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Insights from short-term post-fire monitoring of a population of Hermann's Tortoise, *Testudo hermanni* Gmelin, 1789, in Calabria, southern Italy

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Tortoises (family Testudinidae) are one of the most threatened group of vertebrates in the world (Rhodin et al., 2018; Stanford et al., 2018), including land tortoise species in the Mediterranean region of the genus *Testudo* Linnaeus, 1758. Although the Hermann's Tortoise, *Testudo hermanni* Gmelin, 1789, is widely distributed in the Mediterranean region, from Turkey to Spain (Bertolero et al., 2011), the nominal subspecies *T. h. hermanni* occurs only in Spain, France and Italy. The Italian peninsula is home to most of its populations, which are now fragmented and isolated (Corti et al., 2013), and classified as endangered by the IUCN (Rondinini et al., 2022). In southern Italy, the Calabria region represents one of the last refuges for a rich array of wildlife (Greco et al., 2018), including tortoises, largely due to the wilderness of many of its territories. Furthermore, recent genetic investigations have highlighted that this region is a hotspot of genetic diversity for the Hermann's Tortoise, hosting a unique genetic cluster with high values of both heterozygosity and allelic richness (Biello et al., 2021; Chiocchio et al., 2022). Despite their high conservation value, these populations, and others throughout their range, face numerous threats. Since the second half of the 20th century, the spread of urbanisation and intensive crops and farming importantly diminished the suitable habitat, as well as poaching (Graciá et al., 2020). However, fire has played a crucial role in making the sub-species endangered (Cheylan, 1984; Félix et al., 1989; Couturier et al., 2014): its impacts include both direct effects, such as mortality of individuals, and indirect effects, such as changes in the vegetation structure, decreased refugia availability and subsequent increase in predation risk, increased daily temperature fluctuations (Popgeorgiev, 2008).

The aim of this paper is to report some evidences concerning the impacts of a fire on a population of Hermann's Tortoise from southern Italy over a two-year period, detailing the morphological features of the surviving tortoises.

Materials and Methods

Field activities were carried out in a hilly area near Catanzaro (38.9083°N, 16.5901°E) in Calabria (southern Italy) (Fig. 1), not far from the Ionian Sea coast (about two kilometres). The study area is an open uncultivated valley of approximately 3 ha and the elevation range is 100–135 m (Fig. 1). The vegetation consists mainly of bushes of *Artemisia campestris*, *Pistacia lentiscus*, *Rubus* sp. some patches of ferns (probably *Dryopteris* sp.), growing on sandy soil. The study area, as well as the neighbouring hills, is periodically affected by fires of anthropogenic origin, probably to keep the area

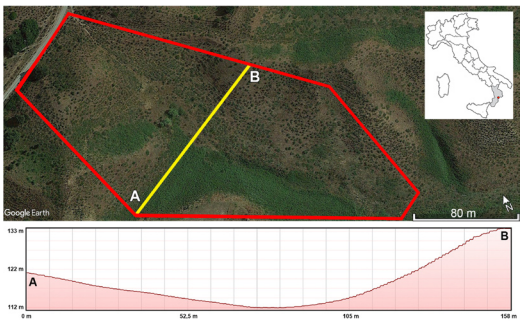

Figure 1. Above: study area in red and elevation profile line A-B in yellow. Below: elevation profile from point A to point B; the ordinate axis reports the meters above sea level, the abscissa axis reports the distance from point A.

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suitable for grazing.

The population was localised in July 2019, thanks to sightings of local people and following the umpteenth fire that devastated the valley (red polygon in Fig. 1). Data collection was carried out from July to September 2019, in May 2020 and from September to October 2020, with an effort of one person per two hours per session for a total of 19 sampling sessions (Table 1). Efforts were carried out with clear sky and no or weak wind, during the first (05:00–08:00 h) or last hours (17:00–19:00 h) of the day in summer and during the central hours (10:00–14:00 h) of the day in autumn. Tortoises were spotted by using a "visual encounter survey" technique during random walking (Stubbs et al., 1984). We recorded the following data from each individual: date and time of capture, coordinates, weather conditions, sex, straight carapace length, carapace width, carapace height, plastron length, plastron width, pectoral plate length, femoral plate length, tail length and weight. Length measurements were taken using a calliper with 1 mm accuracy and weight using an electronic balance with 1 g accuracy. Photographs of the front, back, upper, ventral and both sides of the shell were taken before tortoises were released at the same place of capture. All individuals found measuring at least 10 cm in straight carapace length were considered adults (Stubbs et al., 1984; Stubbs and Swingland, 1985). Sex was determined checking the sexual characters: long enlarged tails and concave plastron in males, short narrow tails, and flat plastron in females. Recaptures were verified using the software I^{3}S Pattern. As an index of population stability in *T. hermanni*, the ratio of juveniles to adult females was calculated, following Hailey et al. (1988), who reported values ranging from approximately 0.1 in highly disturbed sites to about four in protected areas. Statistical analyses were conducted on all morphometric parameters using PAST software (version 4.15). Prior to parametric testing, the assumptions of normality and homogeneity of variances were verified using the Shapiro-Wilk and Levene's tests, respectively; in all cases, *p*-values exceeded 0.05. Consequently, two-sample *t*-tests were applied to assess intersexual differences.

Table 1. Sampling sessions list with reported the number and type of tortoise sightings (F: females; M: males; J: juveniles; U: undetermined).

Date	Living					Dead				
	F	M	J	U	Total	F	M	J	U	Total
31/07/19	-	-	-	-	-	-	1	4	1	6
02/08/19	-	-	4	-	4	-	-	-	-	-
03/08/19	-	-	1	-	1	1	-	1	-	2
07/08/19	1	-	-	-	1	-	1	-	-	1
08/08/19	1	-	1	-	2	-	-	-	-	-
25/08/19	1	-	-	-	1	-	-	-	-	-
01/09/19	-	1	-	-	1	-	-	-	-	-
05/09/19	3	2	1	-	6	-	-	-	-	-
06/09/19	-	3	2	-	5	-	-	-	-	-
07/09/19	4	2	3	1	10	1	-	-	4	5
13/09/19	2	-	-	-	2	-	-	-	-	-
15/09/19	3	2	-	-	5	-	-	-	-	-
21/09/19	1	2	-	-	3	-	-	-	-	-
12/05/20	1	-	-	-	1	-	-	-	-	-
19/09/20	1	1	1	-	3	-	-	1	-	1
21/09/20	-	2	-	-	2	-	-	-	-	-
22/09/20	1	-	-	-	1	-	-	-	-	-
25/09/20	2	-	-	-	2	-	-	-	-	-
02/10/20	2	2	-	-	4	-	-	-	-	-

Results

A total of 69 tortoises were found between 2019 and 2020 (Table 1), of which 54 were living and 15 were dead (burned corpses, empty shells or parts of shells). Among the living tortoises 22 were females, 14 males, 13 juveniles and one undetermined (hidden in a large and dense bush of *Rubus* sp.). Thus, the percentage of observed juvenile individuals was 26%; three tortoises were recaptured multiple times (one juvenile captured two times, one male three times and one female two times).

Males were smaller than females in all considered parameters (except for the total tail length). Also, the length of the pectoral plate was found to be less than the length of the femoral plate in 94% of cases (only in two females the lengths were the same) (Table 2).

Discussion

The results of this study indicate that wildfires do not necessarily result in the death of all tortoises within affected habitats; even juveniles, despite being more vulnerable than adults, can survive in some cases. Despite the high impact of fire on tortoise habitats, particularly on juveniles (Stubbs et al., 1985; Hailey, 2000), the juvenile-to-adult female ratio in our study (0.6) remains relatively high, suggesting a degree of population resilience. The study area had also been affected by previous wildfires, as indicated by burn

Table 2. Morphometric data of a free ranging population of *Testudo hermanni* in Calabria (CL: Carapace Length; CW: Carapace Width; CH: Carapace Height; PL: Plastron Length; PW: Plastron Width; TTL: Total Tail Length; PPL: Pectoral Plate Length; FPL: Femoral Plate Length; W: Weight). Mean ± standard deviation in mm and g; minimum and maximum, and sample size are shown. *T*-values are reported; statistically significant differences ($p < 0.05$) are highlighted in bold.

	Males	Females	*T*	*P*
CL	118.14 ±9.23; 98–130 (14)	140.5 ±14.36; 109–158 (20)	5.1201	**0.0001**
CW	92.93 ±6.31; 79–101 (14)	106.2 ±8.36; 86–120 (20)	5.0169	**0.0002**
CH	58 ±3.49; 51–64 (14)	70.45 ±5.43; 59–77 (20)	7.5376	**0.0001**
PL	88.79 ±7.2; 77–102 (14)	116.6 ±10.24; 94–128 (20)	8.743	**0.0001**
PW	79.79 ±5.83; 70–90 (14)	91.55 ±6.89; 75–100 (20)	5.2068	**0.0002**
TTL	45.57 ±3.32; 40–50 (14)	30.3 ±4.89; 20–41 (20)	10.141	**0.0001**
PPL	6.36 ±1.22; 5–8 (14)	8.55 ±1.23; 7–11 (20)	5.1293	**0.0001**
FPL	9. 5±1.09; 8–11 (14)	11.4 ±2.11; 8–16 (20)	3.2572	**0.0022**
W	346.58 ±61.76; 244–447 (12)	618.3 ±144.47; 293–917(20)	6.1549	**0.0001**

marks in various stages of healing on the shells of some adult tortoises observed during the initial survey sessions (Fig. 2A), and confirmed by local people. Although the population appears to be demographically active and structured, considering the percentage of juveniles and the occurrence of all age categories (Fig. 2A–D), the ratio of juveniles to adult females shows that the population has started to decline most likely due to fires that are set too frequently to keep the pastures suitable. A high frequency of fires not only deviates rate mortality from physiological values (Fig. 2E, F), especially affecting juveniles ones (Stubbs et al., 1985; Hailey, 2000), but also destroys the habitat with such a recurrence that the tortoise population cannot recover (Couturier et al., 2014). The relatively high percentage of juveniles recorded in our study (26%) may be partly explained by increased detectability following the absence of dense vegetation. Notably, most juveniles were observed during the first year of sampling, when vegetation in the study area had been largely destroyed. In several studies carried out in the Italian peninsula, the percentage of juveniles found was below 7% (Tommasetti and Bossuto, 2000; Corti and Zuffi, 2003; Loy et al., 2007; Cutuli et al., 2013), only Filippi et al. (2010) recorded a percentage of 50% of juveniles in a growing population from the Tolfa mountains. Since recaptures have always been carried out a few tens of meters from the first sighting, it is possible to infer that tortoises occupy the same "home" sites also following catastrophic events such as fires that make the habitat unsuitable before the vegetation is restored.

The sizes of the tortoises found in this study, are among the smallest in Italy (Paglione and Carbone, 1990; Tommasetti and Bossuto, 2000; Corti et al., 2003; Corti and Zuffi, 2003; Loy et al., 2007; Giacalone et al., 2008; Filippi et al., 2010; Di Tizio et al., 2013; Cutuli et al, 2013) with an average length of 118.14 ±9.23 mm for males and 140.5 ±14.36 mm for females. Unlike the population of Hermann's Tortoise from Abruzzo region in which two tortoises were considered hybrid on morphological basis (Di Tizio et al., 2023), all tortoises found during the present study were characterised by the diagnostic morphological features of the nominal subspecies *Testudo hermanni hermanni* (Cheylan, 1981, 1984). In the studied population, the condition that the pectoral plate seam on the plastron is shorter than that of the femoral, which is the only measurable one, occurred in 94% of cases with a clear difference between the length of the two plate seams (for both sexes, Table 2). This condition has been verified in another population of *T. h. hermanni* from Latium, while in populations referable to the eastern subspecies *T. h. boetggeri*, as in Greece, the opposite situation occurs (Mazzotti et al., 2007).

Further studies aimed at detailing the population dynamic and identifying all the causes of decline are needed to implement useful conservation measures. Since the Calabria region is considered a hotspot of genetic diversity for the Hermann's Tortoise (Biello et al., 2021; Chiocchio et al., 2022), none of its populations should go extinction to avoid losing a part of unique genome mainly because the species is already considered threatened in the western part of its range.

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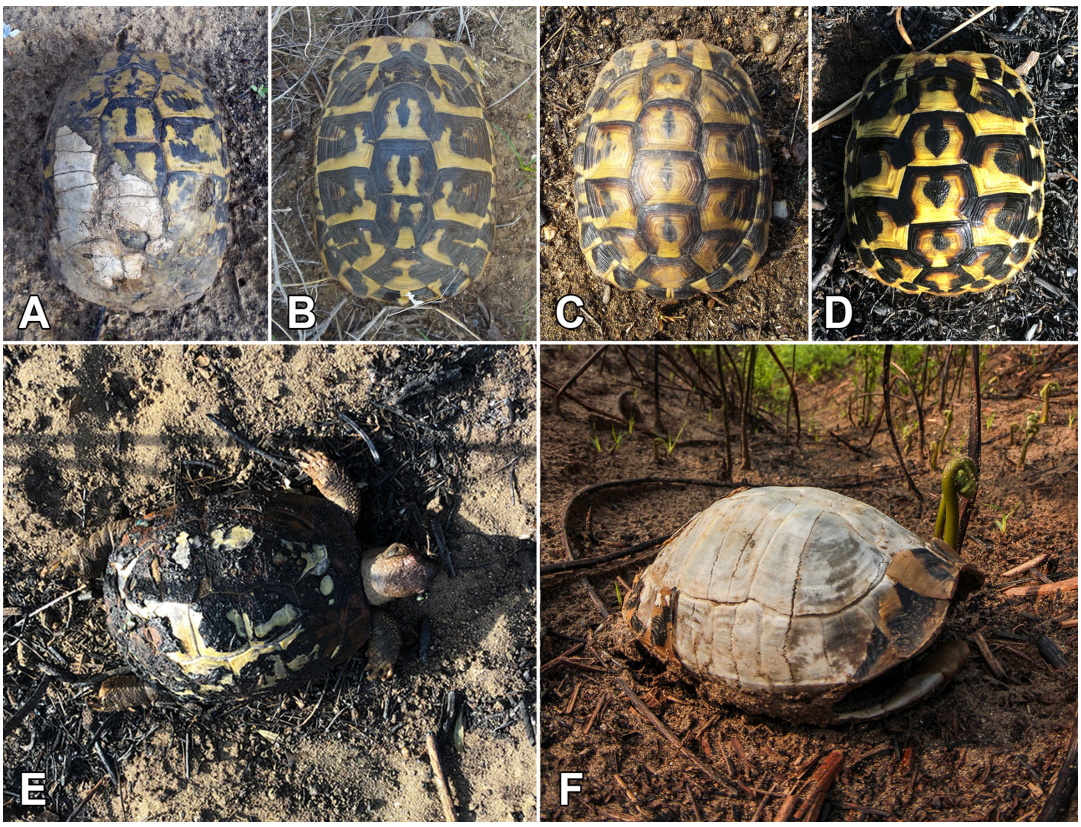

Figure 2. Specimens of different ages and some victims of fire (carapace length and weight are shown in brackets): (A) old female (158mm, 812g), (B) adult female (150mm, 692g), (C) sub-adult male (96mm, 186g), (D) juvenile (63mm, 51g); (E) corpse burned; (F) empty shell of a female. Photos by Francesco L. Leonetti (A, B, C, F) and Antonio G. Adamo (D, E).

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