Catalonia) (Bertolero 2002). In France, it disappeared from Roussillon in the 1960s and can only be found in Provence, in the Massif des Maures, and in the Massif de l'Estérel, in a territory of about 337 km² (Cheylan 2001). In Corsica, it inhabits a small part of the island, forming five isolated populations (Cheylan 1995). In Italy, the species has disappeared from many areas (Ballasina 1995; Vetter 2006; Mazzotti 2006); at the present time it shows a diffuse distribution over a wide area in the coastal regions of the peninsula (Mazzotti 2006, Cheylan et al. 2010). The main populations are located in Tuscany and in Latium on the western coast and in the Apulia and Calabria regions in the extreme south. In Sicily, it is located in the coastal areas of the north and southeast (Mazzotti 2006). In Sardinia, it

only inhabits a small area in the northwest (Ballasina 1995; Mazzotti 2006).

In the Balkans, the eastern subspecies inhabits the coastal areas along the Dalmatian Coast, from Istria in the north to Podgorica in Montenegro. From there, the limit of its distribution goes north through southeast Serbia to the banks of the Danube River. In Romania, the species can only be found near Orsova, in the area of the Iron Gates. The populations there are very reduced and isolated from the rest of the distribution by the Danube River (Maran 2007). In the south of the Balkans, it inhabits a large part of Bulgaria, Greece, Macedonia, Albania, Kosovo, and part of the Turkish territory in Europe.

Habitat and Ecology. — *Testudo hermanni* inhabits most of the Mediterranean vegetation types, from the shores of the sea to 1300 m altitude in the Balkans, but most populations are found below 500 m. It inhabits a large range of habitats, substrates usually being sandy or stony: coastal dunes, pastures, orchards in terraces, scrubs and sparse vegetation, open forests of evergreen oaks or pine trees. However, the typical is Mediterranean semi-open formations of stony, sun-drenched hills with low and sparse vegetation and grass. It can frequently be encountered in areas of traditional agriculture, if not too mechanized: orchards of olive trees, almond trees, orange trees, pastures, etc. It avoids marshy areas, dense forests (mostly pine trees), areas of intensive agriculture and stony hills with steep slopes (Cheylan 1981, 2001; Mazzotti 2006; Vetter 2006). Seasonal movements between vegetation types may, however, be a complicating factor for assessing habitat preferences. In the Mediterranean, *T. hermanni* mainly inhabits the bioclimatic zone of evergreen oak trees (which covers most of the distribution

area in the western Mediterranean, in Dalmatia, Albania and in southeastern Greece) and more marginally the sub-humid zone. In regions of cold climate with dry summers, it inhabits the zones of submediterranean oaks and pines, mostly in peninsular Italy, on the Dalmatian coast, and in the coastal regions of the Aegean Sea. In humid temperate and cold climates, it sporadically inhabits the zones of the western dry and hilly layer (coastal areas of the Gulf of Venice, middle valley of the Danube River) and is much more abundant in the plant formations of the western humid hilly layer (central regions of Greece, Bulgaria, and Serbia). This zone marks the ecological limit of the species. It disappears in the humid mountain zone characterized by beech (*Fagus sylvatica*) forests.

Growth and Sexual Maturity. — Most studies of growth in *T. hermanni* have used counts of growth rings in scutes as the measure of age. Increases in growth ring counts were verified in wild *T. hermanni* over 2 years by Stubbs et al. (1985) and over 10 years by Bertolero et al. (2005). Additionally, Castanet and Cheylan (1979) verified that scute growth rings were similar to osseous growth rings in limb bones. These studies suggest that growth rings are a reliable measure of age until growth slows at maturity, with osseous growth rings being reliable for a longer period of up to 20 years. The reliability of scute growth ring counts after maturity may depend on the care with which observations are made (e.g., by using a lens), but in wild populations there are usually old individuals with worn scutes that cannot be accurately aged.

A typical growth curve for *T. hermanni* might be described as constant linear growth at a rate of about 10 mm/year CL until maturity at 8–12 yrs, followed by a continuously decreasing growth rate giving an approach to an asymptotic size in very old individuals (without observable scute growth rings) (Stubbs et al. 1985; Willemsen and Hailey 2001a). This pattern does not fit the von Bertalanffy growth curve in detail, which requires that the growth rate is highest in the smallest individuals and decreases linearly throughout life as a direct function of increased size (Hailey and Coulson 1999). Nevertheless, integrated growth curves (i.e., of size on age) produced by the von Bertalanffy and other growth models may be very similar to linear growth (Hailey and Coulson 1999). Even a plot of growth rate on size may be well described by the von Bertalanffy model if data on small individuals are scarce (Živkov et al. 2007). Growth ends earlier in males than females, giving them a smaller adult size; the degree of sexual size dimorphism is relatively constant across populations (Willemsen and Hailey 1999b).

Modifications of this typical growth curve are in two parameters: the annual growth rate, and the age at which growth slows (usually assumed to be the age at maturity). Growth rate among Greek populations of *T. hermanni* varies from about 8–13 mm/year, but is not significantly related to their mean body size—if anything, tortoises in populations of large adult size grow more slowly (Willemsen and Hailey 1999b). Instead, inter-population differences in

adult size are due to variation in the age at which growth slows, which varies widely from about 9 to 18 yrs, giving the large variation of mean adult size (a three-fold range of mass) in Greece. Variation of mean adult size in Greece is most effectively explained by environmental temperatures, with tortoises from cooler sites being larger (Willemsen and Hailey 1999b).

It has not yet been proven that the age at which growth rate changes in *T. hermanni* corresponds directly to the age of sexual maturity of the individual. Within one population it has been shown, however, that the growth estimates of the size at sexual maturity correspond to the sizes at which sexual behavior is shown in males (Hailey 1990), and X-ray studies show females to be reproductive (Hailey and Loubourdis 1990). Although it is difficult for humans to determine in the field whether a female *T. hermanni* is sexually mature, male *T. hermanni* can do so by using olfactory cues from the femoral and cloacal regions (Galeotti et al. 2007).

Inter-population differences in the duration of growth produce a clear cline of adult size of *T. h. boettgeri* in Greece, with larger tortoises at northern sites, although even further north the trend is apparently reversed (Willemsen and Hailey 1999b). A cline of larger body size in the north is also found in *T. h. hermanni* in Italy, although with a much smaller size range (Willemsen and Hailey 1999b; Sacchi et al. 2007), but there is no general size trend in western populations as these are divided among many islands and widely separated areas. Island populations of *T. hermanni* tend to have larger body sizes, as in Sardinia (Corti and Zuffi 2003) and Corsica compared to mainland France (Cheylan 1992) or Spain (Bertolero et al. 2007b). Adult *T. hermanni* are smaller in Italy than in Greece at the same environmental temperatures (Willemsen and Hailey 1999b).

Home Range and Movements. — There have been a number of studies of the spatial ecology of *T. hermanni*, using radiotracking, thread-trailing, mark-recapture, modeling, and experimental or conservation relocations. As a result there are many non-standard data such as daily displacement and daily movement distances and short-term home ranges that make direct comparison among studies difficult, but allow a comprehensive view of the home range and movements of this species.

The home range of an adult *T. hermanni* is generally one or two hectares, and about half as large in males as in females. Long-term (several month) home ranges of 1.6, 1.2, and 0.7 ha in males and 2.4, 2.4, and 1.5 ha in females have been reported from France, Greece, and Italy, respectively (Swingland et al. 1986; Hailey 1989; Calzolari and Chelazzi 1991). Similar home range sizes were found by Huot-Daubremont (1996) in France and by Bossuto et al. (2000) in Italy (cited by Mazzotti et al. 2002). Larger home ranges, but with similar sexual differentiation (4.6 ha in males and 7.4 ha in females) occur in northern Italy, and were attributed by Mazzotti et al. (2002) to food scarcity and low population density. Weekly home ranges of 1.2 ha in males and 2.1 ha in females in France show a similar sexual pattern; the home range saturated more rapidly than

in Greece (where weekly home ranges were only 0.3–0.4 ha) possibly due to utilization of greater habitat complexity in France (Longepierre et al. 2001). Guyot (1996) found no sexual differences in home range, but individuals using only garrigue (0.6 ha) or cultivated (0.7 ha) habitats had smaller home ranges than those using both habitats (2.6 ha). Factors believed to increase the home range in *T. hermanni* are thus the use of particular resources (nesting areas by females), requirements for habitat diversity, and low food supply. In a dune habitat in Spain, home range was larger in males (2.7 ha) than in females (1.8 ha) (Bertolero 2002), the reversed sexual difference perhaps due to this being an introduced population and thus without historical nesting areas to which females were migrating.

Daily movement distances (total distance moved per day, as determined by thread trails) in Greece average 80–85 m, varying seasonally, with an individual total of about 140 days active per year out of a 210-day active season, and a total annual movement of some 12 km (Hailey 1989). Females tend to move further than males in the nesting season (May to July), and males further than females in other months, so that total annual activity is similar in the sexes. Males have larger daily displacement distances (between capture locations, as determined by radio fixes) than females, averaging 29 m and 15 m, respectively, in one study (Chelazzi and Francisci 1979) and 11 m and 7 m in another (Calzolari and Chelazzi 1991). Males thus saturate their home ranges more rapidly than females; displacement distances over 10 days were already equivalent to annual displacements in males, while this equivalence was not reached until 2–3 months in females (Calzolari and Chelazzi 1991). Two thirds of refuges used are insubstantial and offer little physical protection apart from shade, presumably because of effective carapacial armor; this frees tortoises from dependence on a central location, and only 9% of daily movements return to the same refuge (Hailey 1989).

Home ranges are stable over long periods (Chelazzi and Francisci 1979; Swingland et al. 1986) and individuals return to them if displaced by 0.4–1.6 km (Chelazzi and Francisci 1980). Return to the home range follows a remarkably straight path, compared to the typical convoluted movement pattern, but at a similar rate of movement (of about 73 m/day, calculated from Fig. 15 of Chelazzi and Francisci 1979). Translocated individuals show inactivity lasting from several hours to a few days, followed by altered movement with unusually linear routes (Chelazzi and Francisci 1980). The homing ability is non-topographic as it is successful in thick vegetation, and occurs even within uniform habitat and when tortoises are transported in opaque containers. Homing is dependent on olfaction, as determined by loss of this ability after destruction of the olfactory mucosa (Chelazzi et al. 1981; Chelazzi and Delfino 1986). Familiarity with the home range may produce thermal benefits (Chelazzi and Calzolari 1986), although it is not possible to confirm that reduced thermoregulation by non-residents is due to inability to use the thermal environment effectively. The changes in activity and movement in translocated tortoises

(Chelazzi and Francisci 1980) could also account for reduced thermoregulation in non-residents.

Chelazzi and Carlà (1986) modeled possible mechanisms allowing for a stable home range in *T. hermanni*. A simple dependence of distance and direction of movements on distance from a center was insufficient; by itself this would lead to a focal distribution. An additional mechanism for resetting to a shifting local focus was necessary to give the observed pattern of more uniform utilization of the home range. Chelazzi and Carlà (1986) suggested that this allows dynamic use of different parts of the home range at different times and for different functions, with greater efficiency than random wandering or searching for critical sites. Shifting local use of the home range is permitted by the use of multiple transient refuges throughout the area (Hailey 1989). Adults relocated to within 1 km of their home ranges after their original habitat had been destroyed did not preferentially occupy the nearest adjacent habitat, but established new home ranges that could be in the opposite direction from the release site (Guyot and Clobert 1997). Immature individuals relocated to novel areas may settle near the release point or move up to 2 km before establishing a home range (Guyot 1996). In both cases it is clear that homing efforts do not continue indefinitely, but if homing is unsuccessful the tortoise settles in a new home range area within a year, a pattern which is beneficial to conservation.

Survivorship and Longevity. — The annual survival rate (S) of adult *T. hermanni* in wild populations studied by mark-recapture is in the range 0.85–0.97 in mainland France (Stubbs and Swingland 1985; Guyot 1996; Cheylan 2001), Corsica (Henry et al. 1999), Greece (Hailey 1990, 2000a; Willemsen and Hailey 2001a), and Spain (Fernández-Chacón et al. 2011). Similarly high survival has been estimated for reintroduced individuals in Spain (Bertolero et al. 2007d). The survival rate is positively related to mean adult body size among Greek populations; a life table model suggests that differences in survival may be the selection pressure for the substantial variation in adult size (Willemsen and Hailey 2001a). Lower survival rates of females compared to males have been reported in some Greek populations, leading to male-biased sex ratios (Hailey 1990; Hailey and Willemsen 2000).

Although some of the estimates of survival have narrow confidence intervals, small changes in S when this is as high as 0.9 have large consequences for longevity. It is likely that some individual Hermann's Tortoises reach ages of several decades in some wild populations, but mark-recapture studies have not yet shown whether mortality increases in old individuals, so uncertainty remains over maximum longevity in the wild. There is no uncertainty, however, over the consequences of lower adult survival rates, which would be unsustainable (Guyot 1996; Bertolero 2002); lower values have been reported due to fires and habitat destruction (Hailey 2000) and pesticide spraying (Willemsen and Hailey 2001b) in Greece. Henry et al. (1999) also reported survival rates for juvenile ($S = 0.52$) and immature ($S = 0.88$) *T. hermanni* in Corsica, and Fernández-Chacón et al. (2011) for each

age from 0–5 yrs old in Spain. In addition to having lower survival rates than adults in apparently stable populations, juveniles are susceptible to predation by mammals and birds, and may have even lower survival in these circumstances, at least as shown by the lower relative numbers observed (Hailey and Goutner 2002).

Reproduction. — Eggs are white, hard-shelled and almost elliptical in shape, averaging 27.2×34.3 mm in size and 15.1 g in weight in *T. h. hermanni*, and 27.9×37.4 mm and 17.1 g in *T. h. boettgeri* (Cruce and Răducan 1976; Cheylan 1981; Esteban 1987; Hailey and Loumbourdis 1988, 1990; Fertard 1992; Longepierre et al. 2003; Bertolero et al. 2007a, c). Most clutches are laid between mid-May and the end of June (Cruce and Răducan 1976; Swingland and Stubbs 1985a; Fertard 1992; Bertolero et al. 2007b). Nevertheless, some clutches are recorded as early as mid-April and the last ones in early July. Incubation time ranges from 90–124 days in the wild (Cruce and Răducan 1976; Cheylan 1981; Nougarede 1998) and from 56–102 days under artificial conditions with a range of temperatures from 22–35°C (Kirsche 1967; Ehrengart 1971; Esteban 1987; Hailey and Loumbourdis 1990; Eendebak 1995).

The length of the incubation period is temperature-dependent, but the relationship is not linear (Eendebak 1995). Minimum and maximum temperatures for embryological development are 23°C and 35°C, respectively (Eendebak 1995). However, with constant temperatures of 25°C and 33–34°C, embryo mortality is near 50%, and below 23°C and above 34°C mortality rate increases to 100% (Eendebak 1995). As in other species of chelonians, sex determination is temperature-dependent. Thus, eggs of *T. h. boettgeri* incubated at temperatures from 25–30°C produced 100% males, and from 33–34°C produced 100% females (Pieau 2002). Eendebak (1995) has estimated that the pivotal temperature (to obtain a sex-ratio of 50:50) is 31.5°C.

Hatchlings emerge from late August to October, normally after rainfall at the end of summer, with a peak from mid-September to mid-October (Cruce and Răducan 1976; Hailey and Loumbourdis 1990; Nougarede 1998; Bertolero, Cheylan and Nougarede, unpubl. data). However, some hatchlings can overwinter in the nest and emerge the next spring (Bertolero, unpubl. data). The length of the female breeding season, defined as the time between the estimated date of the ovulation of the first clutch and the estimated date of the oviposition of the last clutch, varies between years depending on the weather, from 33.1 ± 2.6 (SE) to 44.7 ± 3.3 days (Bertolero et al. 2007b). The mean clutch retention time ranges from 20.5 ± 0.6 days for the first clutch to 12.9 ± 0.7 days for the third, thus this has a tendency to be shorter as the breeding season progresses (Bertolero et al. 2007b). The mean inter-clutch interval ranges from 10 to 27.5 days, with a mean of 20.2 ± 0.8 days in Corsica and 18.1 ± 0.9 days in Maures (France) (Swingland and Stubbs 1985a; Fertard 1992; Bertolero et al. 2007b).

Clutch size ranges from 1–7 eggs for *T. h. hermanni* and 1–9 eggs for *T. h. boettgeri*, with mean clutch sizes of 3.3 and 4.3 eggs, respectively (Swingland and Stubbs 1985a;

Esteban 1987; Hailey and Loumbourdis 1988, 1990; Fertard 1992; Nougarede 1998; Longepierre et al. 2003; Bertolero et al. 2007c). Mean annual clutch frequency ranges from 1.4 to 2.4, with a maximum of 3 clutches in Corsica and Greece (Hailey and Loumbourdis 1988; Bertolero et al. 2007c). Nevertheless, not all adult females reproduce every year in some western populations (Bertolero et al. 2007c).

In general, breeding traits are related to female body size, thus the biggest females have increased reproductive output (Cruce and Răducan 1976; Hailey and Loumbourdis 1988; Fertard 1992; Longepierre et al. 2003; Bertolero et al. 2007c). Hermann's Tortoises do not show size-based assortative mating. Nevertheless, it has been demonstrated that females prefer males that show high-pitched calls emitted at high rate and with a short duration during the courtship behavior (Galeotti et al. 2005a, b). Other signals selected positively by females are number of bites given by the male and the rate of sexual interaction (Galeotti et al. 2005b). As these courtship signals are related to the quality of the male, females may use these traits to select partners of high quality (Galeotti et al. 2005a, b).

Behavior. — In the early part of the day almost all individuals are found basking (Willemsen 1991; Cheylan 2001), from a body temperature (T_b) starting at about 20°C (Huot-Daubremont 1996). Animals orient perpendicular to the sun (Cheylan 1981), but often in summer they will bask in partial shade, especially juveniles. Once the optimal body temperature has been reached they either become active or, especially in summer, they disappear under cover and only become active again in the evening. Juveniles have a much shorter basking time than adults and are seldom found in full sun. In dense populations many animals may bask together at special basking sites, often climbing on each other in up to three layers; no aggressive behavior has ever been seen in such circumstances (Willemsen, pers. obs.). Basking time is short in summer and increases again in autumn, when many individuals bask in sheltered positions as their sole daily activity.

Body temperature depends more on the air than on the substrate temperature (Meek 1984; Panagiota and Valakos 1992; Carretero et al. 1995) and its regulation is mainly behavioral. *Testudo hermanni* is active with a minimum T_b from 12.3°C (Huot-Daubremont 1996), is fully active at a T_b of 25°C (Meek 1984, 1988a; Willemsen 1991) and has a thermal preference between 25 and 30°C (Cherchi 1956; Huot-Daubremont 1996). Most behaviors occur within this range of T_b , apart from nesting when T_b may be higher (to 32.1°C; Meek 1988b; Huot-Daubremont 1996). In the same thermal environment, T_b in females is lower than in males (Paglione 1988; Panagiota and Valakos 1992; Carretero et al. 1995; Huot-Daubremont 1996). Cherchi (1956) found that the overall temperature tolerance of *T. hermanni* is from -2 to 44°C. In the field no voluntary T_b over 38°C has been found (Meek 1984, 1988a, b; Paglione 1988; Wright et al. 1988; Willemsen 1991; Panagiota and Valakos 1992; Carretero et al. 1995) and not over 39.9°C in semi-captive conditions (Huot-Daubremont 1996). The lowest T_b recorded

is -0.4°C (Cherchi 1960). During hibernation T_b is higher than 0°C (Huot-Daubremont 1996, 2002); hibernating tortoises are able to endure exceptional winter conditions with air temperatures below -18°C in Provence (Cheylan 2001) and -23°C in Munich (Hediger 1958).

During spring, feeding activity is high in Greece, accounting for over 20% of observed animals. In the middle of the summer the feeding frequency decreases, to increase again in autumn (Willemsen 1991). In the wetter and cooler climate of Italy feeding frequency is more even over the course of a year.

Mating starts soon after hibernation and extends over the entire activity season, although mating frequency is low during the nesting season. Smell plays an important role in finding a mate in both sexes (Galleotti et al. 2007). During courtship the male shows vertical head-nodding, carapace bumping, and biting of the female's limbs. At the finish of courtship the male mounts the female and tries to copulate. During copulation the male makes sounds; Galleotti et al. (2005a,b) found that these sounds make the females more willing to mate. The female usually tries to escape and the male often falls off the female's carapace. In dense populations a female can be courted by several males at the same time until she can escape into cover. Successful copulation is apparently rare (Hailey 1990; Hailey and Willemsen 2000); during more than 14,000 field sightings of *T. hermanni* only two successful matings were seen (Willemsen, pers. obs.).

Testudo hermanni is one of the few tortoises with a horny claw-like scale at the tip of the tail. In dense populations mating frequency can be so high that females can be seriously injured in the caudal region by male courtship activity, which can cause death. This could explain strongly male-biased populations at some sites in Greece (Hailey 1990, 1991).

Fighting between males is common in *T. hermanni* (Cheylan 1981; Stubbs et al. 1981; Calzolari and Chelazzi 1991; Willemsen and Hailey 1999b). Males try to bite each other in the limbs and head, and bump with their carapaces. It often ends in one being tipped on its back; on a steep hill the loser can fall or roll a long distance and sometimes becomes seriously wounded. Except in these cases no serious damage was ever seen from fighting. Many of the fighting behavioral patterns are also seen in courtship.

Females often return to traditional nesting sites (Swingland and Stubbs 1985a). Nesting starts either at the morning or at the end of the day (Swingland and Stubbs 1985a; Fertard 1992), and can last from 40 min to 6 hrs. Females that start nesting in the morning are at risk of overheating and death. Females may stop nesting before egg laying starts when it becomes too hot during morning (Willemsen, pers. obs.). Nesting during evening can last long after sunset (Fertard 1992).

If *T. hermanni* is threatened, its behavior is passive defensive, by withdrawal of head and limbs within the carapace. However if the animal is on the edge of a ditch with dense vegetation, it will often try active defense, by disap-

pearing into it (Willemsen, pers. obs.). Struggling responses are relatively infrequent to mild handling in the field, but are given more often at higher body temperatures: 2–3% in males below 26°C rising to about 30% above 34°C (Hailey and Theophilidis 1987). Withdrawal into the carapace can be a possible indicator of wild origin of an animal, as its absence signals a captive-bred individual or an animal that has regularly been handled by a human being. However, after handling wild animals frequently over a long period they develop escape behavior (Willemsen, pers. obs.).

Predation. — At least 13 mammal and 13 bird species have been identified as predators of *T. hermanni* (Cheylan 2001). At the large immature and adult stage this predation is mainly by large birds of prey: *Aquila chrysaetos*, *A. heliaca*, *Haliaeetus albicilla*, *Gypaetus barbatus*, *Aegypius monachus*, and *Neophron percnopterus*. The Royal Eagle is the main consumer of tortoises in the Balkans (Andrinos 1987; Kouzmanov et al. 1996). According to Andrinos (1987), the raising of an eaglet causes the capture of around 90 to 100 tortoises. Predation by crows and gulls has been reported by several authors (López-Jurado et al. 1979; Joubert and Cheylan 1989; Beshkov 1993; Madec 1999; Nougarede 1998), mostly on juveniles. Predation by mammals concerns essentially eggs and young tortoises. The immature individuals are consumed on occasion by *Vulpes vulpes* (Chelazzi and Francisci 1979; Joubert and Cheylan 1989; Beshkov 1993), *Sus scrofa* (Carbone 1988; Beshkov 1993), *Canis aureus* (Beshkov 1993), *Mustela nivalis* (Beshkov 1993), and very likely by *Martes foina*, *Meles meles*, and *Mustela putorius*. In Provence, predation by domestic dogs is important, as revealed by the high percentage of wounded tortoises found in the wild (Cheylan 2001). Predation by rodents concerns essentially the winter period; the main predator is *Rattus rattus* (López-Jurado et al. 1979; Cheylan 2001) which can consume a whole hibernating tortoise. Predation on eggs has been observed in most regions (Swingland and Stubbs 1985a, b; Carbone 1988; Hailey and Loumbourdis 1990; Schweiger 1992; Beshkov 1993; Willemsen 1995; Nougarede 1998; Madec 1996, 1999; Hailey and Goutner 2002). It can affect 95% of nests in some areas (Swingland and Stubbs 1985b). This predation is mainly due to *Martes foina* and *Meles meles* and occasionally to *Erinaceus europaeus*, *Vulpes vulpes*, and *Sus scrofa*.

Diet. — The diet is mostly plants, to which can be added invertebrates, carrion, dung, feathers, and bones (Cheylan 2001). The studies of Meek (1989), Calzolari and Chelazzi (1991), Nougarede (1998), Budó et al. (2009), and Del Vecchio et al. (2011) give a glimpse of the consumed plants in Croatia, Tuscany, Corsica, Albaro, and Roma. Generally, *T. hermanni* consumes a large range of plants; 134 species belonging to 46 families have been identified. The preferred families are the Asteraceae (ex Compositae), Fabaceae (ex Papilionaceae), to a lesser extent Ranunculaceae, and occasionally Poaceae (ex Gramineae). Most of the consumed plants are annuals. Plants that are ligneous (trees, bushes, leathery vines), aromatic (e.g. *Thymus*, *Lavandula*, *Rosmarinus*, *Myrtus*, *Cistus*) resinous (e.g. *Pinus*, *Pistacia*,

Juniperus), milky (*Euphorbia*), or with hairy leaves (e.g. *Inula viscosa*, *Phlomis*) are generally rejected. On the other hand, *T. hermanni* actively seeks some plants that are toxic to mammals, such as *Tamus communis*, *Arum* sp., *Ranunculus* sp., *Digitalis* sp., and mushrooms. Longepierre and Grenot (1999) suggested that these plants are used to get rid of intestinal parasites. Fruits are appreciated as well: *Ficus carica*, *Morus* sp., *Opuntia*, grapes, medlars, *Arbutus unedo*. To this list are added mushrooms (*Boletus* sp., *Inocybe heimii*, *Sciurus mediterraneensis*), algae, cyanobacteria (*Nostoc* sp.), snails (*Helix aspersa*, *Eobania vermiculada*), various invertebrates (Coleoptera, Diplopoda) as well as feces from various species (dogs, foxes, humans) which seem to be appreciated for the hair and bone fragments or moisture that they contain.

Activity Rhythms. — The distribution area of *T. hermanni* can be divided into a region with a hot Mediterranean climate (Greece, southern Italy, France, and Spain), and a region with a cooler climate (Serbia, Montenegro, Kosovo, Bulgaria, Romania and north Italy) or at higher altitudes.

The activity patterns in the hot Mediterranean region are described by Cheylan (1981), Stubbs et al. (1981), Willemsen (1991), Huot-Daubremont and Grenot (1997) and Bertolero (2002). Hibernation ends, depending on weather conditions, in February or March, with full activity in the second half of March, but only on sunny days. Activity is unimodal until the last part of May, towards the end of which activity decreases after noon. During the summer months the activity pattern is bimodal, starting early in the morning (from 0500 hrs standard time). On hot summer days tortoises soon disappear after they have reached their optimal temperature, before noon. Evening activity starts again about 1600 hrs and ends shortly after sunset. During summer *T. hermanni* is often more active during evening than during the morning. After August the activity pattern is again unimodal; it starts later in the morning and ends earlier than in spring, and the number of active tortoises is lower. Juveniles have a similar activity pattern to adults, but their daily activity period is shorter. Hibernation starts in late October or November and finishes in February in Greece, the Ebro Delta (Spain) and Provence (France).

In the cooler regions activity often remains unimodal during the summer (Cruce and Răducan 1975; Meek 1988a; Hailey et al. 1984; Mazotti et al. 2002), but on hot days it may stop about noon or become bimodal (Willemsen 1990). In southern Greece at an altitude of about 1300 m the activity is unimodal in summer. Hibernation occurs from October or November to the end of February or April (Haxhiu 1995; Mazotti et al. 2002); it starts later in Italy than in Greece (D. Ballasina, pers. comm.), but there is little difference in the end of hibernation between cooler and hot regions.

Cruce and Răducan (1975), Artner and Artner (1997), (Cheylan 2001) and Bertolero (2002) found differences in activity patterns between females and males. In Greece and in Spain samples were more female-biased during the nesting season and more male-biased during autumn (Willemsen, unpubl. data; Bertolero 2002).

During the active season *T. hermanni* is not always active; individuals were only active on 67% of days during the active season (Hailey 1989), and only 10–30% of individuals were active at any given time (Hailey 1988). At most Greek sites, activity of adult tortoises decreases after late spring and increases again in autumn. In France, Huot-Daubremont and Grenot (1997) found in semicaptivity that 52% of tortoises were active daily from March to April, 94% from May to August, and 79% from September to October.

Body Condition. — Body mass condition can be assessed using the ratio of observed mass, M , to that predicted from the allometric relationship with body length, M' (separately for males and females, as their shape differs). The index $\log(M/M')$ gave the best performance in Greek populations (Hailey 2000b). In the field this ranged from about -0.1 to +0.1 (80–120% of predicted mass), and varied seasonally, being lowest after emergence from hibernation, maximal in spring (April–June), and decreasing in autumn; details differed between males, females, and immatures (Hailey 2000b). The pattern also varied with region and habitat, with a steeper and later peak in northern Greece, and a greater summer decline at xeric sites (Willemsen and Hailey 2002). Captive individuals in northern Europe showed a later peak of condition, in summer rather than in spring, and body mass condition can be used to identify captive individuals or collections in poor health (Willemsen et al. 2002). An online condition calculator for *T. hermanni* is available at <http://www.ahailey.force9.co.uk/cond.htm>.

Parasites. — External parasites are mainly represented by ticks, frequent on individuals in the Balkans (Kopstein and Wettstein 1921; Nöllert and Nöllert 1981; Hailey et al. 1988; Zlatanova 1991; Široký et al. 2006) but scarcely found in the western populations (Cheylan 2001). In Bulgaria, Zlatanova (1991) and Široký et al. (2006) identified 6 species: *Hyalomma aegyptium*, *Hy. marginatum marginatum* (indicated as *Hy. plumbeum* by Zlatanova [1991]), *Hy. anatolicum excavatum*, *Haemaphysalis sulcata*, *Ha. inermes*, and *Ha. erinacei taurica*. The most frequent is *Hy. aegyptium*, found in Greece, Bulgaria, and Corsica (Matsumoto et al. 2004; Široký et al. 2006).

Internal parasites are mainly represented by nematodes; Pharyngodonidae (14 taxa) and less commonly by Atractidae (2 taxa); up to 16 taxa were identified in the caecum of individuals from several localities (Petter 1966; Longepierre and Grenot 1999; Bouamer and Morand 2002; Gagno 2002; Traversa et al. 2005). Longepierre and Grenot (1999) observed that parasitized individuals actively consumed toxic plants with a high laxative effect, such as Ranunculaceae, Poaceae, and Asteraceae.

Population Status. — *Testudo hermanni* is strongly declining in most of its distribution range (Cheylan 1984, 1995; Ballasina 1995; Willemsen and Hailey 1989; Llorente et al. 2002; Mazotti 2006). The historic and archaeo-zoological data indicate that this decline started very early in antiquity, notably in France and in Spain, where the species previously inhabited a large part of the Mediterranean coast (Cheylan 1981; Fèlix et al. 2006; Morales and Sanchis 2009). The

majority of the remaining populations in France, Spain, and Italy are highly scattered and most are declining. The status of populations in the Balkans appears to be better, but little information is available for these regions. Evidence of decline has however been demonstrated in Greece (Willemsen and Hailey 1989; Willemsen 1995; Hailey and Willemsen 2003) and in Bulgaria (Petrov 2007).

Bulgaria. — The species is endangered in Bulgaria, with rapid population decline from collection for consumption and trade; ca. 200–400 are confiscated annually from poachers and merchants (Petrov 2007). The species was formerly very common, and widely distributed, apart from high mountain plateaus, but populations are now isolated and depleted (Beshkov 1993; Petrov 2007).

France. — The species used to inhabit the entire French Mediterranean region in prehistoric times and undoubtedly in historic times as well (Cheylan 1981; Hervet 2000). By the end of the 19th century, it only inhabited two very small areas: the eastern tip of the Albera Massif in Roussillon and the Massif des Maures and the Massif de l'Estérel in Provence. The population in Roussillon disappeared in the 1960s, and the population in Provence has decreased greatly and become more fragmented (Cheylan et al. 2009). At the present time, the population in Provence inhabits about 337 km², in 29 separate core areas. The largest population is at present located in the Plaine des Maures, where recent estimations (2006–08) indicate 37,000 individuals (range 29,680–49,480), giving an average density of 6.3 turtles/ha (Cheylan et al., unpubl. data).

On Corsica, the situation is more stable, with five core areas. The populations generally show a good level of recruitment and demographic dynamism and are not endangered in the short or medium term.

Greece. — The species is widespread throughout Greece, though it is progressively replaced in many habitats by *T. graeca* towards the northeast and the border with Turkey (Wright et al. 1988). Hermann's Tortoise remains common in Greece, although about a third of the populations can be regarded as being immediately threatened by catastrophic decline, and another third have declined in the past or are liable to long-term decline (Willemsen and Hailey 1989). The most threatened populations tend to be coastal and the least threatened are in mountainous areas. Habitat loss is currently the greatest threat (Hailey and Willemsen 2003); habitat degradation affects juveniles in particular (Hailey et al. 1988; Hailey 2000a).

Italy. — In Italy the distribution of *T. hermanni* is scarce and scattered, with most populations in the Tyrrhenian area (Mazzotti 2006; Cheylan et al. 2010). It is found in large regions of southern Tuscany (Ballasina 1995; Willemsen 1990; Ballasina and Willemsen 1990), but most populations are at low densities. All populations were depleted by collecting in the past, which was banned after 1980 and today has mostly ceased. Many juveniles and subadults were found in 1990, showing that legal protection had benefited the species (Willemsen 1990). Subsequently the wild boar (*Sus scrofa*) population has grown strongly and the number of tortoises

has decreased (Mazzotti 2004); most adults have marks of wild boar attacks, and since 2001 almost no juveniles have been found (Willemsen, unpubl. data). All populations in southern Tuscany can be considered as endangered by this threat. Several populations are found in Latium (Bruno 1981; Frisenda and Ballasina 1990; Ballasina 1995, 1996; Cheylan et al. 2010). Some of these populations are in protected areas, and are not threatened. In Abruzzes, Fabrizio (1992) noted that only one population had survived and it was considered as vulnerable then; no further data are available, so its current status is unknown. In Ferrara, in the delta of the River Po one population occurs in a protected area, but it is not clear if it is introduced (Mazzotti and Stagni 1993; Mazzotti et al. 1999); it is not considered to be threatened. Scattered populations are found on the coast of Veneto and near Trieste (Cheylan et al. 2010).

Ballasina (1995, 1996) stated that *T. hermanni* was extinct in Liguria; Jesu (1994) found some individuals, but these could have been introduced animals. In Campania it is likely that *T. hermanni* is extinct in most of its former area. Near Naples some populations survive (Ballasina 1995), but could be introduced animals; it is likely that they are all endangered. In Calabria *T. hermanni* has disappeared from most of its former distribution area but is still found along the Gulf of Tarent (Ballasina 1995, SHI 1996), where populations are all endangered. In Apulia *T. hermanni* was found in rather dense populations of very small adults (Willemsen 1990), which were decreasing fast due to illegal collecting (Frisenda and Ballasina 1990). All of these populations are considered vulnerable. In Molize the status must be considered as vulnerable; Bruno (1971) and Ballasina (1995) stated that the species was locally extinct, but Bruno and Guacci (1993) found a population.

On the island of Elba *T. hermanni* was common during the 19th century (Lortet 1887), but Sochurek (1954), Stemmler (1968b), and Ballasina (1995) stated that the species was extirpated. However, in 1999 W.E. Engelmann found one free-living tortoise (Cheylan 2001). In spite of this single observation, which could be an introduced animal, the species can be considered as locally extinct. On Sicily *T. hermanni* is common in the north and southeast coastal regions (SHI 1996). On Sardinia the species was recently found to be common in the north and northwest (Stemmler 1959; Tiedemann 1978; Ballasina 1995; Fritz et al. 1995, 1996). According to Bruno (1986) it was also common in the center of Sardinia and also found in the south (Stemmler 1959; SHI 1996). It is also found on the small islands around Sicily, Sardinia and near Tuscany, but it is not clear if these populations were introduced (Stemmler 1968a; Tortonese and Lanza 1968; Lanza 1973; Tiedemann 1978; Ballasina 1995).

Romania. — Hermann's Tortoise in Romania is restricted to the southwest of the country, where its distribution extends over nearly 4400 km² (Rozyłowicz and Dobre 2009). However, this distribution includes a high proportion of unfavorable habitats and only 668 km² are actually occupied and have favorable habitats (Rozyłowicz and Dobre 2009). In

the 1970s Cruce (1978) estimated a density of 44.5 tortoises/ha in Coșuștei Hills and, more recently, Rozyłowicz (2008) estimated 12 tortoises/ha in Almăj and Mehedinți Mountains. The species has shown a strong decline owing to habitat loss, human activities, increase of fire frequency and, perhaps, climate change (Rozyłowicz and Dobre 2009).

Spain. — On the Spanish mainland, the population of Hermann's Tortoise in Albera (eastern Pyrenees, Catalonia) is the most threatened in the whole range of *T. h. hermanni*. This population shows a marked decline principally due to forest fires (Fèlix et al. 1989), habitat destruction and degradation, illegal collecting, increased numbers of predators (carnivores and wild boars) and high rates of nest predation (Budó et al. 2002, 2005). The areas of occupancy have contracted and now cover less than 150 km², within which some subpopulations are fragmented. An overall density is estimated at less than 0.3 tortoises/ha (Bertolero 2007).

In the Balearic Islands the situation is better and there are very good populations of Hermann's Tortoise. On Majorca two main populations persist, surrounded by some small and declining populations. On Minorca the species occupies most of the island with a patchy distribution, and in some localities the densities are high or very high (more than 30 adults/ha in some small areas) (Bertolero 2006; Bertolero and Pretus, in press). Some of these populations have a high proportion of juveniles and subadults relative to adults, indicating good recruitment.

Other populations in Spain (Ebro Delta, Garraf, and Montsant in Catalonia; Serra d'Irta in Valencia) are the result of reintroduction programs in natural parks (see below). Another population estimated at 400 individuals has been recently discovered near Marçà in Catalonia (E. Soler, pers. comm.). This population is probably formed by individuals escaped from captivity or from uncontrolled releases. Genetic analysis using mitochondrial genes (cytochrome *b* and 12S rRNA) indicate that they have the same haplotypes as populations from Albera and Minorca (Carranza and Roca 2007).

Threats to Survival. — Threats to *T. hermanni* can be divided into two categories; those impacting its habitat, leading to permanent or temporary loss or degradation; and those acting solely on individuals without affecting habitats. These threats are not specific to tortoises, but when they impact small populations, they promote decline by increasing their susceptibility to stochastic and catastrophic events (McDougal 2000).

Habitat loss and degradation is mostly related to development and the spread of urbanization, linked to a strong increase of human population in some areas (e.g. more than 44% over 10 years in southern France, INSEE). Another cause of habitat degradation is forest fires (Cheylan 2004), which caused the disappearance of tortoises from the Massif de l'Estérel, Albères, and Corbières in France at the end of the 19th century (reviewed in Cheylan 1984). Mortality from fires can reach between 50 and 85% of adults in France (Cheylan 1984), 30.4% for all age classes in Spain (Fèlix et al. 1989) and 5.9–37.3% of sexable individuals in Greece

(Hailey 2000a). The mortality of the juveniles is higher than adults, but more difficult to estimate. In southern France, 55% of the historical area of distribution of the species has burnt at least once since 1965, and there is a strong negative correlation between the abundance of individuals and the history of forest fires (Cheylan 1984). Climate change should increase forest fires in southern France, Spain, Greece, and the Balkans, because of drier summers. In some mountainous parts of the area of distribution, the disappearance of traditional activities such as exploitation of oak trees and heather, livestock, and charcoal, have caused gradual forest closure and have probably impacted tortoise populations negatively. As open spaces disappear, nests become concentrated in a few spots where predation on eggs and juveniles can be very high (Madedec 1999).

Collecting for the pet trade is probably the greatest threat acting on individuals, and mostly impacts adults. Although many campaigns have tried to sensitize the general public, collection of wild individuals has never stopped, most of the time being purely opportunistic or accidental. There is a strong positive correlation between the volume of public visits to a site and the rarity of tortoises there (Budó 2002). Loss of tortoises is also linked to overpopulation of predators in some areas, especially boars and perhaps stone martens.

Genetic problems are poorly known within each subspecies. In Var, France, recent genetic studies have noted the high homozygosity of the populations (Bertorelle et al. 2007). Hybridization between subspecies is mostly related to captive breeding, with admixed individuals thereafter released in the wild (up to 6% in southern France; Bertorelle et al. 2007). Within the subspecies *T. h. hermanni*, no study has been implemented so far to estimate the flow of individuals between France and Corsica, although anecdotal reports of translocations have been recorded. This could have some impact on the mainland populations, as recent genetic studies have concluded that mainland French and Corsican tortoises constitute two different genetic entities (Fritz et al. 2006).

Diseases have not been studied in the wild in this species. In captivity, herpesviruses imported by *T. graeca* can cause important mortality in *T. hermanni* (SOPTOM, unpubl. data). Infection by exotic parasites could also decrease the fitness of indigenous tortoises, but more studies are needed to confirm this hypothesis. A precautionary principle is recommended, especially for reintroduction or release programs.

Conservation Measures Taken. — Hermann's Tortoise is under the following general legislative protection: CITES (Appendix II for outside the European Community and Appendix A for within the European Community; Council Regulation [EC] No. 338/97); Habitat Directive (Annexes II and IV); Bern Convention (Annex II). In addition to this general legislation, the species is also protected by specific legislation in the following countries: Bulgaria, Biological Diversity Act (Annex 2); France, Ministerial Decree of 19 November 2007 (article 2); Spain, Royal Decrees 439/1990, 1997/1995 (Annex IV), 1193/1998 (Annex II), Laws 3/88 and 12/2006 of the Government of Catalonia (Annex II),

Decree 32/2004 of the Government of Valencia, Decree 75/2005 of the Government of the Balearic Islands.

The species is included on the IUCN 2010 Red List as Lower Risk/near threatened (LR/nt), assessed in 1996, but needing updating. At present subspecies are not included on the IUCN Red List. The IUCN 2009 European Red List of Reptiles (Cox and Temple 2009) also listed the species as Near Threatened (NT).

Practical conservation measures have mostly been undertaken where the species is most vulnerable: in the western subspecies in France, Spain, and Italy, and in the eastern subspecies at its northern limit in Romania.

France. — In the new French national Red List (IUCN France et al. 2009), Hermann's Tortoise is classified as Vulnerable, with the Var population assessed as Endangered.

For years, the only sustainable protection has been achieved by NGOs (Conservatoire d'Espaces Naturels de Provence-Alpes-Côte d'Azur [CEEP], SOPTOM) and Government (Conservatoire du Littoral) through acquisition of land. Since 2008 two reserves have been created to protect the species and its habitats: a national reserve in Plaine des Maures and an integral reserve in Massif des Maures. The Natura 2000 network in Var started to be established in Plaine and Massif des Maures, and in some other areas (e.g. Callas, Argens), and should encourage adaptive management of natural and agricultural spaces. Another set of actions have been implemented by several NGOs (e.g. Société Nationale de Protection de la Nature [SNPN]) to advocate against the destruction of important populations by urbanization and infrastructure development. Several projects are currently being promoted, encouraged by the launch of the first National Action Plan for Hermann's Tortoise (Cheylan et al. 2009).

An acknowledged cause of destruction of individuals is related to the lack of awareness of the endangered status of the species, and a lack of concern by most of the general public. Information for the public has been widely spread during the past 20 years by SOPTOM Tortoise Village in Gonfaron, but the message of Hermann's Tortoise being a wild animal has been somewhat discredited by ongoing private captive breeding and trade.

In 1975–77 a reintroduction program was implemented in the National Park of Port-Cros, but did not succeed in establishing a viable population (Cheylan 1983). Between 1986 and 1998, SOPTOM also released several thousand captive tortoises, but only with occasional follow up (Devaux 1990, Devaux and Stubbs 1997, Culorier-Cornuault et al. 2006). Censuses in 2001–05 concluded that less than 4% of these released animals were still observable in the wild, and very few of them remained in protected areas (Livoreil 2007). Thus, the release of *T. hermanni* in Var may encounter some unexpected difficulties, while it has been successful in Spain (Bertolero et al. 2007d).

Romania. — The Romanian national population has recently been classified as Endangered (Rozyłowicz and Dobre 2009). A portion of its habitat is protected in Iron Gates Natural Park and in three other Natura 2000 sites. From 2001–04 the conservation and management of habitats

occupied by tortoises have benefited from a LIFE project funding in Iron Gates Natural Park.

Breeding in captivity for conservation programs is carried out at the Centre for Hermann's Tortoise Captive Breeding in Eşelnița (Mehedinți). This center also recovers individuals harvested or sold illegally and reintroduces them into suitable habitats (Rozyłowicz and Dobre 2009). Awareness campaigns are carried out in schools and in the media for the general public to explain the importance of the species and its problems.

Spain. — For the new edition of the *Catálogo Nacional de Especies Amenazadas*, *T. h. hermanni* has been proposed as Endangered (modification of the Royal Decree 439/90, Government of Spain). In the national Spanish Red Book it is classified as Endangered (Pleguezuelos et al. 2002) and in the Balearic Islands Red Data Book it is classified as Near Threatened (Viada 2006).

The habitats of Hermann's Tortoise in Spain are partially protected in Albera and the Balearic Islands. In Albera the area protected has recently been increased and the Natura 2000 site now includes most of the current distribution range. In the Balearic Islands, 23 localities of this species are included in the Natura 2000 network, but most of the distribution is outside of the reserves. Most of the reintroduced populations inhabit protected areas such as natural parks.

To increase the number of populations in mainland Spain (compared to only one at the end of the 1980s) the managers of the Ebro Delta Natural Park launched a conservation introduction project in 1983. Although there are no data on the former presence of *T. hermanni* at the site, the Ebro Delta Natural Park is within its historical range (Bertolero and Martínez Vilalta 1994). The individuals released since 1987 now form a self-sustaining viable population (Bertolero 2002; Bertolero and Donoyan 2002). Other reintroduction projects in Spain started later: 1022 tortoises were released in the Garraf Natural Park from 1993 to 2005 (Soler et al. 2002; Soler and Martínez Silvestre 2005); 679 tortoises were released in the Montsant Natural Park (Catalonia) from 2005 to 2008 (Soler and Martínez Silvestre 2008); and 124 tortoises were released in Serra d'Irta Natural Park (Valencia) in 2005, and the project continues. The Government of the Balearic Islands and some NGOs have carried out several translocations and reinforcements in Majorca and Minorca since the 1980s. The Grup d'Ornitologia Balear (GOB) has collected thousands of tortoises kept in captivity by islanders and has released them in the wild, mostly in Minorca. These tortoises are screened by veterinarians before their reintroduction and released in localities where densities of tortoises are presumed to be low. Nevertheless, other projects have not obtained the same success. An introduction project launched in the Cap de Creus Natural Park (Catalonia) in 2000, and one started in the Desert de les Palmes Natural Park (Valencia) in 2002 both had unsuccessful results, and were discontinued by their managers (Bertolero 2010).

Among the conservation actions carried out in Spain, management of captive populations and breeding programs

have played a decisive role in the improvement of Spanish populations by means of reintroduction and reinforcement programs. Most of these have been accomplished in Catalonia: the Centre de Recuperació d'Amfibis i Rèptils de Catalunya (CRARC-COMAM), in Masquefa, and the Centre de Reproducció de Tortugues de l'Albera (CRT), in Garriguella, initiated their own projects in 1988 and 2002, respectively, and a new breeding center was created in Marçà in 2007. The CRT captive breeding program works exclusively on tortoises coming from the Albera population and provides juveniles for the reinforcement of this wild population. The CRARC-COMAM manages the captive population for several reintroduction projects in Catalonia and coordinates breeding programs carried out by private citizens under the authorization of the Government of Catalonia. In addition, CRT, CRARC-COMAM, and GOB conduct educational programs and campaigns to promote the concept that Hermann's Tortoise (as well as other species of chelonians) is an endangered wild species and not a pet or a garden animal.

Conservation Measures Proposed. — We believe that it is necessary to update the IUCN Red List status of the species and to include the subspecies. However, the large range of distribution, the very different conservation situations and the level of knowledge of each population make this task very difficult. At the specific level, we consider that the present category of Lower Risk/near threatened (LR/nt) should remain the same (but now rendered by IUCN simply as Near Threatened). Many populations (both eastern and western) are currently in decline, their habitat is more fragmented or degraded and the numbers of predators of nests and juveniles are increasing. At the subspecific level, we would assess *T. h. hermanni* as Vulnerable, as it meets the following Red List criteria: VU A2abc+4abc; B1ab(i,ii,iii,v). We would assess *T. h. boettgeri* as Near Threatened because we believe that this subspecies does not reach any Red List criteria of threat and remains widespread. However, for both subspecies some local populations may be classified as Endangered. This is the case of at least the populations of Albera (Spain), Maures (France), most Italian populations, and the entire Romanian range.

Captive breeding is not a priority over most of the species' range. Captive breeding programs may be necessary for the most threatened populations only if these are carried out with local tortoises (e.g. Albera, some Italian populations, Romania). Genetic and sanitary controls are required, but releases in the wild are not a priority until suitable areas are protected for the long term and population dynamic studies have shown the need for supplementation of individuals or reintroductions. The ability of released animals to survive and reproduce seems to be clearly affected by the quality of the habitat. Headstarting would be easy to implement as juveniles are easy to obtain, but the high mortality of such animals does not ensure success in the long term, as one has to wait about 10 years to estimate the survival and reproductive abilities of these individuals. Releases of subadults or adults may seem more appropriate as they should be more resistant

to predation. Yet, the numerous years spent in captivity may seriously affect their behavior and survival abilities as captive breeding centers do not offer habitats comparable to the wild (e.g., for size of home range, diversity of microhabitats, diversified diet). More studies would be needed to assess limiting factors on such programs. Currently, given that natural spaces are preserved, support of natural populations through appropriate management of habitat may be a better investment than captive breeding and reintroduction.

Habitat restoration and improvement are needed in some areas where populations are in decline. Forest and *maquis* closure may be a threat for some populations, as is the case in Albera. The recovery of pastoral practices is necessary to keep habitats open and create landscape heterogeneity. It is also important that no further development impact or fragment the shrunken habitats still occupied by Hermann's Tortoises.

Greater educational efforts are needed in all European countries so that both children and adults are informed that Hermann's Tortoise is a wild and protected species. Control of wild boars is necessary in some regions of Spain, France, and Italy, where their increase is causing further decline of tortoises. Long-term studies on demography of *T. hermanni* are in progress in Spain; however, these also need to be carried out in other habitats and locations that could inform future regional conservation efforts.

Captive Husbandry. — Vetter (2006) provided complete information for care and breeding in captivity. Within the natural distribution range, tortoises are easily kept in captivity in outside enclosures. In cold climates they can live in outside enclosures with a greenhouse.

Captive breeding for conservation purposes was initiated 20 years ago at the SOPTOM Tortoise Village in Gonfaron, France, and is used today as an insurance program in case of major losses in the wild. In Spain there are insurance colonies in the CRT (Garriguella) and in the CRARC (Masquefa). In Italy the CARAPAX Centre (Massa Maritima) has been holding some Italian and other populations.

Current Research. — In France scientific research has been mostly related to educational studies and produced some important results on ecology, biology, population dynamics, and ethology. Much of this remains unpublished or in the gray literature, which limits its access and spread within the scientific community. The relationship between scientists and managers is favored by meeting and working groups, although communication is strongly needed to encourage mutual understanding of needs and limitations.

The introduced population in Ebro Delta Natural Park has been monitored since 1987 and is the longest project ever carried out on the species in Spain. This research continues to monitor the long term survival, the colonization process, and demography and ecology of the species (Bertolero 2002; Bertolero et al. 2007d). In the Balearic Islands, several populations have been monitored in Minorca since 2003 (Bertolero 2006), and population genetics and the connectivity in a fragmented landscape are being studied. Since 1994, the CRT has studied populations from Albera,

including the effects of fire (Franch et al. 2002) and habitat use (Vilardell et al. 2005). The most recent studies at this site are determination of the most important areas for tortoises (Vilardell et al. 2007), census and current distribution evaluated by occupancy estimation models (Bertolero 2007, 2008) and assessment of nest predation (Vilardell et al. 2008).

Acknowledgments. — We thank Laurențiu Rozyłowicz, Eduard Soler, and Donato Ballasina for providing information to the authors.

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Citation Format for this Account:

- BERTOLERO, A., CHEYLAN, M., HAILEY, A., LIVOREIL, B., AND WILLEMSEN, R.E. 2011. *Testudo hermanni* (Gmelin 1789) – Hermann's Tortoise. In: Rhodin, A.G.J., Pritchard, P.C.H., van Dijk, P.P., Saumure, R.A., Buhlmann, K.A., Iverson, J.B., and Mittermeier, R.A. (Eds.). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs No. 5, pp. 059.1–059.20, doi:10.3854/crm.5.059.hermann.v1.2011, <http://www.iucn-tftsg.org/cbftt/>.