Herpetological Conservation and Biology 13(3):673–690.
Submitted: 1 September 2017; Accepted: 7 July 2018; Published: 16 December 2018.

Why an Apparently Prosperous Subspecies Needs Strict Protection: The Case of *Testudo hermanni boettgeri* From the Central Balkans

Sonja Nikolić[1], Ana Golubović[1], Xavier Bonnet[2], Dragan Arsovski[2], Jean-Marie Ballouard[3], Rastko Ajtić[4], Bogoljub Sterijovski[5], Vuk Iković[6], Ana Vujović[7] and Ljiljana Tomović[1,8]

[1]*University of Belgrade, Faculty of Biology, Institute of Zoology, Studentski trg 16, 11000 Belgrade, Serbia*
[2]*UMR 7372, Centre National de la Recherche Scientifique Université de La Rochelle, Centre d'Etudes Biologiques de Chizé, 79360 Villiers-en-Bois, France*
[3]*Station d'Observation et de Protection des Tortues et de leurs Milieux (SOPTOM), 1065, Route du Luc F-83660 Carnoules, France*
[4]*Institute for Nature Conservation of Serbia, 91 Dr Ivana Ribara Street, 11070 Belgrade, Serbia*
[5]*Macedonian Ecological Society, 10 Vladimir Nazor Street, 1000 Skopje, Macedonia*
[6]*Montenegrin Ecologists' Society. 73 Svetog Petra Cetinjskog, 81000 Podgorica, Montenegro*
[7]*Natural History Association of Montenegro, Pažići, 81410 Danilovgrad, Montenegro*
[8]*Corresponding author, e-mail: lili@bio.bg.ac.rs*

***Abstract*.—According to the International Union for Conservation of Nature (IUCN), more than half of all chelonian species are seriously threatened. Habitat loss and illegal trade contribute substantially to this trend. Rare and vulnerable taxa often enjoy formal protection while taxa with large populations are usually neglected, despite worrying trends. The two subspecies of the Hermann's Tortoise (*Testudo hermanni*) present a good example of this contrast: the western subspecies (*T. h. hermanni*) is rare, while the eastern conspecific (*T. h. boettgeri*) is still relatively common in appropriate habitats. The IUCN lists the entire species as Near Threatened. In practice, the western subspecies is treated as endangered, while the assessment of the conservation status of the eastern counterpart is still lacking. Using field data collected from five populations of *T. h. boettgeri* in three Balkan countries, we aim at filling this gap. Population Viability Analyses (PVAs) suggest that even large and dense populations inhabiting favorable environments could face extinction by over-harvesting in a matter of years. Natural causes (e.g., higher female mortality) or stochastic events (e.g., wildfires) could be detrimental to peculiar isolated populations. The uncertain viability of the studied populations casts considerable doubt over the apparent stability of *T. h. boettgeri*. For this subspecies to avoid the fate of its western cousin, we propose the upgrade of its IUCN category to Vulnerable throughout its distribution range.**

Key Words.—anthropogenic pressure; conservation status; Eastern Hermann's Tortoise; Population Viability Analyses (PVAs)

Introduction

More than one half of all modern chelonians are officially listed as Threatened by the International Union for Conservation of Nature (IUCN), which lists 148 of 356 species as Critically Endangered, Endangered or Vulnerable; seven species have recently gone extinct (Stanford et al. 2018). One major culprit, alongside habitat deterioration and loss, is illegal tortoise collection for trade or consumption (Auliya et al. 2016; Luiselli et al. 2016; Stanford et al. 2018). High chelonian sensitivity to human-induced stress (including trade) can be traced to their exceptional longevity and the associated life-history characteristics (Reznick et al. 2002). Chelonian population viability is particularly sensitive to the survival of the long-lasting adult stage (Hailey 1990; Hailey and Willemsen 2003; Couturier et al. 2014), especially in terrestrial tortoises (Hailey 1990; Miller et al. 2001; Bertolero et al. 2011). Even short-term disasters, or moderate persistent perturbations in annual fecundity and adult survival can lead to an imperceptible, yet irreversible tipping point towards extinction (Jonsson and Ebenman 2001; Shoemaker et al. 2013; Badiane et al. 2017). Therefore, the assessment of population extinction risk under various circumstances across chelonian distribution ranges underlies any reliable forecast of the consequences from possible long-term perturbations (viz. collection for the pet trade).

According to the IUCN Red List (assessed in 2004) the Hermann's Tortoise (*Testudo hermanni*) is Near Threatened. Because its populations are in significant

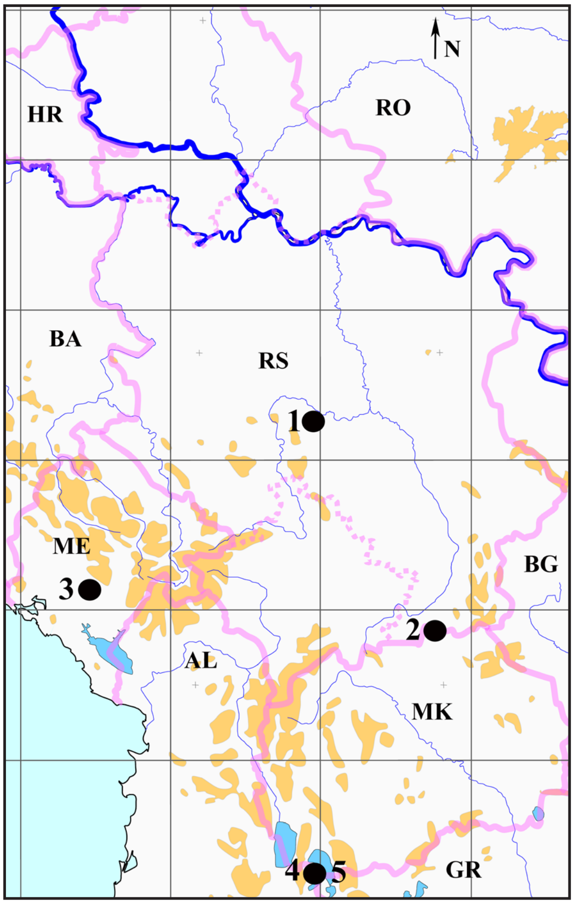

Figure 1. Study sites for the eastern subspecies of the Hermann's Tortoise (*Testudo hermanni boettgeri*): 1 - Trstenik, 2 - Pčinja River valley, 3 - Danilovgrad, 4 - Konjsko village, and 5 - Golem Grad Island, Country abbreviations are: RS - Serbia, HR - Croatia, RO - Romania, BG - Bulgaria, MK - Macedonia, GR - Greece, AL - Albania, ME - Montenegro, and BA - Bosnia & Herzegovina.

decline, it has been acknowledged that the species is close to qualifying for Vulnerable (van Dijk et al. 2004). During the past decade, the necessity to upgrade the conservation status of the *Testudo hermanni* and its two subspecies has been suggested at several occasions (Rozylowicz and Dobre 2010; Bertolero et al. 2011; Đorđević and Ljubisavljević 2015). The two subspecies differ markedly in their threat level and conservation status. The nominotypic (western) subspecies (*T. h. hermanni*) is a taxon of high conservation and education interest (Lepeigneul et al. 2014) and recognized as a flagship species with a high public profile (Livoreil 2009). It is regarded as one the most threatened reptiles in Western Europe (van Dijk et al. 2014; Zenboudji et al. 2016; Badiane et al. 2017) and therefore classified as Endangered in Spain, France, and Italy (Luiselli et al. 2014; Vilardell-Bartino et al. 2015), as well as at the international level (European Reptile and Amphibian Specialist Group 1996). In contrast, the eastern subspecies (*T. h. boettgeri*) does not benefit from a strict conservation status according to international criteria, whereas the IUCN states that field assessments of conservation status are highly desirable (van Dijk et al. 2004; Bertolero et al. 2011; Ljubisavljević et al. 2011, 2014).

Population viability simulations are a relatively rigorous tool used in species conservation offering insight into population dynamics with cascading effects on policy making. Nevertheless, they require data that are often hard to obtain (Akçakaya and Sjögren-Gulve 2000; Brook et al. 2000) making long-lived species with elusive life stages and high inter-population variability in life-history traits a particular challenge for researchers and conservationists (Willemsen and Hailey 1999; Pike et al. 2008). Although mathematical simulations based on limited information are merely approximations and extrapolations of the available data, and their repeatability is often questionable, they are necessary in assessments of population dynamics and useful in deciding on management strategies (Morrison et al. 2016). Their accuracy and reliability strongly depend on the quality of input data, i.e., precision in population parameter estimation and conservation rely heavily on intense field effort and a systematic approach (Morrison et al. 2016). In this study, we aimed to: (1) present basic demographic data for five populations of the *T. h. boettgeri* from the central Balkans (Serbia, Montenegro, and Macedonia); (2) apply Population Viability Analyses (PVA) on our field data and published data to evaluate viability probabilities of populations under various natural or human-imposed stresses, and (3) provide overview of the legal protection and conservation status of the subspecies in all countries of the Balkan Peninsula and re-asses its global conservation status according to IUCN criteria.

Materials and Methods

Study sites and field procedure.—Between 2008 and 2013, we conducted Capture-Mark-Recapture (CMR) surveys on five populations of *T. h. boettgeri* in Serbia (two populations), Montenegro (one population) and Macedonia (two populations; Fig. 1). Study sites differ in surveyed area, degree of urbanization, site protection status and identified (observed and/or reported) threats (Table 1). We searched for tortoises during the daytime by walking transects through the sites, with unbalanced search effort (51–1,330 person-days). We assessed the sizes of surveyed areas with Google maps (www.daftlogic.com/projects-google-maps-area-calculator-tool.htm). The insular population (Golem Grad) is naturally restricted to 20 ha, whereas the one in Danilovgrad is artificially cut off and restricted to 4.3 ha.

The remaining three sampled populations occupy parts of large areas of suitable habitats, without obstacles to tortoise movements.

We permanently marked all captured individuals by notching their marginal scutes, following the standard procedure (Stubbs et al. 1984). We determined sex using tail length (Willemsen and Hailey 2003) and recorded straight carapace length (SCL) to 1 mm and body mass (BM) to 1 g (Djordjević et al. 2011). We assigned individuals to three age classes: adults (SCL ≥ 13 cm for males and SCL ≥ 15 cm for females), juveniles (SCL < 10 cm), and sub-adults (intermediate SCL; Willemsen and Hailey 1999). We also assessed their approximate ages by counting growth rings on carapacial scutes (Bertolero et al. 2005). Males and females were considered sexually mature at nine and 11 y of age, respectively (Hailey 1990). Using the number of growth annuli for chelonian age determination is reliable for juvenile and sub-adult animals; rings narrow with age and in mature individuals, rings eventually become hardly distinguishable (Wilson et al. 2003; Bertolero et al. 2005; Arsovski et al. 2018). *Testudo hermanni* can live upwards of 50 y, therefore we thought it reasonable to classify individuals with very worn shells as > 25 y. On Golem Grad island, we determined age of all individuals when possible, the oldest being 17 y, and the numbers of individuals for which we could determine age reduced dramatically after the age of 12 y (Table 1 in Arsovski et al. 2018). Our data did not allow for robust population size and density estimations; hence we only calculated the densities of marked individuals in their respective sites.

Population Viability Analyses (PVAs).—We used the VORTEX software (version 10.1., Lacy and Pollak 2014) previously used on chelonian data including *Testudo hermanni* (Miller et al. 2001; Hailey and Willemsen 2003). Instead of testing a wide spectrum of scenarios to account for many possible demographic and conservation scenarios, we used actual field data, and where appropriate, we implemented realistic, site-specific threats. We compiled demographic traits used in all VORTEX simulations from our field data and from literature (Table 2; Hailey and Loumbourdis 1988; Hailey 1990; Willemsen and Hailey 2003; Bertolero et al. 2011; Couturier et al. 2014). First, we modeled scenarios under baseline conditions without threats to assess the future of the observed populations if nothing dramatic occurs. Then we modeled several additional scenarios taking respective observed threats (Table 1) into account. As initial population sizes, we used the exact numbers of marked individuals in each sampled population. To assess carrying capacities, which can be defined as the maximum number of individuals that the environment can sustain over time in the absence of unnatural disturbances (Lacy et al. 2014), we scaled carrying capacities (K) against the most thoroughly sampled (1,330 person-days) and densest population (1,733 individuals) on Golem Grad Island (20 ha), where both catchability and survival rates are very high (Bonnet et al. 2016). We set all standard deviations of K at 10% of K (Willemsen and Hailey 2003; Lacy et al. 2014).

Because we could not determine accurately the age of all individuals (especially older specimens), we used both accurate (e.g., young individuals marked soon after hatching) and broad age classes to assign individuals to main age categories, allowing us to apply the Specified Age Distribution (SpAD). Circumventing this step leads to the automatic and unrealistic assignment generated by the alternative Stable Age Distribution option (StAD; e.g., assuming up to 80% of immature individuals). For each population, simulations were set at 100 and 1,000 y. The former was chosen according to the ranking criteria of the IUCN for listing endangered species (IUCN 2014). Nevertheless, 100 y are likely insufficient to assess population viability in a species where individual longevity can exceed 50 y and generation time is about 20 y (Hailey 1990; Shoemaker et al. 2013; Reed and McCoy 2014). Therefore, to follow the recommendations of Hailey and Willemsen (2003) and Reed and McCoy (2014) on running PVAs for Greek populations of *T. h. boettgeri* and other chelonians, respectively, we also performed 1,000-y simulations.

For selected populations, we simulated realistic but possibly underestimated disturbances and catastrophes. For Trstenik we introduced a harvest of 200 adult individuals (150 females and 50 males) every 3 y; this is the current officially allowed quota for tortoise collection from the wild (Official Gazette of the Republic of Serbia 2010). In Danilovgrad we simulated wildfires at 50%, which is one every other year that we estimate is a severe underestimation (see Vujović et al. 2015). For the insular population we checked the inbreeding option (default values) at first run and increased adult female mortality to subadult mortality level (as in Willemsen and Hailey 2003) for a second run. We repeated all scenarios with disturbances 100 times (iterations). Simulations were not run as population-based models. We left the correlation of Environmental Variation (EV) between reproduction and survival at the default value.

National and global conservation status.—To get an insight into the conservation status of *T. h. boettgeri* across its distribution range in the Balkans, we reviewed available literature of articles published in various journals, national legal acts, national Red Lists or Red

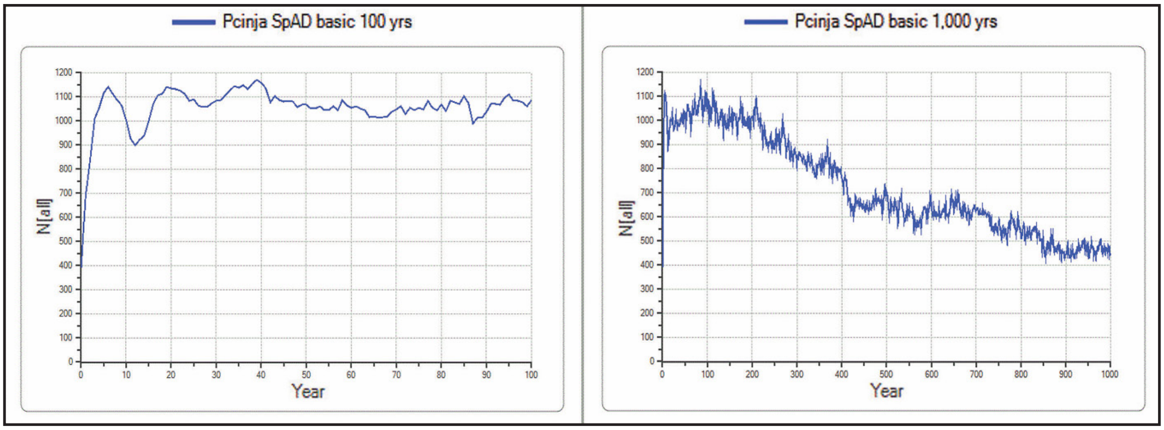

Figure 2. Outcomes of PVA simulations for the Pčinja River valley population of the Hermann's Tortoise (*Testudo hermanni boettgeri*) under baseline circumstances after 100 y (left) and after 1,000 y (right).

Books, and the official website of the IUCN (Table 3). For some countries we were not able to find appropriate publications, so we contacted local experts.

Results

Basic demographic information.—Populations of *T. h. boettgeri* differed substantially in basic demographic parameters and differences in sampling efforts could not fully account for this disparity (Table 1). Adult sex ratios (males/females) among populations ranged between 0.5 and 13.0. Proportions of juveniles and sub-adults varied from 11.0 to 29.3. Because field effort was highly uneven and recapture rates low (except on Golem Grad), we could not make proper population density assessments. Therefore, we only calculated the densities of marked individuals in their respective sites. These also varied greatly: from 12.6 to 78.8 individuals per hectare. We recorded maximum values on Golem Grad island where the area was intensively patrolled and thoroughly searched.

Population Viability Analyses.—First we present baseline PVA simulation results for the two supposedly unaffected tortoise populations in the Pčinja River valley and Konjsko village. In Pčinja the population remained stable after 100 y, at approximately one third of the hypothesized carrying capacity, but started to decrease after 200 y (Fig. 2). Nevertheless, the projected final population size did not drop below 400 individuals. Extinction probabilities between the two simulated periods (100 and 1,000 y) differ considerably: 0.04 and 0.56, respectively (Table 4). In Konjsko, the population also remained relatively stable during the first 100 y but started declining afterwards (Fig. 3). Again, population size remained at approximately 400 individuals and extinction probabilities differed considerably between simulated time periods (0.01 for 100 y and 0.49 for 1,000 y; Table 4).

For the three populations in Trstenik, Danilovgrad, and Golem Grad Island facing intense threats, we first provide baseline circumstance results of VORTEX simulations followed by those including disturbances and catastrophic events. In the baseline Trstenik

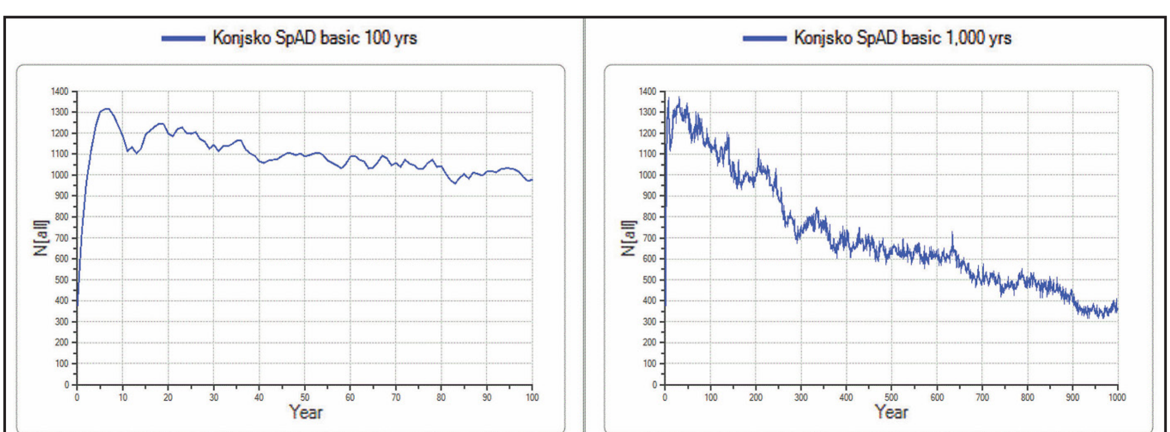

Figure 3. Outcomes of PVA simulations for the Konjsko village population of the Hermann's Tortoise (*Testudo hermanni boettgeri*) under baseline circumstances after 100 y (left) and after 1,000 y (right).

Table 1. Basic characteristics of the five study sites in Serbia, Montenegro, and Macedonia including the approximate surveyed area (ha), degree of urbanization, site protection status, identified (observed and/or reported) threats, crude survey effort, numbers of processed animals (captures and total re-captures), numbers of adult males and females and adult sex ratios, percentages of juveniles and sub-adults, and densities of marked individuals in the surveyed areas.

Study site	Trstenik (surroundings)	Danilovgrad (surroundings)	Golem Grad Island	Pčinja River valley	Konjsko village
Approximate surveyed surface (ha)	25	4.3	20	25	15
Urbanization	Villages and weekend houses, arable land	Surrounded by motorway, arable land and settlement	Uninhabited, tourists	Weekend houses, gardens	Uninhabited village, tourists
Site protection status	None: sub-urban area	None: sub-urban area	Strictly protected part of the National Park	Landscape of Outstanding Features	National Park
Threats	Illegal collection, agriculture, vehicle collisions	Wildfires, vehicle collisions, urbanization	Closed population, male-biased sex ratio, increased female mortality	None recorded	None recorded
Search effort (person-days)	17 d, 2–4 people (51); 2009, 2011 and 2012	48 d, 1–5 people (144); 2010–2012	133 d, 4–17 people (1,330); 2008–2013	26 d, 4–10 people (182); 2008, 2009 and 2012	22 d, 4–8 people (132); 2010–2012
Total / recaptured numbers of marked individuals	316 / 49	200 / 153	1,733 / 7,499	395 / 117	379 / 165
No. of adult males / females; adult sex ratio (M/F)	78 / 161; 0.48	104 / 74; 1.41	1,143 / 88; 12.99	175 / 140; 1.25	139 / 155; 0.90
Percentage of juveniles and sub-adults	24.61	11.00	29.29	20.45	21.41
Density of population samples (marked ind. / surveyed area, ha)	12.6	46.5	78.8	15.8	25.3

simulation the population increased; even after 1,000 y there was no dramatic decrease (Fig. 4). Nevertheless, when we introduced a realistic (legally allowed) level of harvest, the population vanished in fewer than 20 y, with a median time to first extinction of only 9 y. Probabilities of extinction in 100 and 1,000 y were respectively 0.02 and 0.43 under baseline circumstances, but with harvest, reached 1.00 in both scenarios (Table 4).

In Danilovgrad, the simulated population decreased to extinction even without added catastrophes or pressures. Under baseline circumstances, probabilities of extinction in 100 and 1,000 y were 0.27 and 0.95, respectively (Table 4). With added wildfires set to occur every other year, the population started dying out in 6 y (Fig. 5). On Golem Grad Island, baseline simulations did not lead to extinction (Fig. 6), with probabilities of extinction in 100 and 1,000 y being 0.01 and 0.56, respectively (Table 4). Both inbreeding, which we consider hypothetical because the population is completely isolated from conspecifics and females are a tiny minority of the population, and increased female mortality caused a rapid decline and eventual extinction of the population after about 100 y on average, with probabilities of extinction being 0.25 and 0.90 between 100 and 1,000 y simulations, respectively.

Conservation status.—Overview of the legal protection and conservation status of *T. h. boettgeri* in all countries of the Balkan Peninsula revealed that in most of the 10 countries of concern, *T. h. boettgeri* is legally protected or strictly protected (except in Albania). At the very least, the taxon is under some kind of protection or trade control on the international level (Table 3). Among seven Balkan countries, however, national conservation status varies from Least Concern to Endangered; for the remaining three we could not find precise information regarding the conservation status of *T. h. boettgeri*.

(Re)assessment of the conservation status.—Populations of *T. h. boettgeri* from the region of concern may easily decline by > 30% in fewer than 100 y (current results; Rozylowicz and Dobre 2010; Ljubisavljević et al. 2011; IUCN criterion A4d). The probability of extinction predicted by VORTEX was at least 10% within 100 y (IUCN criterion E). In some

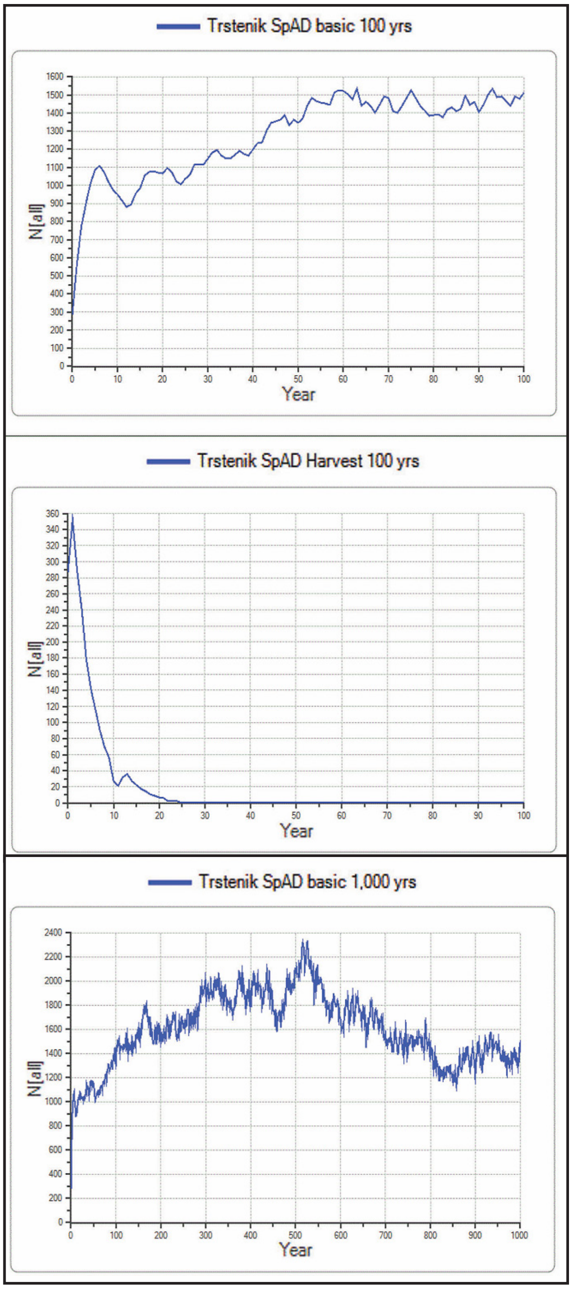

Figure 4. Outcomes of PVA simulations for Trstenik tortoise population of the Hermann's Tortoise (*Testudo hermanni boettgeri*) under baseline circumstances, after 100 y (top) and 1,000 y (bottom), and with maximum previously allowed harvest during 100 y (middle).

populations under study, this value reached 100% in short time periods, particularly under harvest, wildfires, or higher female mortality, all pressures we documented in the field. The meeting of these criteria should qualify *T. h. boettgeri* as Vulnerable. Higher ranking (such as Endangered) would be inappropriate due to the wide distributional range of the subspecies (criterion B) and large assumed population size (criteria C and D).

Table 2. Input data used in all VORTEX simulations of the eastern subspecies of the Hermann's Tortoise (*Testudo hermanni boettgeri*).

Reproductive System	Rates
Age at first offspring females	11
Age at first offspring males	9
Maximum lifespan	60
Maximum number of broods per year	1
Maximum number of progeny per brood	15
Sex ratio at birth - % males	50
Maximum age of female reproduction	50
Maximum age of male reproduction	50
Percent of adult females breeding	100 ± 10
Percent of adult males in the pool of breeders	100
Mean number of offspring per female per brood	4.3 ± 1
Mortality rates	
From age 0 to 1	50 ± 25
Juveniles and sub-adults (from year 1 to 9, i.e. 11)	20 ± 10
Adults (after year 9, i.e. 11)	10 ± 5
Initial population size / Carrying capacity	
Trstenik	316 / 10,301
Danilovgrad	200 / 397
Golem Grad Island	1,733 / 2,000
Pčinja River valley	395 / 3,608
Konjsko village	379 / 2,864

Discussion

Basic population parameters.—There is no substitute to long-term field research for obtaining precise key parameters required for Population Viability Analyses (Lacy et al. 2014; Reed and McCoy 2014). Due to logistical difficulties and time constraints, many analyses are based on published species-mean values and sometimes extrapolated from studies carried out on related taxa (Pike et al. 2008). Possible limited applicability of mean values to the singular situation of different populations should be considered. Our results show that populations that differ markedly in one or more of their demographic traits can generate contrasting PVA outcomes.

The wide range of demographic trait variation observed in this assessment is based on five distinct populations. Comparison with other studies suggests that this variation is representative of the variety of natural circumstances experienced *T. h. boettgeri* throughout their distributional range. For example, our population density estimates ranged between 12.6 and 78.8 ind/ha. These values lie in the range of previously reported variation from 3.0 individuals/ha in Romania to 77.0 individuals/ha in Greece (Hailey and Willemsen 2000; Rozylowicz and Dobre 2010). Adult sex ratios (M/F)

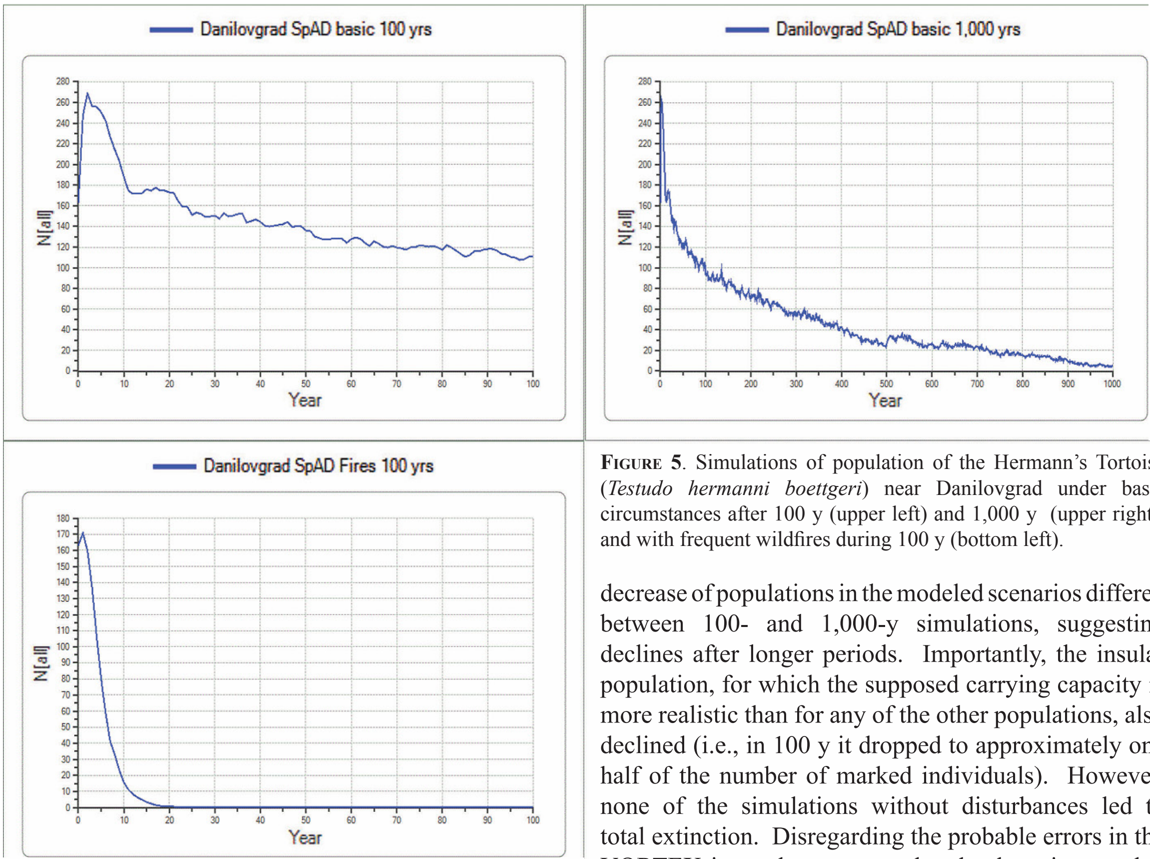

Figure 5. Simulations of population of the Hermann's Tortoise (*Testudo hermanni boettgeri*) near Danilovgrad under basic circumstances after 100 y (upper left) and 1,000 y (upper right), and with frequent wildfires during 100 y (bottom left).

ranged from 0.48 in Trstenik to 1.41 in Danilovgrad under usual circumstances, with an extreme of 12.99 on Golem Grad. Wide variations have been observed previously: from 0.55 to 6.41 (Stubbs et al. 1985; Hailey et al. 1988; Hailey 1990; Hailey and Willemsen 2000). In general, strong population divergences exist in estimates of life-history traits among reptile populations (Willemsen and Hailey 1999; Shine 2005), and our data are no exception, thus assuring robust inferences of Population Viability Analyses of *T. h. boettgeri*.

Population Viability Analyses.—VORTEX PVAs have seldom been applied to tortoise populations (Miller et al. 2001; Hailey and Willemsen 2003). Miller et al. (2001) suggested that isolated populations of the Gopher Tortoise (Gopherus polyphemus) may persist unless substantial perturbations occur, such as an increase in disease prevalence or in juvenile mortality. Our simulation showing the collapse of the Golem Grad Island population under increased female mortality (unpublished data) corroborates this result.

In general, our PVAs suggest that *T. h. boettgeri* populations in the central Balkans are relatively stable. Final population sizes projected by VORTEX simulations depended on initial population sizes and on hypothesized carrying capacities. The increase or decrease of populations in the modeled scenarios differed between 100- and 1,000-y simulations, suggesting declines after longer periods. Importantly, the insular population, for which the supposed carrying capacity is more realistic than for any of the other populations, also declined (i.e., in 100 y it dropped to approximately one half of the number of marked individuals). However, none of the simulations without disturbances led to total extinction. Disregarding the probable errors in the VORTEX input data, our results clearly point out that any disturbance such as wildfires and harvesting has the potential to rapidly drive populations to extinction. Life-history characteristics of tortoises do not provide buffering against major threats such as removal of adult individuals for the pet trade. Similar results were obtained in Greece from 75 populations of three *Testudo* species: 46% of the populations were declining and 8% were vanishing due to increasing anthropogenic pressures, independently from stochastic demographic processes (Hailey and Willemsen 2003). Without proper precautions the situation of the *T. hermanni* in Western Europe indicates a bleak forecast for the eastern subspecies.

Current conservation issues.—Heavy exploitation of tortoises from the territory of former Yugoslavia lasting over half a century (Ljubisavljević et al. 2011) is not diminishing (overview in Appendix). Available data testify to an ongoing demand for *T. hermanni* not satisfied by the allowed quota of more than 60,000 confiscated, illegally collected, individuals. Seizures such as the one amounting to 1,023 individuals between Serbia and Hungary (Hungarian CITES authority. Biennial report to the CITES office for 2013–2014. Available at: https://citesorg/sites/default/files/reports/13-14Hungarypdf. [Accessed 20 February 2017]) further corroborate

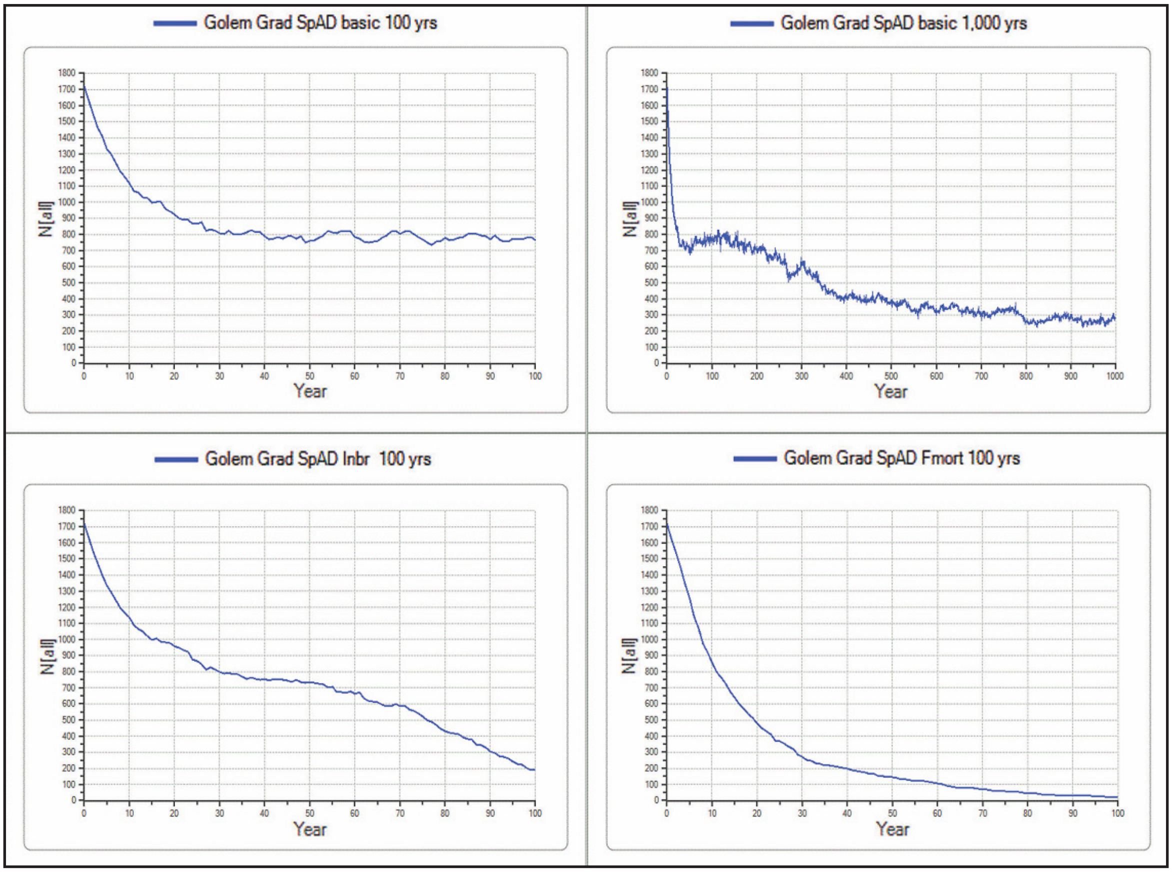

Figure 6. Simulations of population of the Hermann's Tortoise (*Testudo hermanni boettgeri*) from Golem Grad under basic circumstances after 100 y (upper left) and 1,000 y (upper right), with inbreeding (bottom left) and with increased female mortality (bottom right) during 100 y.

the idea that unobserved export probably amounts to worrying proportions.

Some populations are, nonetheless, under their own peculiar threats such as highly male-biased sex ratio on Golem Grad Island (Bonnet et al. 2016), where the lack of females may compromise population viability (Gibbs and Steen 2005). Such oddity is the result of independent factors affecting this isolated population such as a past bottleneck event, or higher female mortality (Hailey 1990; Willemsen and Hailey 1999). Yet, in a globally changing climate, it may well be a plausible scenario at a wider scale for this species with environmental sex determination (Janzen 1994).

In many places in the Balkans, tortoises are still common; they can be easily found in the field in large numbers (Djordjević et al. 2013). Our results suggest that apparently healthy populations of tortoises could be at greater risks of extinction than currently appraised. In Western Europe, previously large and widespread populations of tortoises are now severely fragmented due to illegal harvesting (Appendix); similar pressures currently apply to Eastern European populations. Uplisting *T. h. boettgeri* from Near Threatened to Vulnerable would set in motion necessary conservation actions such as the withdrawal of potentially detrimental collection quotas and initiation of intense conservation and educational campaigns.

Practical recommendations.—To the best of our knowledge, despite prescribed conservation statuses in the countries where we studied *T. h. boettgeri*, in practice hardly any control of tortoise collection from the wild exists. For Serbia, we suggest that the Ordinance and Regulation regarding protected species (Official Gazette of the Republic of Serbia 2010, 2011) should be revised; *T. h. boettgeri* should be considered as strictly protected, and collection of individuals from the wild for commercial purposes should be prohibited. In Macedonia, *T. h. boettgeri* is protected and we propose to upgrade the legal status of this species to strictly protected. Special attention should be paid to the Golem Grad Island population, because it is very easily accessible and hundreds of tortoises can be collected in a single day. This population deserves strict control and special conservation measures, especially as the removal of few adult females could push the population to extinction. Both Serbia and Macedonia authorize captive breeding of tortoises in farms and animals are

Table 3. Review of conservation statuses of the eastern subspecies of the Hermann's Tortoise (*Testudo hermanni boettgeri*) in the countries of the Balkan Peninsula including legal protection status, national conservation status according to corresponding Red Lists or Red Books, national population trends, recorded threats, and source of information.

Country	Legal protection	National conservation status (Red Lists / Red Books)	National population trends	Recorded threats	Information Source
Serbia	Protected; controlled collection from nature allowed	Vulnerable	Unknown	collection, illegal trade	Official Gazette of the Republic of Serbia 2010, 2011
Montenegro	Protected	—	Unknown	wildfires, vehicles	Official Gazette of Montenegro 2006
Macedonia	Protected	—	Unknown	Wildfires	Official Gazette of the Republic of Macedonia 2011
Croatia	Strictly protected	Near Threatened	Declining	collections, illegal trade	Jelić and Gambiroža 2012
Bosnia and Herzegovina	Protected	Vulnerable	Unknown	illegal trade	Lelo et al. 2016
Albania	Not protected	Least Concern	Unknown	—	Ministerial Order of Republic of Albania 2013; E. Saçdanaku, pers. comm.
Greece	Protected	Vulnerable	Declining	intensification of lowland agriculture, tourism, exurban development, vehicles, wildfires	Foufopoulos 2009
Bulgaria	Strictly protected	Endangered	Strongly declining	collection, agriculture, infrastructure building, wildfires	Beschkov 2015
Romania	Protected	Endangered	Strongly declining	habitat loss, human activities, increase of wildfire frequency	Rozylowicz and Dobre 2010
Turkey	Protected	—	Unknown	habitat destructions due to urbanization and agricultural activities	O. Türkozan, pers. comm.

then traded externally and with export permits from local CITES committees. Strict and continuous monitoring of the existing tortoise farms and their activities is necessary because they can easily be (and likely are) used as platforms for the legal export of wild-caught tortoises upon substantial demand. In Montenegro, *T. h. boettgeri* is protected, but we nonetheless propose its upgrade to strictly protected. In this country, tortoises suffer from road mortality and very frequent wildfires (Vujović et al. 2015). Strict and permanent control of wildfires in the region is urgently needed.

One of the most important conservation measures in all three countries of the central Balkans should be the preservation of habitats and mosaic structure of landscapes, as well as prevention and control of wildfires (Livoreil 2009; Rozylowicz and Popescu 2013; Badiane et al. 2017). Intensification of field research would provide a clearer picture of the most appropriate monitoring methodologies and conservation priorities. International cooperation in collecting and analyzing DNA samples of *T. h. boettgeri* from the entire distribution range would facilitate the ability to determine the origin of confiscated animals and therefore their return (Zenboudji et al. 2016). Releasing captive *T. hermanni* in the field has been successfully tested (Pille et al. 2018). Moreover, coordination among scientists and international conservation organizations is desirable because conservation status assessments often differ strongly between responsible authorities (Moser et al. 2016).

Finally, the establishment of regional rescue centers (such as those in Spain and France, Station d'Observation et de Protection des Tortues et de leurs Milieux [SOPTOM]) for confiscated wild-caught tortoises is needed (Nikolić and Golubović 2017). Captive individuals could be used in educational activities and in

Table 4. Results of VORTEX simulations for all studied populations of the eastern subspecies of the Hermann's Tortoise (*Testudo hermanni boettgeri*) under baseline circumstances. Abbreviations are: T = Time period for which the simulations were run; PEx = Probability of Extinction; Me1Ex = Mean Time to 1st Potential Extinction; *r* = Mean Population Growth Rate prior to K Truncation.

		T = 100 y			T = 1,000 y		
Population	Scenario	PEx	Me1Ex	*r*	Pex	Me1Ex	*r*
Trstenik	basic	0.02	42.50	0.0123	0.43	495.13	0.0030
	harvest	1.00	8.97	-0.1583	--	--	--
Danilovgrad	basic	0.27	54.20	0.0119	0.95	118.85	0.0127
	wildfires	1.00	6.00	-0.1188	--	--	--
Golem Grad	basic	0.01	61.25	-0.0063	0.56	443.51	0.0014
	inbreeding	0.25	84.80	-0.0227	--	--	--
	high F mortality	0.90	57.75	-0.0488	--	--	--
Pčinja River valley	basic	0.04	85.60	0.0082	0.56	433.69	0.0030
Konjsko village	basic	0.01	65.00	0.0096	0.49	501.03	0.0042

reinforcement and repopulation translocation programs (Lepeigneul et al. 2014; Pille et al. 2018). This is especially true following wildfires, which are often destructive to wildlife (Couturier et al. 2014; Vujović et al. 2015; Badiane et al. 2017) but nonetheless create favorable tortoise habitats (Lecq et al. 2014). Based on our results and IUCN criteria, we propose the assignment of *T. h. boettgeri* to the Vulnerable category globally (i.e., throughout its distribution range). Our recommendation is further supported by the recent threat assessment of the *T. h. boettgeri* based on its distribution, ecology, and life-history traits, which clearly showed that it is especially sensitive to anthropogenic pressures and was consequently assigned to the category Vulnerable in Serbia (Tomović et al. 2015).

Acknowledgments.—Our research was funded by the Ministries of Education, Sciences and Technological Development (project No. 173043) and of Agriculture and Environmental Protection (grant No. 401-00-00243/2014-08) of the Republic of Serbia, and by the Rufford Foundation (grant No. 12291-1). Permits for work in protected areas and with protected species were issued by the Ministry of Environment, Mining and Spatial Planning of Serbia (Nos. 03-246, 353-01-46/2012-03), the Agency for Environment Protection of Montenegro (Nos. UPI 953/4 and UPI 2342/6), and by the Ministry of Environment and Spatial Planning of Macedonia and the authorities of National Park "Galičica" (Nos. 11-2817/2, 11-4093/5, and 03-246). The CITES office in Serbia provided support and some basic information concerning the current *Testudo* trade. Colleagues and students from Serbia, Croatia, Montenegro, Macedonia, Bosnia and Herzegovina, France, and Togo took part in various stages of field research. We are grateful to Oguz Türkozan and Enerit Saçdanaku for information provided on the conservation and legal status of *T. h. boettgeri* in their countries.

Literature Cited

Akçakaya H.R., and P. Sjögren-Gulve. 2000. Population viability analysis in conservation planning: an overview. Ecological Bulletins 48:9–21.

Arsovski, D., Lj. Tomović, A. Golubović, S. Nikolić, B. Sterijovski, R. Ajtić, and X. Bonnet. 2018. When carapace governs size: variation among age classes and individuals in a free ranging ectotherm with delayed maturity. Oecologia 186:953–963.

Auliya, M., S. Altherr, D. Ariano-Sanchez, E.H. Baard, C. Brown, R.M. Brown, J.-C. Cantu, G. Gentile, P. Gildenhuys, E. Henningheim, et al. 2016. Trade in live reptiles, its impact on wild populations, and the role of the European market. Biological Conservation 204:103–119.

Badiane, A., C. Matos, and X. Santos. 2017. Uncovering environmental, land-use and fire effects on the distribution of a low-dispersal species, the Hermann's Tortoise *Testudo hermanni*. Amphibia-Reptilia 38:67–77.

Bertolero, A., M.A. Carretero, and G.A. Llorente. 2005. An assessment of the reliability of growth rings counts for age determination in the Hermann's Tortoise *Testudo hermanni*. Amphibia-Reptilia 26:17–23.

Bertolero, A., M. Cheylan, A. Hailey, B. Livoreil, and R.E. Willemsen. 2011. *Testudo hermanni* Gmelin 1789 Hermann's Tortoise. Pp. 059.1–059.20 *In* Biology of Freshwater Turtles and Tortoises; A Compilation Project of the International Union for Conservation of Nature / Species Survival Commission Tortoise and Freshwater Specialist Group. Rhodin, A.G.J., C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhlmann, J.B., and R.A. Mittermeier (Eds.). Chelonian Research Monographs. Chelonian Research Foundation, Lunenburg, Massachusetts, USA.

Beschkov, V. 2015. Eastern Hermann's Tortoise *Testudo hermanni boettgeri*. In Red Data Book of the Republic of Bulgaria - digital edition. Joint edition of the Bulgarian Academy of Sciences and Ministry of Environment and Water Sofia, Bulgaria. http://e-ecodbbasbg/rdb/en/vol2/Tehermanhtml.

Bonnet, X., A. Golubović, D. Arsovski, S. Đorđević, J-M. Ballouard, B. Sterijovski, R. Ajtić, C. Barbraud, and L. Tomović. 2016. The prison effect in a wild population: a scarcity of females induces homosexual behaviors in males. Behavioral Ecology 27:1206–1215.

Brook, B.W., J.J. O'Grady, A.P. Chapman, M.A. Burgman, H.R. Akçakaya, and R. Frankham. 2000. Predictive accuracy of population viability analysis in conservation biology. Nature 404:385–387.

Couturier, T., A. Besnard, A. Bertolero, V. Bosc, G. Astruc, and M. Cheylan. 2014. Factors determining the abundance and occurrence of Hermann's Tortoise *Testudo hermanni* in France and Spain: fire regime and landscape changes as the main drivers. Biological Conservation 170:177–187.

Djordjević, S., M. Djurakić, A. Golubović, R. Ajtić, L. Tomović, and X. Bonnet. 2011. Sexual body size and body shape dimorphism of *Testudo hermanni* in central and eastern Serbia. Amphibia-Reptilia 32:445–458.

Djordjević, S., L. Tomović, A. Golubović, A. Simović, B. Sterijovski, M. Djurakić, and X. Bonnet. 2013. Geographic (in-) variability of gender-specific traits in Hermann's Tortoise. Herpetological Journal 23:67–67.

Đorđević, S., and K. Ljubisavljević. 2015. Hermann's Tortoise *Testudo hermanni* Gmelin 1789. Pp. 151–157 *In* Red Book of Fauna of Serbia II - Reptiles. Tomović L., M. Kalezić, and G. Džukić (Eds). Faculty of Biology University of Belgrade and Institute for Nature Conservation of Serbia, Belgrade, Serbia.

European Reptile & Amphibian Specialist Group. 1996. *Testudo hermanni* ssp. *hermanni*. The International Union for Conservation of Nature, Red List of Threatened Species 1996. http://www.iucnredlist.org.

Foufopoulos, J. 2009. *Testudo hermanni* (Gmelin, 1789) Hermann's Tortoise. Pp. 200–202 I*n* Red Book of Endangered Animals in Greece. Legakis, A., and P. Maragos (Eds.). Hellenic Zoological Society, Athens, Greece.

Gibbs, J.P., and D.A. Steen. 2005. Trends in sex ratios of turtles in the United States: implications of road mortality. Conservation Biology 19:552–556.

Hailey, A. 1990. Adult survival and recruitment and the explanation of an uneven sex ratio in a tortoise population. Canadian Journal of Zoology 68:547–555.

Hailey, A., and N.S. Loumbourdis. 1988. Egg size and shape clutch dynamics and reproductive effort in European tortoises. Canadian Journal of Zoology 66:1527–1536.

Hailey, A., and R.E. Willemsen. 2000. Population density and adult sex ratio of the tortoise *Testudo hermanni* in Greece: evidence for intrinsic population regulation. Journal of Zoology 251:325–338.

Hailey, A., and R.E. Willemsen. 2003. Changes in the status of tortoise populations in Greece 1984–2001. Biodiversity and Conservation 12:991–1011.

Hailey, A., J. Wright, and E. Steer. 1988. Population ecology and conservation of tortoises. the effects of disturbance. Herpetological Journal 1:294–301.

International Union for Conservation of Nature (IUCN). 2014. Standards and Petitions Subcommittee Guidelines for Using the IUCN Red List Categories and Criteria Version 1.1. http://www.iucnredlist.org/documents/RedListGuidelines.pdf.

Janzen, F.J. 1994. Climate change and temperature-dependent sex determination in reptiles. Proceedings of the National Academy of Sciences of the USA 91:7487–7490.

Jelić, D., and P. Gambiroža. (Eds.). 2012. Kopnena kornjača *Testudo hermanni* Gmelin 1789. Pp. 159–162 *In* Red book of Amphibians and Reptiles of Croatia. Ministry of Environmental and Nature Protection, and State Institute for Nature Protection, Zagreb, Croatia.

Jonsson, A., and B. Ebenman. 2001. Are certain life histories particularly prone to local extinction? Journal of Theoretical Biology 209:455–463.

Lacy, R.C., and J.P. Pollak. 2014. Vortex: A Stochastic Simulation of the Extinction Process. Version 10. Chicago Zoological Society, Brookfield, Illinois, USA.

Lacy, R.C., P.S. Miller, and K. Traylor-Holzer. 2014. Vortex 10 User's Manual. International Union for Conservation of Nature / Species Survival Commission. Conservation Breeding Specialist Group and Chicago Zoological Society, Apple Valley, Minnesota, USA.

Lecq, S., J-M. Ballouard, S. Caron, B. Livoreil, V. Seynaeve, L.A. Matthieu, and X. Bonnet. 2014. Body condition and habitat use by Hermann's Tortoises in burnt and intact habitats. Conservation Physiology 2: doi:10.1093/conphys/cou019.

Lelo, S., A. Zimić, and E. Šunje. 2016. Crvena lista gmizavaca (Chordata: Vertebrata: Reptilia) Federacije Bosne i Hercegovine. Prilozi fauni Bosne i Hercegovine [in Bosnian] 12:31–42.

Lepeigneul, O., J-M. Ballouard, X. Bonnet, E. Beck, M. Barbier, A. Ekori, E. Buisson, and S. Caron. 2014. Immediate response to translocation without acclimation from captivity to the wild in Hermann's

Tortoise. European Journal of Wildlife Research 60:897–907.

Livoreil, B. 2009. Distribution of the endangered Hermann's Tortoise *Testudo hermanni hermanni* in Var France and recommendations for its conservation. Oryx 43:299–305.

Ljubisavljević, K., G. Džukić, and M.L. Kalezić. 2011. The commercial export of land tortoises (*Testudo* spp.) from the territory of the former Yugoslavia: a historical review and the impact of overharvesting on wild populations. North-Western Journal of Zoology 7:250–260.

Ljubisavljević, K., G. Džukić, T.D. Vukov, and M.L. Kalezić. 2014. Distribution patterns of Hermann's Tortoise *Testudo hermanni* Gmelin 1789 in the region of former Yugoslavia. Herpetozoa 26:125–138.

Luiselli, L., M. Capula, R.L. Burke, L. Rugiero, and D. Capizzi. 2014. Sighting frequency decreases over two decades in three populations of *Testudo hermanni* from central Italy. Biodiversity and Conservation 23:3091–3100.

Luiselli, L., A. Starita, G.M. Carpaneto, G.H. Segniagbeto, and G. Amori. 2016. Short review of the international trade of wild tortoises and freshwater turtles across the world and throughout two decades. Chelonian Conservation and Biology 15:167–172.

Miller, P.S., and Participants in PVA Workshop. 2001. Preliminary population viability assessment for the Gopher Tortoise (*Gopherus polyphemus*) in Florida. Gopher Tortoise Population Viability Workshop, Tallahassee, Florida, 11–12 September 2001. Conservation Breeding Specialist Group, International Union for Conservation of Nature / Species Survival Commission, World Conservation Union, Apple Valley, Minnesota, USA. 45 p.

Ministerial Order of Republic of Albania. 2013. Red List of Wild Flora and Fauna of Albania. Ministerial Order of Republic of Albania No. 1280, Tirana, Albania.

Morrison, C., C. Wardle, and J.G. Castley. 2016. Repeatability and reproducibility of Population Viability Analysis (PVA) and the implications for threatened species management. Frontiers in Ecology and Evolution 4:98.

Moser, D., T. Ellmauer, D. Evans, K.P. Zulka, M. Adam, S. Dullinger, and F. Essl. 2016. Weak agreement between the species conservation status assessments of the European Habitats Directive and Red Lists. Biological Conservation 198:1–8.

Nikolić, S., and A. Golubović. 2017. Confiscated *Emys orbicularis* (L., 1758) dying out in a "temporary" reception facility in Serbia: a case study showing the urgency for a regional reptile rescue centre. Acta Zoologica Bulgarica Supplementum 10:115–120.

Official Gazette of Montenegro. 2006. Decree on the protection of certain plant and animal species. Official Gazette of Montenegro No. 76/06, Podgorica, Montenegro.

Official Gazette of the Republic of Macedonia 2011. Directories on determining strictly protected and protected wildlife. Official Gazette of the Republic of Macedonia No. 139, Skopje, Macedonia.

Official Gazette of the Republic of Serbia. 2010. Ordinance on the control of use and trade in wild flora and fauna. Official Gazette of the Republic of Serbia Nos. 31/2005 45/2005 22/2007 38/2008 and 09/2010, Belgrade, Serbia.

Official Gazette of the Republic of Serbia 2011. Regulation on the designation and protection of strictly protected and protected species of wild flora, fauna and fungi. Official Gazette of the Republic of Serbia Nos. 5/2010 and 47/2011, Belgrade, Serbia.

Pike, D.A., L. Pizzatto, B.A. Pike, and R. Shine. 2008. Estimating survival rates of uncatchable animals: the myth of high juvenile mortality in reptiles. Ecology 89:607–611.

Pille, F., S. Caron, X. Bonnet, S. Deleuze, D. Busson, T. Etien, F. Girard, and J.M. Ballouard 2018. Settlement pattern of tortoises translocated into the wild: a key to evaluate population reinforcement success. Biodiversity and Conservation 27:437–457.

Reed, J.M., and E.D. McCoy. 2014. Relation of minimum viable population size to biology time frame and objective. Conservation Biology 28:867–870.

Reznick, D., M.J. Bryant, and F. Bashey. 2002. R- and K-selection revisited: the role of population regulation in life history evolution. Ecology 83:1509–1520.

Rozylowicz, L., and M. Dobre. 2010. Assessment of threatened status of *Testudo hermanni boettgeri* Mojsisovics 1889 (Reptilia: Testudines: Testudinidae) population from Romania. North-Western Journal of Zoology 6:190–202.

Rozylowicz, L., and V.D. Popescu. 2013. Habitat selection and movement ecology of Eastern Hermann's Tortoises in a rural Romanian landscape. European Journal of Wildlife Research 59:47–55.

Shine, R. 2005. Life-history evolution in reptiles. Annual Review of Ecology and Systematics 36:23–46.

Shoemaker, K.T., A.R. Breisch, J.W. Jaycox, and J.P. Gibbs. 2013. Re-examining the Minimum Viable Population concept for long-lived species. Conservation Biology 27:542–551.

Stanford, C.B., A.G.J. Rhodin, P.P. van Dijk, B.D. Horne, T. Blanck, E.V. Goode, R. Hudson, R.A. Mittermeier, A. Currylow, C. Eixemberg, et al. (Eds.). 2018. Turtles in Trouble: The World's 25+ most Endangered Tortoises and Freshwater

Turtles - 2018. Turtle Conservation Coalition, Ojai, California, USA. 54 p.

Stubbs, D., A. Hailey, E. Pulford, and W. Tyler. 1984. Population ecology of European tortoises: review of field techniques. Amphibia-Reptilia 5:57–68.

Stubbs, D., I.R. Swingland, A. Hailey, and E. Pulford. 1985. The ecology of the Mediterranean Tortoise *Testudo hermanni* in northern Greece: the effects of a catastrophe on population structure and density. Biological Conservation 31:125–152.

Tomović, L., A. Urošević, T. Vukov, R. Ajtić, K. Ljubisavljević, I. Krizmanić, D. Jović, N. Labus, S. Đorđević, M.L. Kalezić, et al. 2015. Threatening levels and extinction risks based on distributional ecological and life-history datasets (DELH) versus IUCN criteria - example of Serbian Reptiles. Biodiversity and Conservation 24:2913–2934.

van Dijk, P.P., C. Corti, V.P. Mellado, and M. Cheylan. 2004. *Testudo hermanni*. The International Union for Conservation of Nature, Red List of Threatened Species 2004. http://www.iucnredlist.org .

van Dijk, P.P., J.B. Iverson, A.G.J. Rhodin, H.B. Shaffer, and R. Bour. 2014. Turtles of the World, 7th Edition: Annotated Checklist of Taxonomy Synonymy Distribution with Maps and Conservation Status. Pp. 329–479 *In* Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the International Union for Conservation of Nature / Species Survival Commission Tortoise and Freshwater Turtle Specialist Group. Rhodin, A.G.J., P.C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhlmann, J.B. Iverson, and R.A. Mittermeier. (Eds.). Chelonian Research Monographs 5. Chelonian Research Foundation, Lunenburg, Massachusetts, USA.

Vilardell-Bartino, A., X. Capalleras, J. Budó, R. Bosch, and P. Pons. 2015. Knowledge of habitat preferences applied to habitat management: the case of an endangered tortoise population. Amphibia-Reptilia 36:13–25.

Vujović, A., V. Iković, A. Golubović, S. Đorđević, R. Ajtić, V. Pešić, and L. Tomović. 2015. Effects of fires and roadkills on the isolated population of *Testudo hermanni* Gmelin 1789 (Reptilia: Testudinidae) in central Montenegro. Acta Zoologica Bulgarica 67:75–84.

Willemsen, R.E., and A. Hailey. 1999. Variation in adult body size of the tortoise *Testudo hermanni* in Greece: proximate and ultimate causes. Journal of Zoology 248:379–396.

Willemsen, R.E., and A. Hailey. 2003. Sexual dimorphism of body size and shell shape in European tortoises. Journal of Zoology 260:353–365.

Wilson, D.S., C.R. Tracy, and C.R. Tracy. 2003. Estimating age of turtles from growth rings: a critical evaluation of the technique. Herpetologica 59:178–194.

Zenboudji, S., M. Cheylan, V. Arnal, A. Bertolero, R. Leblois, G. Astruc, G. Bertorelle, J. Ll. Pretus, M. Valvo, G. Sotgiu, and C. Montgelard. 2016. Conservation of the endangered Mediterranean Tortoise *Testudo hermanni hermanni*: The contribution of population genetics and historical demography. Biological Conservation 195:279–291.

Sonja Nikolić works as a Research Associate at the University of Belgrade, Faculty of Biology, Institute of Zoology, Serbia. With a team of herpetologists, she has been involved in studies of snakes and chelonians in Serbia and few ex-Yugoslav countries. Her PhD dissertation was on sexual dimorphism of *Testudo hermanni boettgeri*. She is one of the founders of the Serbian Herpetological Society "Milutin Radovanović." (Photographed by Tamara Karan-Žnidaršič).

Ana Golubović is an Assistant Professor at the Faculty of Biology, Belgrade University in Serbia. Since 2009 she has been studying chelonians and snakes across the central part of Balkan Peninsula. Main topics of interest are behavior, functional morphology, ecology and conservation through long term field studies, which were covered in her PhD thesis. (Photographed by Miloš Popović).

Xavier Bonnet is a Director of Research at the Centre d'Etudes Biologiques de Chizé (UMR CNRS-Université de la Rochelle) in France. During the past 27 y, he has been studying snakes and tortoises in different places (France, Morocco, Togo, Australia, New Caledonia, China, Macedonia). Interested in ecology, evolution, conservation and environmental education, his specialty is to set up long-term field studies and to use eco-physiological investigations. (Photographed by Jean Marie Ballouard).

Dragan Arsovski is a third year Ph.D. student at the Centre d'Etudes Biologiques de Chizé (UMR CNRS-Université de la Rochelle) in France under the supervision of Xavier Bonnet and Ljiljana Tomović. He has actively been involved in faunistic, population and behavioral studies on reptiles and amphibians of parts of the Balkans and Western Europe since the beginning of his studies in 2009. Dragan is mostly interested in intense long-term studies, amassing big datasets, and translating them into reliable models offering insight into the evolutionary ecology and often conservation of species. (Photographed by Ivo Kunovski).

Jean-Marie Ballouard is a project officer at the Research Center for Chelonian Conservation (SOPTOM-CRCC), a French NGO. Since 2003 he has studied crocodiles (Nepal), snakes and tortoises in France notably. He is mainly focused on questions regarding conservation, with strong emphasis on environmental education and wildlife population management. (Photographed by Maxime Briola).

Rastko Ajtić is a Senior Expert Associate at the Institute for Nature Conservation of Serbia. During the past 20 y, he has been studying mostly snakes, but also other reptiles in the Balkan Peninsula. Rastko is interested in taxonomy, ecology, evolution, conservation and environmental education. His specialties are education and long-term field studies. (Photographed by Rastko Ajtić).

Bogoljub Sterijovski has been involved in studying the biodiversity of amphibians and reptiles in Macedonia during the past 18 y. Currently he is employed in the Macedonian Ecological society as an Assistant Project Manager where he is fulfilling the challenges in the field of population biology, ecology, conservation and protection of herpetofauna in Macedonia. (Photographed by Xavier Bonnet).

Vuk Iković works as a Project Coordinator in the Montenegrin Ecologists' Society. During the past 8 y he has been studying the diversity of reptiles and amphibians in Montenegro. His master's thesis was related to the impact of traffic on amphibians and reptiles in Montenegro. His work includes Environmental Impact Assessment and different aspects of amphibian and reptile research including distribution, ecology, morphology, taxonomy, conservation, etc. (Photographed by Milivoj Krstić).

Ana Vujović is one of the founders of the Natural History Association of Montenegro. She has been Project Coordinator and Researcher of birds and turtles/tortoises in Montenegro for 7 y, since 2010. Fields of interest are: protection, conservation, ecology, environmental education and population biology. (Photographed by Đuro Ilić).

Ljiljana Tomović works as Professor of Vertebrate Morphology, Systematics and Phylogeny, at the University of Belgrade, Faculty of Biology. She has been studying vipers (Vipera ammodytes, V. berus and V. ursinii), Dice Snakes (*Natrix tessellata*) and tortoises (*Testudo hermanni*) in the central part of the Balkan Peninsula since 1995. Her specialties are herpetology, morphology, systematics, population ecology, and ethology. (Photographed by Metodija Velevski).

Appendix. Known traffic from the Balkans between 1977 and 2016 according to TRAFFIC's bulletins of seizures and prosecutions, CITES biennial reports, as well as https://trade.cites.org/en/cites_trade. For clarity names of importer and exporter countries are given in internationally used two letters abbreviations (https://www.all-acad.com/docs/country_abbreviations.html).

Year	Taxon	Importer	Exporter	Importer quantity	Exporter quantity	Term	Purpose	Source
1977	*Testudo hermanni*	CH	GR	6		live	Personal	
1980	*Testudo hermanni*	CH	GR	13		live	Personal	
1982	*Testudo hermanni*	GB	BG	1		live	Personal	
1989	*Testudo hermanni*	DK	GR	2		live	Personal	
1989	*Testudo hermanni*	NL	GR	12		live		Confiscation
1990	*Testudo hermanni*	DK	GR	2		live	Personal	
1991	*Testudo hermanni*	DK	GR	2		live	Personal	Wild
1993	*Testudo hermanni*	CZ	GR	16		live	Commercial	Unknown
1996	*Testudo hermanni*	DE	YU	88		live	Personal	Seizure
1997	*Testudo hermanni*	US	BG	1		live		Confiscation
1997	*Testudo hermanni*	AT	GR	426		live		Confiscation
1997	*Testudo hermanni*	DE	HR	1		live	Personal	Wild
1998	*Testudo hermanni*	AT	GR	30		live		Confiscation
1998	*Testudo hermanni*	US	GR	1		live	Personal	Wild
1998	*Testudo hermanni*	CZ	HR	3		live	Commercial	Confiscation
1999	*Testudo hermanni*	US	HR	3		live		Captive-Bred
2001	*Testudo hermanni*	US	BG		1	live	Scientific	Wild
2001	*Testudo hermanni*	AT	HR	2		live		Confiscation
2002	*Testudo hermanni*	AT	HR	1		live		Confiscation
2003	*Testudo hermanni*	DE	GR		400	live	Commercial	Captive-Bred
2003	*Testudo hermanni*	DK	GR	1		live	Personal	Pre-Convention
2003	*Testudo hermanni*	JP	GR	200	400	live	Commercial	Captive-Bred
2003	*Testudo hermanni*	SI	GR		755	live	Commercial	Captive-Bred
2003	*Testudo hermanni*	AT	HR	2		live		Confiscation
2003	*Testudo hermanni*	DK	HR	1	1	carapaces	Educational	Confiscation
2003	*Testudo hermanni*	AT	MK	11		live		Confiscation
2003	*Testudo hermanni*	PL	MK	1,200	1,200	live	Commercial	Ranched
2004	*Testudo hermanni*	GB	AL	1		live		Confiscation
2004	*Testudo hermanni*	DK	HR	1	1	carapaces	Educational	Confiscation
2004	*Testudo hermanni*	SI	HR	9		live		Confiscation
2004	*Testudo hermanni*	PL	MK	1,500	1,500	live	Commercial	Captive-Bred
2005	*Testudo hermanni*	CH	BG		3	live	Personal	Wild
2005	*Testudo hermanni*	SI	HR	2		live	Personal	Unknown
2006	*Testudo hermanni*	SI	HR	2	1	live	Personal	Captive-Bred
2006	*Testudo hermanni*	SI	HR	3		live		Confiscation
2006	*Testudo hermanni*	DE	MK	22		live		Seizure
2006	*Testudo hermanni*	SI	MK		1,000	live	Commercial	Captive-Bred
2006	*Testudo hermanni*	SI	MK	11		live		Confiscation
2006	*Testudo hermanni*	HU	RS	3		live		Confiscation
2006	*Testudo hermanni*	HU	RS	381		live		Confiscation
2006	*Testudo hermanni*	SI	RS	1		live		Confiscation
2007	*Testudo hermanni*	SI	HR	2		live	Personal	Unknown

Appendix (continued). Known traffic from the Balkans between 1977 and 2016 according to TRAFFIC's bulletins of seizures and prosecutions, CITES biennial reports, as well as https://trade.cites.org/en/cites_trade. For clarity names of importer and exporter countries are given in internationally used two letters abbreviations (https://www.all-acad.com/docs/country_abbreviations.html).

Year	Taxon	Importer	Exporter	Importer quantity	Exporter quantity	Term	Purpose	Source
2007	*Testudo hermanni*	GB	MK	200		live		Confiscation
2007	*Testudo hermanni*	SI	MK	2,958	2,458	live	Commercial	Captive-Bred
2007	*Testudo hermanni*	UA	MK		1,000	live	Commercial	Captive-Bred
2008	*Testudo hermanni*	CH	HR	1		live	Personal	Wild
2008	*Testudo hermanni*	SI	HR	1		live	Personal	Unknown
2008	*Testudo hermanni*	SI	HR	2		live	Personal	Unknown
2008	*Testudo hermanni*	SI	HR	200		live	Commercial	Captive-Bred
2008	*Testudo hermanni*	GB	MK	2,900	2,700	live	Commercial	Captive-Bred
2008	*Testudo hermanni*	IE	MK	100		live	Commercial	Captive-Bred
2008	*Testudo hermanni*	UA	MK	700		live	Commercial	Captive-Bred
2008	*Testudo hermanni*	CZ	RS		200	live	Commercial	Captive-Bred
2008	*Testudo hermanni*	HU	RS		300	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	SI	HR	2		live	Personal	Unknown
2009	*Testudo hermanni*	SI	HR	100	200	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	FR	MK	700	350	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	GB	MK	4,300	4,500	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	JP	MK	200	400	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	UA	MK		600	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	CZ	RS	200	150	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	GB	RS		6	live	Personal	Captive-Bred
2009	*Testudo hermanni*	GB	RS		100	live	Commercial	Captive-Bred
2009	*Testudo hermanni*	HU	RS	300	300	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	SI	HR	2		live	Personal	Unknown
2010	*Testudo hermanni*	SI	HR		100	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	ES	MK		100	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	ES	MK		100	live	Commercial	Ranched
2010	*Testudo hermanni*	FR	MK	1,050	1,050	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	JP	MK	300	600	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	PL	MK	300	300	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	US	MK	500	500	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	CZ	RS	352	702	live	Commercial	Captive-Bred
2010	*Testudo hermanni*	HU	RS	300	400	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	XX	BG		12	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	CZ	HR	500		live	Commercial	Captive-Bred
2011	*Testudo hermanni*	CZ	HR		500	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	CL	MK		100	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	CN	MK		1,000	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	FR	MK	400	1,200	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	GB	MK	1,015	5,500	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	HK	MK	794		live	Commercial	Captive-Bred
2011	*Testudo hermanni*	JP	MK	1,000	800	live	Commercial	Captive-Bred
2011	*Testudo hermanni*	KR	MK	50		live	Commercial	Captive-Bred

Appendix (continued). Known traffic from the Balkans between 1977 and 2016 according to TRAFFIC's bulletins of seizures and prosecutions, CITES biennial reports, as well as https://trade.cites.org/en/cites_trade. For clarity names of importer and exporter countries are given in internationally used two letters abbreviations (https://www.all-acad.com/docs/country_abbreviations.html).

Year	Taxon	Importer	Exporter	Importer quantity	Exporter quantity	Term	Purpose	Source
2011	*Testudo hermanni*	CZ	RS	500		live	Commercial	Captive-Bred
2011	*Testudo hermanni*	HU	RS	400		live	Commercial	Captive-Bred
2012	*Testudo hermanni*	CN	MK		400	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	FR	MK	2,000	2,000	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	GB	MK	2,775	3,500	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	HK	MK	400		live	Commercial	Captive-Bred
2012	*Testudo hermanni*	JP	MK	800	800	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	KR	MK	50	50	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	PL	MK		300	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	SK	MK		101	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	TW	MK		250	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	US	MK	300	500	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	US	MK	200		live	Commercial	Born in Captivity
2012	*Testudo hermanni*	CZ	RS		100	live	Commercial	Captive-Bred
2012	*Testudo hermanni*	HU	RS		200	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	CN	MK		700	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	DE	MK	550	550	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	FR	MK	2,170	2,370	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	GB	MK	2,500	3,500	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	HK	MK	1,700	1,000	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	JP	MK	126	151	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	PL	MK	300	300	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	US	MK	1,030	1,030	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	UZ	MK	500	500	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	CZ	RS	100	200	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	HK	RS	100	200	live	Commercial	Captive-Bred
2013	*Testudo hermanni*	HU	RS	1,200	1,000	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	IT	AL	51		live	Personal	Captive-Bred
2014	*Testudo hermanni*	IT	AL		77	live	Commercial	
2014	*Testudo hermanni*	CH	MK	255	255	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	CN	MK		1,000	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	DE	MK	1,700	1,700	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	FR	MK	1,460	1,460	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	GB	MK		1,000	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	HK	MK	6,200	6,000	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	TW	MK		530	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	US	MK	507	525	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	CZ	RS	200	150	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	GB	RS	350	350	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	HK	RS	800	800	live	Commercial	Captive-Bred
2014	*Testudo hermanni*	HU	RS	800	800	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	CH	MK	70		live	Commercial	Captive-Bred

Appendix (continued). Known traffic from the Balkans between 1977 and 2016 according to TRAFFIC's bulletins of seizures and prosecutions, CITES biennial reports, as well as https://trade.cites.org/en/cites_trade. For clarity names of importer and exporter countries are given in internationally used two letters abbreviations (https://www.all-acad.com/docs/country_abbreviations.html).

Year	Taxon	Importer	Exporter	Importer quantity	Exporter quantity	Term	Purpose	Source
2015	*Testudo hermanni*	CH	MK		70	live	Commercial	
2015	*Testudo hermanni*	CN	MK		1,900	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	CN	MK		700	live	Commercial	
2015	*Testudo hermanni*	DE	MK	2,541	1,550	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	DE	MK		1,060	live	Commercial	
2015	*Testudo hermanni*	FR	MK	1,300	700	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	FR	MK		1,200	live	Commercial	
2015	*Testudo hermanni*	GB	MK	1,000		live	Commercial	Captive-Bred
2015	*Testudo hermanni*	GB	MK		1,000	live	Commercial	
2015	*Testudo hermanni*	HK	MK	7,600	3,700	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	HK	MK		3,500	live	Commercial	
2015	*Testudo hermanni*	JP	MK	770	670	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	JP	MK		100	live	Commercial	
2015	*Testudo hermanni*	KR	MK	50		live	Commercial	Captive-Bred
2015	*Testudo hermanni*	PL	MK	200	200	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	TW	MK		500	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	TW	MK		200	live	Commercial	
2015	*Testudo hermanni*	UA	MK		500	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	US	MK	1,330	1,080	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	US	MK		355	live	Commercial	
2015	*Testudo hermanni*	CZ	RS	150		live	Commercial	Captive-Bred
2015	*Testudo hermanni*	GB	RS	1,900	1,900	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	HK	RS	600	600	live	Commercial	Captive-Bred
2015	*Testudo hermanni*	HU	RS	300		live	Commercial	Captive-Bred
2015	*Testudo hermanni*	GB	TR	22	160	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	CL	MK	150	150	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	CZ	MK	2,300	2,300	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	DE	MK	2,700	3,300	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	FR	MK	970	1,970	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	GB	MK	3,200	4,000	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	HK	MK	14,600	16,100	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	JP	MK	562	582	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	KR	MK		40	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	TW	MK		300	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	US	MK	275	325	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	GB	RS	1,800	1,800	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	DE	TR		325	live	Commercial	Captive-Bred
2016	*Testudo hermanni*	DE	TR		230	live	Commercial	Ranched
2016	*Testudo hermanni*	FR	TR	50		live	Commercial	Captive-Bred
2016	*Testudo hermanni*	FR	TR		50	live	Commercial	Captive-Bred