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Density, Threats, and Conservation of Leopard Tortoises (*Stigmochelys pardalis*) in Ethiopia

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Abstract.—**Little published information has been available on the ecology and conservation of Leopard Tortoises (*Stigmochelys pardalis*) in Ethiopia. In this study, we undertook field surveys of tortoises at seven sites over 3 y (2015–2017) to provide a rough estimate of population density of the species. In addition, in 2019, we interviewed managers of wildlife protected areas in Ethiopia to explore the conservation and management status, population abundance, and threats facing the species in the country. We estimated mean density of Leopard Tortoises at 0.0343 ± 0.0048 (standard error) individuals per ha across all sites. We also confirmed that Leopard Tortoises occur in at least half of protected areas of the country. The majority of protected area managers reported their perception of the present population abundance of the species to be common and the population trend in the last 10 y to have been stable. While managers reported their response of the current population status of the species with relatively high certainty levels, they reported trends in abundance with relatively low certainty. Although managers perceived that trends in overall threats facing the species had been stable in the last 10 y, they reported this with low level of certainty. They also indicated, however, with high certainty, that current Leopard Tortoise hunting was occurring at an unprecedented rate. These findings may suggest that managers are more certain about current situations than about trends. In conclusion, our results provide basic information to aid management decisions and encourage future research.**

Key Words.—CITES; hunting; illegal trade; interview; management; manager perceptions; protected areas; traditional use

Introduction

Leopard Tortoises (*Stigmochelys pardalis*) are the most abundant and widely distributed member of the Testudinidae family in sub-Saharan Africa (Baker et al. 2015). They occur throughout the arid and Savanna regions of eastern and southern parts of Africa, from South Sudan and Somalia to Namibia and South Africa (Malonza et al. 2006; Baker et al. 2015; South African National Biodiversity Institute [SANBI]. 2019. Leopard Tortoise. Available from http//:www.sanbi.org/home/animaloftheweek/leopardtortoise [Accessed 25 April 2019]). The species is the most habitat generalist of any sub-Saharan tortoise species, inhabiting a range of habitat types, including Karroid Fynbos, mesic thicket, arid and mesic Savanna, Thorn Scrub, and Grassland (Mason et al. 2000; Malonza et al. 2006; Drabik-Hamshare 2016). Its altitudinal distribution is from sea-level to 2,900 m asl (Branch 2008).

Leopard tortoises have been subjected to various human actions, such as hunting and trapping for trade, livestock grazing, and habitat burning, all of which could cause significant changes in the distribution and abundance of the species across its range (Baker et al. 2015; Drabik-Hamshare and Downs 2017). The International Union for Conservation of Nature (IUCN) classifies the species as Least Concern, based on the criteria that the impacts of threats on populations are at low levels (Broadley 1989; Baker et al. 2015; IUCN 2019a); however, this status assessment was based on limited data from only a few countries (see Baker et al. 2015). This may obscure the true status of populations at national levels, some of which are significantly threatened due to various anthropogenic-induced factors (Baker et al. 2015; Drabik-Hamshare 2016; Tessema et al. 2019). Management decisions are often made nationally, but for many countries, there is little information and understanding of national-level distributions, population status, and threats to the species (Amir 2007; Baker et al. 2015). Updated, reliable scientific data across the range of a species, particularly in countries where data are deficient, will help identify populations at risk (Smith et al. 2011).

Ethiopia is one of the countries where little is known about Leopard Tortoise ecology, use, trade, and conservation. There are three main reasons, however, why increased knowledge is paramount for the conservation Leopard Tortoises. First, Ethiopia is among the countries with highest rate of human

population growth (about 2.89% per y in the last decade) in the world (The World Bank. 2019. Population growth (annual %) – Ethiopia. Available from https://data.worldbank.org/indicator/SP.POP.GROW?locations=ET [Accessed 5 November 2020]), leading to an increasing demand of land for cultivation, livestock grazing, and other forms of natural resources use. In the last three decades, natural ecosystems in Ethiopia, particularly protected wildlife areas (PAs), have rapidly changed due to expansion of industry (including sugar production factories and mining) and infrastructure (e.g., highway roads and railways; Berhanu et al. 2011; Tessema et al. 2019). These land uses have contributed to a high rate of ecological change that has not only severely affected biodiversity, but also the critical ecosystems that provide vital services to the wellbeing of people of the country (Berhanu et al. 2011; van Zyl 2012; Vreugdenhil et al. 2012; Tessema et al. 2019).

Second, Leopard Tortoises are among the wildlife species that Ethiopia currently offers to the international wild fauna trade (United Nations Environmental Program-World Conservation Monitoring Center [UNEP-WCMC]. 2013. CITES-Listed Species. Available from http://www.unepwcmcapps.org/citestrade [Accessed 25 April 2019]). The species is listed in Appendix II of the Convention on Trade in Endangered Species of Wild Fauna and Flora (CITES), a convention to which Ethiopia is signatory (CITES. 2019. Checklist CITES. Available from https://checklist.cites.org/#/en [Accessed 25 April 2019]). Basic knowledge and understanding of the ecology, management, and conservation status of the species in the country (Smith et al. 2011; CITES. 2019. *op. cit.*) is critical for both the CITES secretariat authorities and Ethiopian national CITES authorities to ensure effective implementation of the convention and its principles.

Finally, initiatives to conserve the biodiversity of Ethiopia were formally started in the late 1960s through the establishment of wildlife conservation areas such as national parks and sanctuaries (Vreugdenhil et al. 2012). To date, the country has established 73 protected areas under six categories (Table 1), covering about 9.32 million ha, accounting for about 8% of the total land mass of the country (Vreugdenhil et al. 2012; Gizaw and Gebretinsae 2019). Only two of the category types, however, offer effective protection: national parks (equivalent to IUCN PA category II) and wildlife sanctuaries (equivalent to IUCN PA category IV; Federal Democratic Republic of Ethiopia [FDRE] 2005, 2007, 2009; for definitions of the two categories, see IUCN 2019b). These PA categories have allocated basic resources (e.g., human, financial, and infrastructure) required for management and implementation of regular law-enforcement activities.

While the number and coverage of such PAs is increasing, the report by Tessema et al. (2019) on threats to wildlife across some key PAs of Ethiopia highlights the increasing practice of illegal trapping of leopard tortoises for trade. Such illegal harvesting and trade in the country is expected to grow in the future due to political instabilities in the Horn of African region, rapidly growing development of public infrastructures (e.g., road) across borders of Ethiopia and its neighboring countries, and growing influx of foreign investors to the country (Tessema et al. 2017). Our goal was to collect data on the ecology and conservation status of Leopard Tortoise in Ethiopia to provide support for effective management. The specific objectives were: (1) to provide a rough estimate of the density of tortoise populations at some specific sites; (2) to assess the current conservation status (protection status and management policies in place that assist to regulate the use of and trade in the species) in the country; and (3) to provide data on current threats facing the species in Ethiopia.

Table 1. Protected area categories of Ethiopia and their numbers, International Union for the Conservation of Nature (IUCN) category, and total area coverage of protected areas. See Gizaw and Gebretinsae (2019) for more information on each protected area category, and IUCN (2019b) for description of the IUCN category types. The abbreviation NA = not applicable.

Protected area category	Total number	IUCN category	Total area (ha)
National park	27	II	4,364,990
Wildlife sanctuary	2	II	704,100
Wildlife reserve	6	IV	1,882,954
Controlled hunting area	25	VI	795,005
Biosphere reserve	5	NA	1,434,875
Community conserv. area	8	VI	138,072
Total	73		9,319,996

Materials and Methods

Study area.—We conducted the study in Ethiopia, a landlocked country located in the Horn of Africa. With an area of 113 million ha and over 100 million people, the country is the 10th largest and 3rd most populous country in Africa. In general, the biogeography of Ethiopia is characterized by two dominant features: the ancient, arid areas of the Horn of Africa in the eastern, western, and northeastern parts of the country, and the mesic highland plateau in the southeastern, central, and northwestern parts of the country (Williams et al. 2004). Elevations range from 130–4,620 m. This high elevational and topographic variation and climatic variability contribute to the rich biodiversity and endemism characteristic of the country (Yalden and Largen 1992; Williams et al. 2004). Ethiopia includes two of the important global biodiversity hotspots as identified by Conservation International: the Horn of

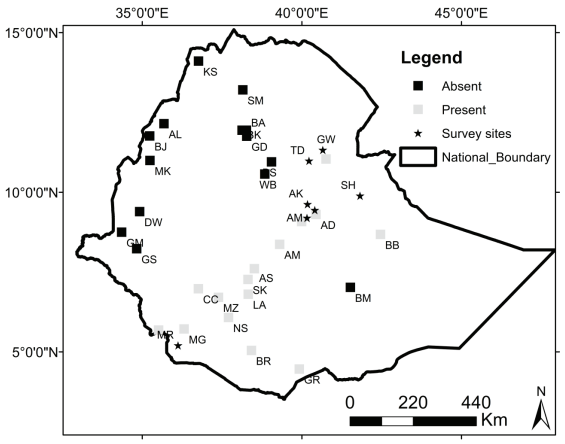

Figure 1. Central locations of the seven study sites where we conducted population surveys and the 29 formally managed protected areas (national parks and sanctuaries). Formally protected areas (grey squares) represent areas where presence of Leopard Tortoise (*Stigmochelys pardalis*) was confirmed and where we undertook in-depth interviews with managers about conservation status and threats to Leopard Tortoise in Ethiopia. Black squares are areas where the species was reported to be absent (see Appendices). See Table 2 for names of sites surveyed given by abbreviations.

Africa and Eastern Afromontane areas (Williams et al. 2004).

We conducted population surveys for tortoises at seven of the 25 (28%) wildlife-controlled hunting areas of the country, including Telalak Dawe, Blen-Ertalle, Shinille-Meto, Amibara, Gewane, Asbari Kebena and Murulle (Fig. 1, Table 2). Despite being situated in different regions of the country (see Fig. 1), the hunting areas were similar in elevation (500–700 m) and dominant vegetation types. The latter included wooded grassland, grasslands, Acacia-*Commiphora* bushlands and thickets, riverine thickets, and scrubland. The characteristic woody species are Black Thorn (*Acacia mellifera*), Gum-arabic Tree (*A. Senegal*), Umbrella Thorn (*A. tortolis*), Desert Date (*Balanitis aegyptica*), Garsa (*Dobera glabra*), Toothbrush Tree (*Salvadora persica*), and myrrhs (*Commiphora* spp). We conducted interviews of managers and experts to inquire about the population status of, and threats to Leopard Tortoises at 15 of the 29 PAs (national parks and sanctuaries). During the interviews, we compiled additional information about these PAs, including year of establishment, management authority (regional versus federal government authorities) and area coverage (Appendix 1).

Data collection.—We used three approaches to obtain data to estimate population density, determine the distribution pattern across PAs, and assess threats to Leopard Tortoise in Ethiopia. In the first approach, we collected population data during field surveys at seven wildlife controlled-hunting areas between 2015–2017 (Table 2) to provide a rough estimate of current population densities. We selected these sites based on our previous knowledge of presence of the species. At each site, we surveyed 2–4 transects, 2,000–10,000 m long each, giving a total length of 98,300 m across all sites (site mean ± standard error = 5,782 ± 606 m, n =17). We did not select transects randomly because of constraints of access, as portions of some of the sites were covered by swamps, rivers, or lakes. As leopard tortoises are not typically found in these wetland and aquatic habitats (Drabik-Hamshare 2016), don't think that this sampling strategy biases our results. Each transect covered only one habitat type (i.e., wooded grassland, grasslands, bushlands and thickets, or scrubland), and we maintained a minimum of 200 m distance between transect start or end points and habitat edges. We also maintained a minimum of a 300 m distance between adjacent transects to minimize the chance of double-counting tortoises on adjacent transects (Blomberg and Shine 1996). We used a Garmin Global Positioning System (GPS) unit to record the geographical coordinates of the start and end of each transect and to navigate each transect. Each transect consisted of a 120 m wide strip within which two persons walked in a zig-zag fashion, each covering a 60 m wide area along the transect strip. Transects were generally accomplished in 3–10 h. We surveyed only one transect per day, and depending on the number of transects it took us 2–4 d to survey each site. We recorded the number of tortoises observed on each transect and within each PA, but we did not record age/size or sex categories. We assumed that the detection probability was uniform across each two-person, 120-m wide transect and between observers. We also recorded opportunistic sightings of threats to the species (e.g., grazing, fire, mortality, invasive plant species, etc.).

The second approach comprised interviewing wildlife managers and experts (hereafter referred to as managers) to assess their knowledge and/or perceptions regarding to the presence-absence, population abundance, traditional use, and threats to Leopard Tortoises in and around PAs of the country. In April 2018, we consulted 27 wildlife managers and experts working in 20 PAs, three scientists conducting biodiversity research in Ethiopia, and an individual engaged in licensed international trade of tortoises to obtain preliminary information on the presence-absence of the species across the PAs of the country. These data helped us decide on which PAs to focus for subsequent, detailed interviews. Twenty-three experts reported their sightings of Leopard Tortoise in 15 PAs (13 national parks and two wildlife sanctuaries) and the researchers and the tortoise exporter we consulted also informed us of the absence of the species in the nine protected areas where we did not consult managers (Fig. 1, Appendix 1). We targeted these 15 PAs for detailed

Table 2. Description of transect length, sampled area (assuming a width of 60 m were covered on each side), total area, total number of tortoises observed, estimated density (number of individuals per ha) and period of survey at seven study sites (controlled hunting areas) where we surveyed for Leopard Tortoise (*Stigmochelys pardalis*) in Ethiopia. We provided geographical locations of the sites on Figure 1, and abbreviations given in brackets following each site name correspond to those used on Figure 1.

Site/transect code	Transect length (m)	Sampled area (ha)	Total area (ha)	No. observed	Density	Period of survey
Blen-Ertalle (BE)			82,400			May 2017
Bl-Ert T1	10,000	120		3	0.0250	
Bl-Ert T2	7,600	91.2		2	0.0219	
Murulle (MR)			38,400			April 2017
MUR_T1	6,000	72		1	0.0139	
MUR_T2	7,000	84		2	0.0238	
MUR_T3	3,000	36		0	0.0000	
ShinilleMeto (SH)			93,500			November 2015
Shin_T1	8,500	102		4	0.0392	
Shin_T2	4,500	54		2	0.0370	
Telalak-Dawe (TD)			50,000			December 2015
Tel_T1	6,000	72		3	0.0417	
Tel_T2	7,000	84		3	0.0357	
Asbari-Kebena (AK)			17,400			April 2016
Asb-Keb_T1	5,700	68.4		3	0.0439	
Asb-Keb_T2	10,000	120		5	0.0417	
Gewane (GW)			32,000			November 2015
GW_T1	4,000	48		2	0.0417	
GW_T2	7,500	90		4	0.0444	
GW_T3	3,500	42		2	0.0476	
GW_T4	3,000	36		0	0.0000	
Amibara (AM)			40,800			November 2015
AM_T1	3,000	36		3	0.0833	
AM_T2	2,000	24		1	0.0417	
Total	98,300	1179.6	354,500	40	N/A	

interviews (Appendix 2). For each area, we interviewed only one person (11 managers and four senior experts), all of whom were among those we initially consulted during the preliminary information gathering.

The interview comprised 25 questions organized in three sections: (1) basic personal information; (2) knowledge of the presence-absence, current population status, and population trend of Leopard Tortoise in or around the PA where the experts were working; and (3) knowledge or perceptions of the types and current levels of threats to the species at present, plus trends in the levels of threats. Regarding current population status, we first asked experts to comment on the overall population status as: abundant, common, or rare. To cross-check their responses, we then asked them the question: How many leopard tortoises would you see in the PA if you went out on a day? Similarly, we asked them to report population trends in the last 10 years on three scales (increasing, stable, or declining). Finally, we asked experts to list major threats to the species in their area and designate trends in the level of combined threats on three scales (present status: high, moderate, or low; trend: increasing, stable, or declining). We also asked the experts to explain how they derived their perceived responses. To assess the reliability of information obtained from the interview, we asked each manager to indicate the level of certainty associated with their responses to each relevant question as: high, medium, or low certainty (Pyhälä et al. 2018).

We informed interviewees of the nature and scope of the study and obtained Free Prior and Informed Consent from all experts. To ensure the anonymity of the individual experts and the PAs they represent, we also agreed that results would only be disseminated at an aggregated scale. The exception was the information on current hunting, trapping, and trade activities where

we received permissions from reporting experts and relevant PA managers to disclose names of the experts and the PAs. In this way, we followed the code of ethics of the American Anthropological Association (American Anthropological Association 2012).

In the third approach, we reviewed policy documents from the archive and websites of Ethiopian Wildlife Conservation Authorities to collate policy information related to use, management, and regulation of international trade in Leopard Tortoise from Ethiopia. We also accessed data on tortoise exports from Ethiopia for the last 15 y (2004–2018; CITES. 2019. CITES Trade Database. Available from https://trade.cites.org [Accessed 9 October 2019]) to assess trends in the trade of the species and the share of that trade in Ethiopia.

Data analysis.—We computed a rough estimate of Leopard Tortoise population density by dividing the number of animals observed in a given transect by the transect area. We determined the mean ± 95% standard error (SE) of the density of Leopard Tortoise based on pooled transect data across sites because our sample size at each site was too small (2–4 transects) to provide precise density estimates at the site level, or to make valid statistical comparisons among sites. Because data were determined to be normal using a skewness test (Quinn and Keough 2002), we computed a parametric mean of tortoise density.

To analyze interview data, we first coded all answers to numerical scores ranging between 1 and -1 (Pyhälä et al. 2018). Accordingly, for the question about current status of population abundance, we classified responses into three broad relative abundance categories: (1) abundant (usually encountered daily in numbers of > 10 individuals), (2) common (likely to be encountered daily, or during a short visit of 2–3 d period, in numbers of 5–10 individuals/time), and (3) rare (only occasionally seen, even during a long visit). Then, following Pyhälä et al. (2018), we assigned a numerical score value to each relative abundance category: abundant = 1, common = 0, and rare = -1. Similarly, for trends both in population and threat level, we assigned score values as: increasing = 1, stable = 0, and declining = -1; and for experts' certainty associated to their responses to each relevant question as: high = 1, moderate = 0, and low = -1. We then used bootstrap analysis (random resampling with replacement, based on 1,000 iterations) to calculate an overall mean ± 95% confidence interval (CI) score values of responses for managers for each question (e.g., population status, or threat level) and their certainty levels associated to each respective responses, following Pyhälä et al. (2018). We used non-overlapping of CIs of mean with zero as an estimate of how significant a reported perceived response to each relevant question (e.g., current population status/trend) could be considered high/increasing or low/decreasing at the national level (Laurance et al. 2012; Pyhälä et al. 2018). For example, if our computed mean score for tortoise population trend was 0.5 ± 0.3, then we assumed that the population would have a significant increasing population trend; if 0.2 ± 0.4, a stable trend; and if -0.5 ± 0.4, a significant declining trend (after Pyhälä et al. 2018). We compiled any textual notes captured during the fieldwork and interviews and used to assist in explaining the results in the Discussion. We carried out all statistical analyses in SPSS version 20 (SPSS Inc., Chicago, Illinois, USA). Where applicable, we computed means along with their 95% SE or 95% CI and used One Sample *t*-tests, at 0.05 alpha levels.

To evaluate the current protection and management (conservation) status of Leopard Tortoise in Ethiopia, we assessed distribution of the species across PAs of the country with effective protection in place. We made this assessment based on the responses of managers and consultations with researchers and tortoise exporter. We counted the number of PAs where we confirmed the presence of the species and computed the percentage of these PAs to the total number of such PAs in the country. We mapped the distribution of Leopard Tortoise across the PAs using ArcGis version 10.4 (Esri, Redlands, California, USA). We also analyzed policy information related to use, management, and regulation of international trade in Leopard Tortoise from Ethiopia.

Results

Population densities.—We encountered 40 Leopard Tortoises on 15 of 17 transects (88%), with the number of tortoises per transect ranging from 1–5 individuals and mean = 2.40 ± 0.33 tortoise per transect (Table 2). Pooling all transects across sites, our estimated mean density of Leopard Tortoise was 0.0343 ± 0.0048 individuals per ha; range, 0.0139–0.0833 individuals per ha.

Respondents characteristics.—The 15 managers we interviewed for the study comprised: (1) four (27%) experts and 11 (73%) wardens/managers; (2) six (40%) and nine (60%) B.Sc. and M.Sc. holders, respectively; and (3) seven (47%) with working experience of < 5 y, six (40%) 5–10 y, and two (13%) ≥ 10 y. Only one female (a manager) was available for interview, and nearly a half of the interviewees had previous experiences of working in one or more PAs other than the one where they were working during the study period.

Perceived current status and trends in population abundance.—The majority of managers (13 of 15; 88%) reported their perception of current population abundance of the species to be common, with CIs of

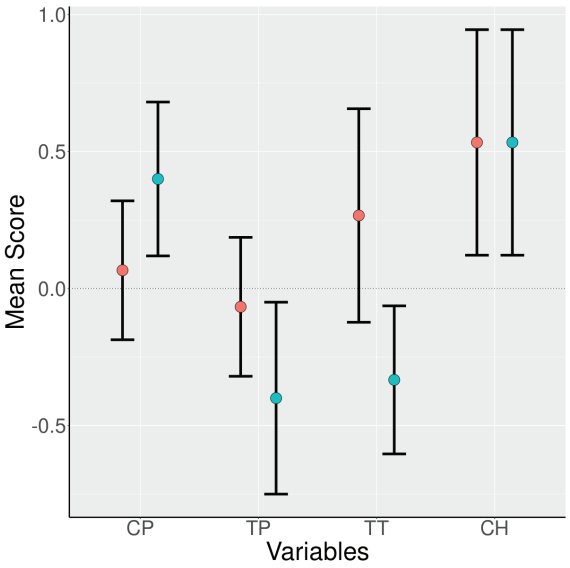

Figure 2. Mean score (± 95% confidence interval) of perceived responses and associated certainty levels by managers of current population abundance (CP), trend in population abundance (TP), trend in overall threat level (TT), and current hunting level (CH) of Leopard Tortoise (*Stigmochelys pardalis*) in Ethiopia. Red symbols are Response and green symbols are Certainty by managers (see Methods). In all cases, scored values ranged from low (−1) to high (1) as reported by protected area managers. Where lines do not cross the zero (dashed) line, reported perceptions or certainty levels of managers were significantly low or high. In all cases, n = 15.

mean response scores overlapping with zero (0.0667 ± 0.200; $t = 0.564$, df = 14, $P > 0.050$). Managers reported this with high (eight, 53%) or medium (four, 30%) score values of certainty (mean = 0.400 ± 0.200; $t = 3.055$, df = 14, $P < 0.050$; Fig. 2). Nearly all of the managers (93%) indicated that the species population trend in the last 10 y has been stable, with CIs of the mean overlapping with zero ($t = -0.564$, df = 14, $P > 0.050$; Fig. 2). They attributed this perception of stable trend to the fact that threats to the species have not been high so far; however, two-thirds of the managers (67%, n = 15) reported their perceived trend with significantly low levels of certainties (mean = -0.400 ± -0.200, $t = -2.450$, df = 14, $P < 0.050$; Fig. 2).

Traditional uses.—Thirteen protected area managers and experts (87% of respondents) indicated that they knew that some urban dwellers in Ethiopia formerly kept or still keep tortoises inside their compounds as pets, and four (27%) indicated people held beliefs that tortoises attract good fortunes (if someone keeps tortoises inside her/his compound, she/he will get richer). Four managers also reported that members of some tribes (e.g., the Mursi tribe) living around Omo and Mago National Parks, both in the southern Ethiopia, sometimes kill tortoises to use the empty shells as cowbells.

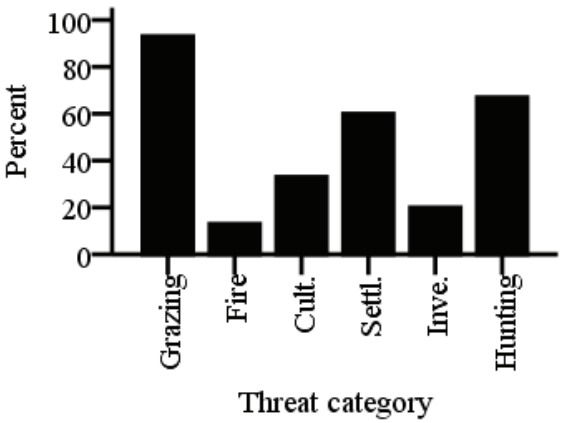

Figure 3. Major types of threats to Leopard Tortoise (*Stigmochelys pardalis*) population across protected areas of Ethiopia and percentage of protected area managers reporting each threat factor (n = 15). Abbreviations are Cult. = cultivation, Settl. = settlement, and Inve. = investment expansion).

International trade.—Based on CITES trade data, Ethiopia has offered under legal procedures 2,255 tortoises to the international trade market in the last 15-y period (2004–2018), on the average exporting 161 ± 44 animals (range, 15–506 individuals) annually. So far, only 147 (7%) exported animals, all in 2015, were from a farm, indicating that exportation of tortoises for trade from Ethiopia mainly relies on collection of wild populations.

Other threats and trends.—PA managers reported that the major threats to Leopard Tortoise populations in Ethiopia were livestock overgrazing, fire, expansion of state investment farms, subsistence cultivation expansion, and hunting and trapping for traditional uses and for the legal and illegal pet trade. Some of these threats appeared to be widespread, almost occurring across the whole range of the species, including livestock grazing as reported by 93% of managers (14 of 15 managers), settlement expansion reported by 60% of managers (nine of 15), and hunting and trapping by 67% (10 of 15). Other threats occur either at moderate to low levels or are localized (e.g., subsistence cultivation expansion and investment expansion; Fig. 3). Ten (67%) managers expressed their critical concerns on the current unprecedented rate of collection of adult tortoises by people in local communities as an emerging threat to the species. According to comments by managers, people in local communities offer trapped tortoises for sale to foreign contractors of Chinese origin working in the country who want the animals for consumption and international trade. The average score of responses by managers of the current level of hunting / trapping of Leopard Tortoises indicated these activities to be occurring significantly at high levels (mean = 0.533 ± 0.333, $t = 2.779$, df = 14, $P < 0.050$; Fig. 2). They

reported this with a high level of certainty associated to their perceived responses (t = 2.779, df = 14, P < 0.050). The perception by 47% of managers (seven of 15) of trends in overall threats (considering all threat types together) to Leopard Tortoises indicated threats to be stable or increasing by 40% of managers (six of 15), with the mean response score including zero (t = 1.468, df = 14, P > 0.050). Levels of certainty associated with their responses, however, were rated significantly at low levels by 33% of managers (five of 15) or moderate levels by 67% (10 of 15; t = -2.646, df = 14, P < 0.050; Fig. 2).

Leopard Tortoise distribution.—Based on data obtained from experts, in addition to the seven wildlife-controlled hunting areas we surveyed, we found that Leopard Tortoises occurred in 52% (15 of 29) PAs of Ethiopia that currently have functional management units. These PAs comprise 48% (13 of 27) of national parks and two wildlife sanctuaries (Fig. 1).

Discussion

Population densities.—Our estimated mean density of 0.0343 (range, 0.0219–0.0833) individuals per ha of Leopard Tortoises across the study sites falls within the range of density values previously reported for this species (Mason et al. 2000; McMaster and Downs 2006) and for other similarly sized tortoise species from elsewhere in Africa (Petrozzi et al. 2018). Despite this, our density estimate is very low compared with reports from some areas, but similar to reports from some other areas. In South Africa, for example, Mason et al. (2000) reported a density of 0.85 Leopard Tortoises per ha in the Eastern Cape, but McMaster and Downs (2006) reported a mean of 0.01 individuals per ha in the semi-arid Nama-Karoo region. The African Spurred Tortoise (*Centrochelys sulcata*) is a large-sized African species similar in size to Leopard Tortoises. It inhabits savannah habitats similar to those occupied by Leopard Tortoises in our Ethiopian study sites. Petrozzi et al. (2018) reported mean densities as low as 0.0021 individuals per ha in Burkina Faso and as high as 0.1670 individuals per ha in Niger. McMaster and Downs (2006) suggest that Leopard Tortoise population numbers in savanna or semi-arid biomes, such as our study sites, are expected to be lower than estimates of densities in the more mesic habitats (e.g., Ethiopian Highlands and Thicket biome of South Africa) where fire is not a dominant component of ecosystems.

We conducted our surveys in the dry season (November or December) or at the on-set of the wet season (April and May) when tortoises are generally thought to be less active above-ground compared with the wet season (Drabik-Hamshare 2016). We could not avoid this timing as most of the sites were difficult to access by vehicle during the rainy season. This might have led to us missing tortoises in the field, resulting in an underestimation of tortoise densities (see McMaster and Downs 2006). We also recognize that our data collection method, and thus our density estimation method, did not take into account differences in detectability between sexes and age/size groups and between habitat types. Similar studies have reported that detectability of Leopard Tortoises varies with sex and age/size of animals of the species (Kabigumila 2001; McMaster and Downs 2006). Therefore, our density estimates are likely to be low, and should be viewed as conservative numbers. Despite this, our density estimates are sufficiently similar to other studies and represent the only published report for Ethiopia. Hence, our findings can guide informed management decisions and stimulate further research in relation to the ecology and conservation of the species.

Perceived current population abundance and trends.—PA managers reported current abundance with high levels of certainty, but trends in population with low levels of certainty. This inconsistency in the certainty levels may suggest that the managers have better knowledge about the current abundance of the species than trends. This low level of manager certainty, and thus their low levels of knowledge about trends in abundance of the species could be attributed to the fact that most of the managers (87%, n = 15) have been working in their respective PAs for fewer than 10 y.

This higher level of certainty in evaluating current situations as opposed to long-term trends is also true of experts (Laurance et al. 2012; Gardner et al. 2013; Pyhälä et al. 2018). Such low levels of uncertainty in assessing trends is due to insufficient, or apparent lack of, long-term monitoring of tortoises populations and the nature and impacts of threats they might have encountered in the PAs (Gardner et al. 2013; Pyhälä et al. 2018). Thus, in line with the suggestions of Laurance et al. (2012), Cook et al. (2014) and Pyhälä et al. (2018), our results indicate that information acquired from PA managers could be useful to make assessments of current situations, but may not permit long-term evaluation of trends in population of Leopard Tortoise and threats to the species.

Perceived current and trends in threats.—While PA managers indicated their perceived current level of hunting and trapping for trade and illegal collections to be high, with a high level of certainty, their certainty was low for overall threats. In addition, some comments by managers, and our field surveys of wildlife-controlled hunting areas also indicate that Leopard Tortoises in Ethiopia are currently facing different types of threats,

including livestock overgrazing, fire, expansion of alien invasive plant species, and investment expansion. These threats result in ecosystem conversion and degradation (Milton 1992; Kabigumila 2001; Baker et al. 2015), which, in turn, have adverse impacts on population of the species in the long-term. For example, at three (Blen-Ertale, Shinile-Meto and Telalak-Dewe) of the seven sites where we undertook field survey of tortoises, we recorded two invasive alien plant species, Mesquite (*Prosopis juliflora*) and Parthenium Weed (*Partenium hysterophorus*) in high abundance. Past studies from the present study sites (Beyene 2010; Asefa et al. 2017a), particularly from those sites located in the north-eastern Ethiopia, reported the dominance of these alien invasive species. The dominance of these invasive species, which has been considered as one of the major ecological and socio-economic concerns in the region, has been attributed to the fostering effects of intensive livestock grazing on the expansion of these exotic plant species (Asefa et al. 2017a).

We recovered six carcasses of tortoises at Blen Ertalle hunting area in the north east Ethiopia during the field survey, four of which we thought died from fire, and two from predation. Human-induced fire in Ethiopia (Hailu et al. 2015) and across Africa (Petrozzi et al. 2017) is a predominant component of semi-arid and savanna habitats in for livestock preferential grazing. In addition to directly causing animal mortalities, many reports have shown the indirect deleterious effects of fire on several tortoise species globally, including Leopard Tortoises, by reducing vegetation cover, altering the composition of diets, and increasing predation risk (Esque et al. 2003; Baker et al. 2015; Petrozzi et al. 2017).

Some experts we interviewed suggested that the current intensification of state farms and the associated change in socio-economic activities of local communities has become a new threat to Leopard Tortoises in Ethiopia (see also Tessema et al. 2019). For example, following the establishment of the Omo Kuraz sugar factory in the lower Omo valley (southern Ethiopia) in 2011, a portion of the Omo National Park was converted to sugarcane plantation and irrigation canal, leading loss of about 73,000 ha of pristine wildlife habitat in the park. Tortoises were among the most impacted animals (Gebre and Nega, unpubl. report; Tsegaye et al., unpubl. report; Tessema et al. 2019).

Trade.—The practice of traditional use of Leopard Tortoises in Ethiopia is low compared with in other African countries, such as in Zambia (Lambert 1995), where some ethnic groups hunt the tortoises for consumption and in Tanzania (Kabigumila 1998) and in Somalia (Amir 2007) for traditional medicinal purposes. None of our respondents informed us, however, of tortoise collection for such traditional uses (i.e., consumption and medicinal uses) in Ethiopia (but see Baker et al. 2015), except the use of their shells for cow-bell, which has been practiced only locally and seems to have little impact. By contrast, a commonly known trade in Leopard Tortoises in Ethiopia has been a collection of animals by local communities for sale to local urban dwellers who want them as pets. Legal exportation of tortoises from Ethiopia for international trade was officially started in the early 2000s, with the annual quota allocation steadily increasing from three animals in 2002 to about 500 animals in 2018 (CITES. 2019. *op. cit*). More recently, the expansion of foreign investment in the country has been accompanied by the intrusion of non-native people, mainly of Chinese origin (Vigne and Martin 2008), into remote wilderness areas, which has stimulated mass harvesting of tortoises for illegal trade (Tessema et al. 2019). Although we currently lack definitive evidence on the extent of collection and trade in the species, and the associated impacts in Ethiopia, unsustainable harvest for the pet trade has resulted in declines in populations of tortoises in some areas of East Africa (Baker et al. 2015) and in Vietnam (van Thong et al. 2019). Given the growing demand of tortoises on the global market (Luisell et al. 2016), ongoing habitat conversion in Ethiopia (Tessema et al 2019), and other threats, the increasing trend of illegal harvesting could have a significant impact on the population of the species in the country. Enhancing law enforcement activities and public awareness education are required to reduce illegal hunting in Ethiopia, particularly at sites where tortoise harvesting at present is considered a serious problem.

Conservation and management.—Leopard tortoises are protected in over a half of the effectively managed PAs of the country throughout its range. The results of our surveys in the wildlife-controlled hunting areas and our interviews of managers of the PAs demonstrate that the species has continuous distribution range, spanning areas in the Rift Valley and east of the Rift Valley regions. Although the percentage of the population currently in these PAs and the total tortoise density in the country are unknown, occurrence of Leopard Tortoises in several PAs of Ethiopia, including national parks and wildlife sanctuaries, may indicate that the species conservation is favorable. Among the Ethiopian PA categories, national parks and wildlife sanctuaries are relatively well protected from human interference through daily ranger patrolling (Vreugdenhil et al. 2012). In addition to protecting their habitats from human activities, game rangers routinely monitor illegal trapping and hunting; however, many of the key PAs in Ethiopia have been affected by human-mediated pressures (Jacobs and Schloeder 2001; Tessema et al. 2019). Few comparative studies exist in assessing the

efficacy of PAs in better conserving wildlife compared with the surrounding unprotected areas (Asefa et al. 2017b). Thus, we are currently unsure of how effectively PAs safeguard Leopard Tortoises and their habitats from the multifaceted threats to the species compared with the other PA categories (e.g., controlled hunting areas) where little to no law enforcement activities are in place. Future studies assessing whether PAs have benefited conservation of tortoises would provide better insight into the protection status of the species in the country. Also, we do not know why the species does not occur in the other 14 PAs. It could be due to historical absence (as a result of lack of suitable habitat) or extirpation. By overlying the map of current knowledge of geographical and elevation distribution ranges and habitat requirements of the species with existing elevation and geospatial map layers of the major habitat types for the country, we estimate that Leopard Tortoises may occur at 64% (16 of 25) of the controlled hunting areas (unpubl. data). This needs to be verified based on further fieldwork.

There are also some administrative tools controlling trade. At the national level, Ethiopia's wildlife laws (FDRE 2005, 2007, 2009) protect the species by restricting harvesting to legally designated controlled hunting areas and ranches where tortoises are captive-bred. At the international level, Ethiopia is signatory to the CITES convention and has enacted a national law in 1989 to implement the convention (The People's Democratic Republic of Ethiopia 1989), which has been in effect since then. The Ethiopian Wildlife Conservation Authority is acting both as management and scientific authorities and monitors all exportation processes according to the regulations, such as export permit licensing systems. The presence and effective implementation of these regulatory systems will likely result to a sustainable annual export of wild individuals for trade and persistence of viable population of the species (see Petrozzi et al. 2017); however, little progress has been achieved in initiating captive-bred ranching and only one ranch has been established in the country so far (Sisay Taye, pers. comm.). So, exporters collect tortoises primarily from the wild, possibly posing detrimental conservation challenges. Tortoise ranching should be further assessed and may need to be expanded to reduce the current dependence on wild populations for trade. Future conservation and research actions should focus on species harvest and trade management by assessing and initiating the establishment of ranches, and monitoring trends in populations, threats, harvest levels and trade. Likewise, continued investigation of the species distribution, density, and demographics (including both protected and unprotected areas) and the percentage of the population existing in protected or regulated areas would inform concerned authorities make effective decisions on conservation and management of the species.

Conclusion.—We have demonstrated that heightened threats, even in the face of perceived stable populations, may have substantial impacts to Leopard Tortoises in Ethiopia. Our results can serve as a foundation for further investigation on the ecology and conservation needs of the species in Ethiopia, and also inform Ethiopian conservation agencies to plan for mitigation of the key threats currently facing the species, including poaching and trade/trafficking. In Ethiopia, animals for trade are currently harvested from the wild, but such dependence on wild population for trade, although the extent of trade is at low level so far, can have undesirable consequences on the population in the long-term (Baker et al. 2015). Thus, tortoise ranching in the country is an option that should be investigated to reduce the pressure on wild populations for trade and its potential impacts on population dynamics of the species. Because poorly implemented tortoise ranching may fail to sustain tortoise export trade, and may have disastrous consequences on the species (Greig 1979; Brautigam 1994; Kabigumila 1998), the establishment of tortoise ranching in Ethiopia should be executed carefully based on a policy formulated to guide farming activities. Enhancing law enforcement activities and public awareness, research on the extent of species occurrence and extent of illegal collection of the species, and developing and implementing systems for monitoring populations, habitat and threats of the species across its range in the country would be crucial to inform effective management and sustainable use of the species.

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Appendix 1. List of protected areas (national parks and wildlife sanctuaries) where we conducted interviews with managers and experts about population status and threats to Leopard Tortoises (*Stigmochelys pardalis*) in Ethiopia, and description of year of establishment, area (in ha), governance type (Federal vs Regional authorities) and presence/absence of Leopard Tortoise in each protected area. Abbreviations we gave in brackets following the name of each protected area denote those we used on the map shown on Figure 1. An asterisk (*) denotes those protected areas where we did not conduct interviews during the first phase of the study but obtained information on the presence-absence of the species from external experts.

Protected area	Year established	Area (ha)	Governance/ Management	Presence of tortoise
Abiata-Shalla Lakes National Park (AS)	1971	88,700	Federal	Present
Alledeghi National Park (AD)	2011	110,000	Federal	Present
Arsi Mountains National Park (AM)	2011	93,100	Regional	Present
Awash National Park (AW)	1966	75,600	Federal	Present
Babile Elephant Sanctuary (BB)	1970	698,700	Federal	Present
Borana National Park (BR)	1986	250,000	Regional	Present
Chebera-Churchura National Park (CC)	2005	119,000	Regional	Present
Gibie Sheleko National Park (GS)*	2009	24,800	Regional	Absent
Geraile National Park (GR)	2006	355,800	Federal	Present
Kafta-Sheraro National Park (KS)	2007	500,000	Federal	Absent
Loka Abaya National Park (LA)*	2009	50,000	Regional	Present
Mago National Park (MN)	1979	194,200	Regional	Present
Maze National Park (MZ)	2005	20,200	Regional	Present
Nech Sar National Park (NS)	1974	51,400	Federal	Present
Omo National Park (ON)	1967	356,600	Federal	Present
Seneklele Swayne's Hartebeest Sanctuary (SK)	1972	5,400	Federal	Present
Yangudirasa National Park (YR)	1977	473,100	Federal	Present
Alitash National Park (AL)*	2005	266,600	Federal	Absent
Bale Mountains National Park (BM)	1970	220,000	Federal	Absent
Bahrdar Tekur-Abay National Park (BD)*	2016	472,900	Regional	Absent
Bijmize National Park (BZ)*	2015	182,000	Regional	Absent
Borena Saynt National Park (BS) *	2008	432,500	Regional	Absent
Dati Welel National Park (DW)	2006	43,100	Regional	Absent
Gambella National Park (GM)	1974	506,100	Federal	Absent
Maokomo National Park (MK)*	2016	230,400	Regional	Absent
Semien Mountains National Park (SM)	1967	41,200	Federal	Absent
Weleka Beto and Abay National Park (WA)*	2017	19,500	Regional	Absent
Bakusa National Park (BK)*	2012	44,700	Regional	Absent
Godebie National Park (GD)*	2017	18,700	Regional	Absent

Appendix 2. Questions we asked wildlife experts working in protected areas of Ethiopia to assess Leopard Tortoise's current and trend in population number, traditional use and trade, and major threats to the species.

Date _____

Section 1. Respondent's Personal information

1. Respondent's name _____
2. Protected area name _____
3. Education level _____
4. Number of years served in the protected area _____
5. Current job position _____
6. Previous experience of working in other PAs (yes/no; and if yes, where and how long in each PA?)

(a) PA 1_____ year: from _____to _____
(b) PA 2_____ year: from _____to _____
(c) PA 3_____ year: from _____to _____

Section 2. Knowledge and perception about Leopard Tortoise population status

7. Have you ever seen Leopard Tortoise in and around the protected area where you are working at present: (a) yes (b) no
8. What do you think of the overall current status (abundance) of the species in/around the protected area you are working? Please use the following ordinary scales to score your response: (a) (very) abundant; (b) common; (c) uncommon; (d) rare/very rare.
9. How many leopard tortoises would you see if you went out on a day?
10. What is the level of your certainty for your response to question no. 8/9 above?

a) high b) medium c) low

11. What is your justification for your response to question no. 8 above?
12. What do you think about the trend in population size of the species in the area in the last 10 years? Please use the following ordinary scale for your response:

a) increasing b) stable c) declining

13. What is the level of your certainty for your response to question no. 12 above?

a) high b) medium c) low

14. What is your justification for your response to question no. 12 above?

Section 3. Threat and use assessment

15. What do you think are the main threats to the species in the area?
16. What is the trend in overall (all threats combined) status of the threats in the last 10 years?

a) declining b) stable c) increasing

17. What is the level of your certainty for your response to question no. 16 above?

a) high b) medium c) low

18. What is your justification for your response to question no. 16 above?
19. Do you know any traditional use of the species by local communities? a) Yes b) no
20. If yes to question no. 18, what are the uses (medicine, food, pet, etc) and which part of the tortoise is used?
21. Do people in the area practice hunting/trapping of the species for trade, and if yes, to whom do they sell their catch?
22. What is the price of sale per tortoise?
23. What do you think of the trend in practices of hunting/trapping of the species for illegal trade in the last 10 years?

a) declining b) stable c) increasing

24. What is the level of your certainty for your response to question no. 23 above?

a) high b) intermediate c) low

25. What do you think are the reasons for your response to question no. 23 above (the trend the declining, stability, or increasing trend of trapping for illegal trade)?