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Trade in spur-thighed tortoises *Testudo graeca* in Morocco: volumes, value and variation between markets

Vincent Nijman*, Daniel Bergin

Abstract. Until the late 1970s spur-thighed tortoises *Testudo graeca*, endemic to the Mediterranean region, were exported from range countries in large volumes for the pet trade. *Testudo graeca* was included on CITES Appendix II in 1975, and in 1978 Morocco introduced national protection, banning domestic and international trade. However, the species is still openly traded in Moroccan markets. In 2013-2014 we conducted 48 surveys in 20 Moroccan towns and cities and single surveys in two Spanish exclaves to assess trade levels, size-composition, turnover, and variation between cities. We recorded 3267 *T. graeca* in 107 shops in 12 cities. Of 989 tortoises measured, two-thirds measured <10 cm (~2-8 years of age) and <3% could comprise first-year individuals. There is a clear relationship between price and size, with 'average' tortoises costing USD 9.20. The largest volumes were observed in Tangier (869) and Rabat (752), two cities that are well-connected centres of export. The largest proportion of shops selling tortoises was in Agadir (78%) and Fez (63%), and turnover was highest in Tangier (32/week) and Casablanca (28/week). Country-wide turnover was ~30% after two weeks and ~80% after 10 weeks. Annual turnover was estimated at 3500-7000 tortoises, with a monetary value of USD 30 000-60 000. Predictors for volumes of trade and proportion of shops selling tortoises are: the number of wildlife shops in markets, diversity of wild vertebrate species the shops have on offer, and city population. While legal, large-scale international trade of spur-thighed tortoises from Morocco has diminished over the last decades, domestic smaller-scale trade continues to impede their conservation. Consistent punitive measures are required to enforce new laws.

Keywords: CITES, conservation management, domestic markets, legislation, reptile, wildlife trade.

Introduction

The removal of tortoises from the wild to fulfil market demand is widespread but may have historically been overlooked as a conservation concern because off-take levels were assumed to be insignificant compared to the rate of replenishment (Schlaepfer, 2005). Trade in tortoises has led to extinctions or near-extinctions in the past (Honegger, 1981; Juvik et al., 1981; van Dijk et al., 2000; Rhodin et al., 2008), and over-exploitation for trade, coupled with habitat loss and anthropogenic disturbance, continues to have severe negative effects on chelonian populations worldwide (Auliya et al., 2016). Tortoises are traded for a variety of reasons, including for food (Smith, 1974; Cheung and Dudgeon, 2006), medicine (Alves and Santana, 2008; Chen et al., 2009) and as pets (Swingland and Klemens, 1989; Gibbons et al., 2000). The tortoise pet trade has both domestic and international components, with animals collected locally and kept as pets (Ceballos and Fitzgerald, 2004; Pérez et al., 2004) or exported in significant numbers to meet demand from abroad (Soorae et al., 2008; Gong et al., 2009; Auliya et al., 2016). While it had been thought that this trade flows mainly from the species-rich but resource-poor tropics and subtropics to the species-poor but resource-rich temperate regions (Auliya, 2003), increasingly it is becoming clear that there is also a considerable trade in tortoises within the tropics and subtropics (Nijman and Shepherd, 2007, 2014; Gong et al., 2009; Anon, 2016).

Tortoises from the Mediterranean (genus *Testudo*) have been kept as pets as far back as Greek and Roman times (Lazenby, 1949) and spur-thighed tortoises *T. graeca* were traded internationally for commercial purposes at least as far back as the 1800s (Inskipp and Wells, 1979). We here report on the trade in spur-thighed tortoises within Morocco, a country that in the 1950s,

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‘60s and early ‘70s exported tens to hundreds of thousands of tortoises each year to supply the international pet trade (Lambert, 1969; Inskipp and Wells, 1979; Highfield and Bayley, 1996). In 1965, Morocco tried to regulate this trade by imposing size restrictions on the tortoises to be exported of between 10 and 15 cm plastron length (Lambert, 1969; Inskipp and Wells, 1979) coinciding with carapace lengths of around 11-17 cm and ages of approximately 5 to 12 years (cf. Turkozan et al., 2003; Znari et al., 2005). In 1978, Morocco banned the large-scale exploitation (and commercial export) of spur-thighed tortoises altogether (Highfield and Bayley, 1996). Over the last 25 years all legal exports of tortoises from Morocco have been for non-commercial reasons (e.g. exchanges between zoos, or private owners taking their tortoise with them across the border) and on average involves about a dozen tortoises a year (V. Nijman, unpubl. data based on CITES trade data).

The global distribution of *Testudo graeca* ranges from Morocco in the west to eastern Iran (Fritz et al., 2007), with three subspecies recognized in Morocco, i.e. *T. g. graeca* (in the northeast), *T. g. marokkensis* (in the north) and *T. g. soussensis* (in the west) (Fritz et al., 2009). In Morocco spur-thighed tortoises face a variety of threats including habitat destruction and habitat alteration, higher road mortality rates resulting from increased road density, and trade (Gibbons et al., 2000; El Mouden et al., 2005). Perez et al. (2012) modelled the effects of exurban sprawl on spur-thighed tortoises in southeast Spain and found that they are very sensitive to pet collection and to an increase in the number of large residential settlements. However, despite legal protection and low levels of legal international trade, illegal exploitation to supply domestic and international pet trade continues and may pose a threat to the survival of the species in Morocco, as it does in Spain (Perez et al., 2012).

Morocco, situated on the northwest coast of Africa, as little as 8 miles from the Spanish mainland, is easily accessible from Europe by airplane, ferry or overland via two small Spanish exclaves (Ceuta and Melilla) and is an important gateway for animals – including tortoises – traded from Africa to Europe (Nijman et al., 2016). Despite conservation laws banning their sale, spur-thighed tortoises are sold openly within Morocco (Bergin and Nijman, 2014). In 2001, Shipp (2002) and Znari et al. (2005) quantified the volumes (and individual sizes in Znari et al.’s case) of tortoises in the city of Marrakesh and found 534 and 692 tortoises for sale, respectively. More contemporary quantitative data is not available, spurring us to conduct a series of countrywide surveys to gain a greater insight in the trade of spur-thighed tortoises. More specifically, we first aimed to assess the scale of the spur-thighed tortoise trade within Morocco, estimating trade volumes, size-composition, and turnover, to establish its monetary value, and to gain insights into the trade network. Secondly, we aimed at documenting variation (if any) between markets and finding predictors (‘correlates’) to explain the variation in the volumes of trade. Spur-thighed tortoises are traded alive for the domestic and international pet trade, their parts for the domestic traditional (‘folk’) medicinal trade, and their carapaces are turned into bellows or banjos for the international tourism industry (Highfield and Bayley, 1996; Znari et al., 2005; Bergin and Nijman, 2014; Nijman and Bergin, 2016). Here we focus on the live trade only.

Legal status of the spur-thighed tortoise

Prior to 2011, Moroccan wildlife was partially protected under hunting laws that prohibited the removal from the wild and trade in protected species within Morocco. These laws were not clear or comprehensive, and did not provide for penalties that represented the seriousness of the crime.

On 2 July 2011, Morocco published the King’s decree *n°* 1-11-84 promulgating *Law n° 29-05 on the Protection of Species of Flora and Fauna and the Control of their Trade* (Law

29-05). This law was brought into effect in 2015 and Le Haut-Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification (High Commission for Waters and Forests and the Fight against Desertification) – commonly known as 'Eaux et Forêts' – have prepared action plans to facilitate its enforcement. In April 2017 Eaux et Forêts held a specialised training workshop with the International Fund for Animal Welfare to instruct enforcement authorities in its implementation. According to this law, any species listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix I, II or III, any species of endangered national flora and fauna, or any species whose trade jeopardizes survival may not be imported, exported, re-exported, introduced from the sea, sold or offered for sale, held, acquired or exhibited for commercial purposes, or used for profit without a permit. Permits are not transferrable and are only issued after consultation with the competent scientific bodies or institutions if it can be proved the trade does not impair the survival of the species concerned and if the applicant can ensure their preservation. Permits are also granted where specimens can be proven to have been sourced pre-CITES convention, form part of the personal effects of the holder, are used for scientific purposes, research, or educational purposes aimed at the protection or conservation, are used for propagation, or are kept in zoos or collections. By law, when a specimen changes hands for any reason, the permit must be returned to the competent authority and a new permit must be issued. The enforcement of this law can be carried out by judicial police officers, customs officers, and members of the Eaux et Forêts.

Spur-thighed tortoises are considered Vulnerable according to the International Union for the Conservation of Nature (IUCN) Red List criteria. This threat category was assessed in 1996 and no regional or subspecific assessments have been made (van Dijk et al., 2014). The species has been listed on the CITES Appendix II since 1 July 1975, regulating their international trade and bringing them within Article 4, Category II: (2) of Law 29-05, prohibiting all trade in species listed on CITES Appendix II for which Morocco has not made any reservation. The EU has included the spur-thighed tortoise on Annex A of Council Regulation (EC) *n° 338/97 on the Protection of Species of Wild Fauna and Flora by Regulating Trade Therein*, which is largely reserved for CITES Appendix I species. Importing spur-thighed tortoises into the EU, including into Ceuta and Melilla, therefore requires, among other documentation, an import permit issued by a management authority of the EU country to which the animal will be imported. Import for commercial purposes is not permitted.

According to Law 29-05, penalties for trading spur-thighed tortoises or otherwise infringing on this law are between USD 2000 and 5000 per specimen held (for specimens that fall under Article 4, Category II; penalties are higher for specimens that fall under Category I), with penalties doubled in cases of re-offending. The law also states that an attempted offence is punished by the same amount as the offence itself.

Methods

Data acquisition

Between 25 April-4 July 2013, 30 April-14 May 2014 and 12-17 December 2014 we made an assessment of the tortoise trade in Morocco. We selected cities on the basis of size (ensuring the largest cities were included) and reports of tortoises for sale, with other cities added when time and accessibility permitted, for a total of 20 cities. These included Morocco's nine largest cities and four border towns (Oujda to Algeria; Tangier to Spain; Fnideq and Beni Nsar to the Spanish exclave cities of Ceuta and Melilla, respectively). Ceuta and Melilla along Morocco's north coast are the only part of the European Union in mainland Africa and were surveyed as well. Eleven cities were surveyed once but repeat surveys were done in the others at various time intervals (2-10 weeks within each assessment period), such that in total we conducted 50 surveys.

Medinas – distinct, typically walled, city sections in which markets are often found – were surveyed exhaustively for all types of wildlife. Markets outside the medinas were visited when learned about. When possible, both daytime

and evening surveys were conducted on the same day in order to minimize the chances of stalls or shops being overlooked (Bergin and Nijman, 2014). Records of individual shops within the markets were kept so that any changes in stock could be detected and turnover could be calculated.

During each survey, the numbers of live tortoises openly for sale were recorded and for 989 of them we measured or estimated carapace size in 2 cm size classes (the same size classes used by Znari et al., 2005). Size classes were converted to age using Znari et al.'s (2005) measurements. Asking prices were obtained for different size classes although this was not always attainable as vendors often expected any discussion of price to lead to an agreement and sale. Initial prices given for many goods in Moroccan markets can be lowered if the buyer is willing to negotiate the price down. However, to avoid stimulating the trade only starting prices ('first quotes') were recorded. Because of the non-invasive nature of market surveys, and because the difficulty in establishing species boundaries in the genus *Testudo* using morphological characteristics has been well documented (van Dijk et al., 2014) we were unable to collect data on the sex or subspecies of the tortoises in the markets. Research complied with the ethic protocols proposed by the Association of Social Anthropologists of the United Kingdom and Commonwealth regarding research purposes, confidentiality of the information and the anonymity of subjects (ASA, 2011).

We obtained data on the illegal export of spur-thighed tortoises based on seizure data from the CITES trade database (https://trade.cites.org/) and the CITES CoP17 Document 73 (which in turn obtained data primarily from the UNODC database of wildlife seizures, supplemented with seizure records in newsletters such as *Traffic Bulletin*, *Robin des Bois' On The Trail*, and a variety of press releases, media reports and technical reports) for the period 2000-2015.

Analysis

Estimating volumes and turnover. We assumed that tortoises observed in the three assessment periods are different individuals, i.e. we set an upper limit of turnover at 31 weeks, this being the shortest interval between assessment periods. Data suggests that after 12 weeks turnover has reached 75% (see Results) making this a realistic assumption. We assume that tortoises do not move between shops or between cities within each assessment period. Tortoises observed in the same shop on repeat surveys during the same assessment periods were included only once as they could represent the same individual; if numbers of animals in a shop decreased between surveys and subsequently were observed to increase, the additional animals were included to the total.

We calculated minimum turnover of tortoises by repeat visits to 16 individual shops in five cities (eight shops in Fez, three in Marrakesh, three in Rabat, one in Meknes, one in Tangier) over two to ten week intervals, and calculating the number of individuals that were sold. It was not possible to calculate turnover when in between surveys a new consignment of tortoises had arrived and the number of tortoises in the shops had increased. Using the relationship between turnover and time we calculated weekly and annual numbers of turnover for each city in which we observed tortoises for sale and combined them for an overall annual estimate.

Large increases in the number of tortoises in these same shops between subsequent surveys in a short timespan (i.e. at least a doubling or an increase by >20 individuals within a 3-week period) are indicative of vendors having received consignments of tortoises. We used these instances to gauge the minimum volumes of these individual consignments.

Znari et al. (2005) presented growth curves for male and female spur-thighed tortoises from three populations in Morocco. We used these data to infer ages of the tortoises we observed in trade, presenting ranges as we do not have comprehensive information on the sex or locations from which the tortoises had been sourced. Individuals with carapace sizes of 12 cm or more are taken to be adults, calculated from Znari et al.'s fig. 5. Graphs were measured to estimate the sizes of tortoises at the stated maturity ranges for males and females, correcting for sample size, and averaged.

Prices and monetary value of the trade. Prices were recorded in Moroccan Dirham. The exchange rate was taken from the OANDA currency exchange database (www.oanda.com) and this differed little between assessment periods (Dirham:US Dollar, May 2013, 1:0.116, May 2014 1:0.121, December 2014: 1:0.112); we used the value for December 2014 to convert prices into US dollars (USD) for analysis.

Tortoises are often on display in batches of similarly-sized individuals, and typically the asking prices for each individual tortoise in this batch is the same. When treating quotes as independent data points, linking each one to a single individual tortoise of a given size, we obtained 58 independent quotes; when taking batch size into account, making data interdependent, we obtained 674 first quotes.

For each size class we took the mean asking price and multiplied that by the number of tortoises of that size class observed in the markets, and summed that for all size classes. This grand total divided by the total number of tortoises observed gave us a mean price for an average-sized tortoise in trade. This value was in turn used to calculate the monetary value of tortoises traded in each city by multiplying it with the estimated total annual turnover values.

Predictor values of tortoise trade. For each city we calculated the proportion of wildlife shops (any outlet selling live or dead wild terrestrial animals, their parts or their derivatives) selling live tortoises, and the mean number of tortoises for sale in each city per survey. We attempted to explain the variation in these values between cities having tortoises for sale by the following predictor variables:

(1) number of surveys conducted;

(2) total number wildlife shops as observed during the surveys;

(3) species diversity, as expressed by a Shannon Wiener index, excluding spur-thighed tortoises and based on the first visit only (thus countering the effects of multiple visits leading to more species being detected);

(4) human population obtained from 2014 census data;

(5) distance in km to the nearest city with a human population of over 600 000.

Statistical analyses. All data were entered into a database and all variables were checked if they departed significantly from a normal distribution. Variables that were not normally distributed were either log-transformed or arcsine transformed to approach a normal distribution more closely. Parametric statistics were run in R and Microsoft Excel 2010; we accept statistical significance when $P < 0.05$ in a two-tailed test. Throughout we report means ± 1 standard error of the mean (s.e.m.).

Results

General observations

We observed live tortoises in trade in 12 of the 20 cities we surveyed in Morocco (table 1). No tortoises were observed in Salé, Taroudant (both surveyed twice), Essaouira, El Jadida, Safi, Asilah, Beni Nsar, Kenitra nor in the Spanish cities of Ceuta or Melilla (all surveyed once). In total 3267 tortoises were observed in trade in 107 different shops, with a great amount of variation between cities. In cities such as Fnideq, Taza and Tetaoun, where relatively few wildlife shops were present, small numbers of tortoises were on sale. Intermediate levels of trade, with between 10 and 100 tortoises for sale per visit per city, were found in Agadir, Chefchaouen, Fez, Meknes and Ouija, whereas large numbers, with for instance more than 100 at a time in a single shop, were recorded in Rabat (159 in a single shop in May 2013 and 102 in May 2014; 190 in another shop in June 2013) and Tangier (153 in June 2013). In cities with more than 10 wildlife shops, i.e. Agadir, Casablanca, Fez, Marrakesh, the percentage of shops selling live tortoises ranged between 40 and 80.

Tortoises were all displayed openly, both inside shops and prominently in front of shops, or even centrally on the pavement partially impeding pedestrian traffic. Several vendors had large, open containers lined or piled up together, with dozens of tortoises in each. For the vast majority of shops in which they were observed, however, tortoises were not the only product on sale. Most shops also sold herbs, spices and other goods or domesticated animals such as dogs, cats or aquarium fish. Vendors talked openly about the tortoise trade and gave prices when asked. Vendors would offer tortoises to tourists as well as local people but reported that Moroccan people were more likely to buy them. In cities where tortoises were observed in trade there was no indication that the trade was anything other than open. In Rabat, police officers on their rounds would ensure that containers with tortoises did not block the flow of pedestrian traffic, urging vendors to move them out of harm's way but otherwise allowing trade to continue. In cities where we did not observe tortoises, there was no indication that the trade was undertaken in a clandestine manner – instead there genuinely did not appear to be any tortoises in trade at the time(s) we conducted our surveys.

No evidence of seasonality in trade volumes was apparent, with numbers of tortoises recorded in December 2014 compared to April 2014 being lower in for instance Tangier (58 vs. 453) and Casablanca (39 vs. 209) but higher for Rabat (195 vs. 170) and Marrakesh (185 vs. 121); combining data from six re-surveys reveals no significant difference (paired t-test, $t = 1.42$, $P = 0.215$). During the December 2014 survey, a vendor in Tangier, where fewer tortoises were observed compared to April 2014, reported that more tortoises would be arriving within the week and that they were delivered on a regular basis throughout the year. Vendors in these cities reported that a tortoise wholesaler (it was unclear whether this person also collected the tortoises or merely transported them) would visit the city occasionally with a consignment of tortoises and the vendors would purchase them, as needed. They could also request a specific number of animals from this person to fill an order if necessary. Vendors in Marrakesh (two), Rabat (one) and Tangier (one) reported that tortoises were sourced locally to their respective cities.

In the period 2000-2015, 1242 live tortoises smuggled out of Morocco were seized and reported to the CITES Secretariat. The majority of these (1209 or 96%) were seized by Spanish authorities and a smaller number by the UK

Table 1. Live spur-thighed tortoises *Testudo graeca* trade in 20 cities in Morocco and the 2 Spanish exclaves of Ceuta and Melilla in 2013-2014. Weekly turnovers are calculated using the turnover value (15.2%) obtained from the relationship between turnover and survey interval (fig. 2); the annual turnover and monetary value is calculated using empirical data based on two-week survey intervals (higher value) and ten-week survey intervals (lower value).

City (surveys)	Human population in 2014	Shops selling tortoises (total wildlife shops)	Mean number tortoises (total)	Weekly turn-over (annual turnover)	Monetary value in USD, annual
Agadir (1)	421 000	10 (13)	47 (47)	7.1 (195-386)	1794 - 3552
Casablanca (3)	3 360 000	12 (31)	193 (578)	29.3 (799-1583)	7354 - 14 561
Chefchaouen (1)	55 000	1 (2)	17 (17)	2.6 (71-140)	648 - 1289
Fez (6)	1 112 000	17 (27)	36 (215)	5.5 (149-194)	1368 - 2708
Fnideq (1)	54 000	1 (1)	1 (1)	0.2 (4-8)	38 - 76
Marrakesh (5)	929 000	33 (60)	95 (476)	14.4 (395-782)	3634 - 7195
Meknes (6)	632 000	8 (20)	40 (241)	6.1 (167-330)	1533 - 3036
Oujda (1)	494 000	9 (9)	60 (60)	9.1 (249-493)	2290 - 4535
Rabat (7)	578 000	5 (12)	107 (752)	16.3 (446-883)	4101 - 8119
Tangier (4)	948 000	8 (16)	217 (869)	33.0 (902-1785)	8293 - 16 420
Taza (1)	144 000	1 (3)	1 (1)	0.2 (4-8)	38 - 76
Tetaoun (2)	464 000	2 (2)	5 (10)	0.8 (21-41)	191 - 378
Asilah (1)	28 000	0 (1)			
Beni Ansar (1)	33 000	0 (0)			
El Jadida (1)	147 000	0 (0)			
Essaouira (1)	70 000	0 (0)			
Kenitra (1)	431 000	0 (1)			
Safi (1)	282 000	0 (1)			
Salé (2)	890 000	0 (1)			
Taroudant (2)	186 000	0 (4)			
Ceuta (1)	85 000	0 (0)			
Melilla (1)	85 000	0 (0)			
All (50)	11 428 000	107 (204)	86 (3267)	124.5 (3409-6819)	31 284 - 61 940

authorities (13 or 1%). It is not clear if these seizures were made in mainland Spain or in the exclave cities of Ceuta and Melilla. No seizures were reported from Gibraltar. The CITES CoP 17-73 reports 570 seizure events of spur-thighed tortoises, representing 22% of all tortoise and freshwater turtle seizure events between 2000 and 2015, though the total number of individuals seized represents 'only' 1.4% of all individuals seized. The same report states that 1073 tortoises or freshwater turtles were confiscated originating in Morocco in 218 seizure events. The vast majority of these are likely to be *T. graeca*, given that this is the only CITES-listed tortoise or freshwater turtle native to Morocco. This compares with a total of 4286 live *T. graeca* seized worldwide in the same period, indicating that Morocco comprises 25% of all seizures in this species by number and 38% of its seizure events.

No permits were displayed with any of the observed tortoises and vendors frequently stated documentation was not required to bring animals across international borders, instead offering ways to smuggle the animals. In order to follow the law, vendors would be required not only to produce these permits, but to return them to the competent authority upon selling an animal.

Size and age composition

We measured the carapace length of 989 individuals and found that two-thirds of the tortoises in trade were below 10 cm in length and ranged in age between 2 and 8 years (fig. 1). Very few individuals (less than 3% of the total) were first-year tortoises. Assuming maturity is reached when tortoises are 12 cm in carapace length, adults accounted for some 18% of the trade. While these percentages appear similar to those obtained by Znari et al. (2005) in 2001, they do differ significantly ($\chi^2_5 = 27.76$, df $= 5$, $P < 0.001$; tortoises > 16.0 cm pooled as to avoid too many low expected values) with slightly more large individuals observed in 2013-2014 compared to 2001.

Estimates of turnover

Turnover of tortoises is higher when considering 2-week intervals compared to 10-week intervals, and reaches towards an asymptote (fig. 2). After one week the estimated turnover is 15.9%, at two weeks 26.0%, at 10 weeks 74.0% and at 12 weeks it reaches 75%. Empirical data fit these data closely, e.g. 31.6% for two weeks and 79.8% for 10 weeks. Weekly turnover in terms of numbers differs greatly between cities, with the largest numbers of tortoises sold in Tangier, Casablanca and Rabat (table 1). The estimated annual number of tortoises sold in Moroccan markets based on empirical turnover data from 10-week interval surveys is some 3500 individuals; based on 2-week interval surveys the estimate increases to almost 7000 individuals.

When taking the number of shops selling tortoises into account, each individual trader deals with only a small number of tortoises. Combined the 107 shops sell some 120 tortoises a week, or about one tortoise a week per shop.

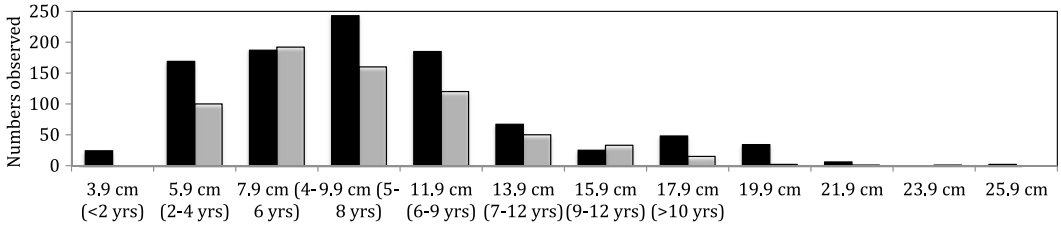

Figure 1. Size and age composition of spur-thighed tortoises *Testudo graeca* observed in trade in 12 markets in Morocco in 2013-2014 (black bars, $n = 990$) and in 1 market (Marrakesh) in 2001 (open bars, $n = 674$; data from Znari et al., 2005). Size refers to carapace size (in cm) and age is inferred from growth curves in Znari et al. (2005).

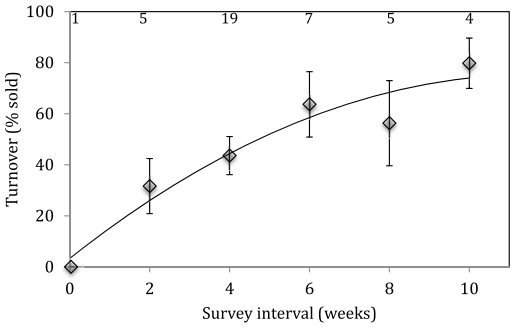

Figure 2. Mean turnover (+/− s.e.m.) of spur-thighed tortoises *Testudo graeca* in five markets in Morocco based on repeat market surveys. Sample sizes (number of repeats) are indicated at the top. The relationship is described by a logarithmic asymptotic function.

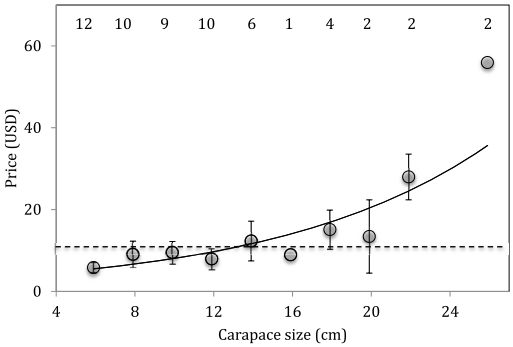

Figure 3. Mean asking prices (in US dollar, +/− s.e.m.) of spur-thighed tortoises *Testudo gracea* in relation to carapace size (in cm) in 12 markets in Morocco between April 2013 and December 2014. Sample sizes (number of independent quotes) is indicated at the top. The relationship is best described by an exponential function. The dashed line indicates the approximate mean price of an 'average-sized tortoise' (USD 9.20).

Six times (twice in Rabat, once in Fez, Meknes, Marrakesh and Tangier) we recorded a large increase in the number of tortoises (i.e. more than doubled or an increase of >20 individuals) between surveys within a 3-week period. The average size of these consignments was 38 ± 14 tortoises (range 18-105), and this can be taken as an indication of the minimum volumes traded in the wholesale trade. This is backed up by a vendor in Rabat who reported that tortoises arrive frequently in the markets, being brought in when needed, and that up to 100 could be obtained at short notice.

Monetary value

The asking price ranged from just over USD 1 for a 5 cm and up to 9 cm small tortoise to USD 34 for a 21 cm or USD 56 for a 24 cm large individual. The mean price of a tortoise based on 58 independent quotes is USD 9.32 ± 14. There was a strong correlation between price and size, either when using the interdependent quotes ($r = 0.50$, $n = 674$, $P < 0.0001$) or the independent quotes ($r = 0.46$, $n = 58$, $P = 0.0002$) (fig. 3). Taking into account the numbers of tortoises of the different size classes (fig. 1) the mean price of an average tortoise is USD 9.20.

The annual monetary value of the tortoise trade in Morocco is estimated at around USD 30 000-60 000, depending on which turnover rate is used (table 1). Cities that contributed most to this were Tangier, Casablanca and Rabat. As with the volumes sold, it is relevant to take the number of shops into account. With 107 shops selling live tortoises the average annual taking per shop is somewhere between USD 300-600. Only in cities like Chefchaouen, Tangier, Casablanca and Rabat does the average trader turn over more than USD 1000 by selling tortoises each year, although this will vary between shops, and in other cities individual vendors may have equal or higher turnovers.

Explaining variation in tortoise trade between markets

There is a large amount of variation between cities in terms of the numbers of tortoises for sale, with single individuals observed in Taza and Fnideq but hundreds in Tangier, Casablanca and Rabat. Likewise, the number and proportion of wildlife shops selling tortoises differs greatly, with the largest numbers observed in Marrakesh, Fez and Casablanca. A series of univariate linear regression models resulted in significant relationships that were not improved by multivariate analyses (table 2).

The best predictors for the mean number of tortoises observed in each city are the number

Table 2. Variables correlated with the volumes of spur-thighed tortoises *Testudo graeca* in trade and the proportion of shops selling tortoises in 12 cities in Morocco based on linear regressions.

Predictor variable	Mean number of tortoises*	Shops selling tortoises**
Number of surveys	$R^2 = 0.36$, $F_{1,10} = 7.31$, $P = 0.022$	$R^2 = 0.11$, $F_{1,10} = 3.19$, $P = 0.105$
Number of wildlife shops*	$R^2 = 0.68$, $F_{1,10} = 24.68$, $P = 0.0006$	$R^2 = 0.15$, $F_{1,10} = 2.93$, $P = 0.118$
Species diversity	$R^2 = 0.49$, $F_{1,10} = 11.64$, $P = 0.007$	$R^2 = 0.33$, $F_{1,10} = 6.52$, $P = 0.029$
Human population*	$R^2 = 0.46$, $F_{1,10} = 10.54$, $P = 0.009$	$R^2 = 0.04$, $F_{1,10} = 1.47$, $P = 0.022$
Distance to large city	$R^2 = 0.02$, $F_{1,10} = 0.79$, $P = 0.395$	$R^2 = 0.03$, $F_{1,10} = 0.68$, $P = 0.429$

*data log-transformed prior to analysis.
**data arcsin transformed prior to analysis.

of wildlife shops, the diversity of species these wildlife shops offer, and, the number of humans living in the cities. Large cities with a greater number of wildlife shops offering a wide range of species besides spur-thighed tortoises are the main centres for trade in tortoises. These were also the cities we re-surveyed the most (but given that all the analyses are based on mean values or data obtained from the first visit this should not have an effect on the outcome).

The best predictors for the proportion of wildlife shops selling live tortoises are human population and species diversity in the shops. With more people a larger proportion of shops offer tortoises and in cities with a larger variety of other wildlife for sale a larger proportion of shops include tortoises in their assortments.

Discussion

From large-scale export to smaller scale domestic trade

We recorded significant numbers of spur-thighed tortoises openly traded throughout Morocco in over half of the cities we surveyed. No spur-thighed tortoises were observed in the Spanish exclaves. Over 100 shops – about half of all the wildlife shops encountered – offered live tortoises for sale in clear contravention of the recently enacted Moroccan wildlife protection law. In cities such as Tangier, Casablanca, Rabat, Marrakesh, Meknes and Fez over a hundred tortoises could be seen displayed in front of shops, in full view of market-goers and officials. While, according to vendors these shops in part cater to international tourists, it is clear that the majority of the tortoises are sold to meet the domestic demand.

The numbers we observed are small compared to those observed by Lambert (1969) at the peak of the tortoise trade in 1969 when he visited three wholesale exporters in Casablanca, having 10 000, 3000 and 500 tortoises in stock respectively. This is unsurprising as the visit was conducted at a time when tortoise trade was not wholly banned and was de facto largely unregulated. The shift from largely export trade to largely domestic trade has seen some clear changes in the volumes, as well as the ages of the tortoises that are traded. Our observations are more in line with those of Znari et al. (2005) who surveyed the Marrakesh markets in 2001. In contrast to the observations by Lambert (1969) but in agreement with Znari et al. (2005), the majority of tortoises observed during our study were probably between 2 and 8 years of age, with few large individuals but even fewer very small ones. In the 1960s and '70s the tortoises that were exported out of Morocco very much comprised a different age class, typically between 5 to 12 years old, although the sizes of tortoises sold within the country at this time are unknown.

Given that the tortoises in trade are mostly over 2 years of age, seasonality in breeding (Diaz-Paniagua et al., 1996) does not seem to affect trade volumes from month to month. Znari et al. (2005) noted that young tortoises

in Morocco are less active in the summer compared to spring or autumn, making it more difficult to collect them during this period. Information from vendors, backed up by our observations in the markets, suggest no, or only limited, seasonality in the volumes of trade. Again, in the 1960s this may have been different, with import restrictions in place in the UK, one of the largest markets, allowing imports only during April-June so that the tortoises could acclimatize before the winter (Lambert, 1979).

Since Morocco ceased bulk exports, the numbers of legally exported spur-thighed tortoises have been low. However, ferries to Spain allow for porous borders and illegally-traded animals may be crossing at these points (van Lavieren, 2008), with traders transporting protected wildlife reporting that the chances of getting caught are slim (van Uhm, 2016). According to CITES CoP 17-73, ferries are the most common method for smuggling tortoises. Morocco, with its ferry routes to Europe constitutes a prime target for animal smuggling, as evidenced by the number of confiscations at these borders – spur-thighed tortoises comprise 25% of all reported tortoise and freshwater turtle confiscation events between 2000 and 2015 and Morocco was the origin country for almost 40% of those confiscations.

Monetary value and turnover for individual shops

Turnover of one tortoise per shop per week, although not always representative of shops in busy areas, is not high, especially considering the low prices the animals frequently sell for. With most shops observed selling a variety of goods, of which tortoises and other animals are only a small part, it seems the selling of wildlife is an additional source of money but not wholly relied upon by many of the vendors. While strict enforcement of the laws will have negative effects on some vendors, the potential instability of this trade, whether because of the depletion of tortoises or the enforcement of laws, makes it likely that vendors will sooner or later be unable to continue selling tortoises.

Explaining the markets and conservation implications

Many factors determine the popularity of goods in markets in different areas of Morocco. A difference can be seen in goods in cities frequented by tourists versus those off the tourist trail, between cities in the North of the country, versus those in the South, between coastal cities and those inland etc.

The cities in which we observed tortoises tended to have larger populations, a greater number of wildlife shops and sell a broad range of species within those shops. Tortoises kept in poor conditions are a relatively perishable good for vendors. This may point to why they are more common in larger cities with heavier foot-traffic and why they are so prominently displayed – it is necessary to sell them quickly before they die. As expected, a greater number of wildlife shops contained a greater number of tortoises. Tortoises also tend to be sold in shops in which other wildlife goods are sold. Shops in Morocco often have a theme and these shops are often grouped together; some streets will have primarily "antique" shops with lamps, ceremonial daggers, jewellery etc., others will have clothing. Herbalist shops often included wildlife products, including tortoises, in their "theme".

Tortoises were reported to have been sourced near the cities in which they were sold. If this is taken to be representative of the trade in all cities, although we could not ascertain with certainty the subspecies used in each city, we can make inferences based on their locality. Following Fritz et al. (2009), the subspecies most likely to be present in Marrakesh and Agadir is *T. g. soussensis*, in Oujda, it is most likely *T. g. graeca*, and in Chefchaouen, Tangier, Casablanca, Fez, Meknes and Rabat, it is most likely *T. g. marokkensis*. If this is taken as representative, the majority of tortoises observed in trade in this study were *T. g. marokkensis* (97%)

with small numbers of *T. g. graeca* (2%) and *T. g. soussensis* (1%).

The subspecies of Moroccan *T. graeca* differ with respect to their climatic adaptation, and most likely natural history due to former niche differentiation (Anadón et al., 2015). From a precautionary perspective as well as from a practical and political perspective, therefore, the three distinct subspecies currently recognized to inhabit Morocco, including two endemic subspecies, should be managed separately by conservationists. Tortoises are long-lived animals with high adult survival rates, late sexual maturity, low hatching and juvenile survival rates and a specialized diet. Because of this, increases in adult mortality due to overexploitation of adult specimens in a tortoise population will have long-term impacts on the population viability, making them very sensitive to the pet trade. (El Mouden et al., 2005; Schlaepfer, 2005; Kaddour et al., 2006; Perez et al., 2012). While numbers of tortoises collected for the pet trade are lower than in the past, the consistent, unregulated offtake of wild individuals could be having very serious effects on their numbers in the wild. The removal of spur-thighed tortoises from the ecosystem will also have larger implications for biodiversity in the region as a whole as they are potentially seed dispersers for a variety of species of plants (Cobo and Andreu, 1988). Because of the long lifespan of tortoises, the effects of overcollection may not become immediately apparent for years after the period of collection, at which time it may prove extremely difficult to reverse the population decline.

Due to the nature of market surveys, numbers observed here represent only a minimum number of tortoises removed from the wild. Animals collected for personal use that do not pass through markets, animals that die in transit or shortly after arriving in the markets or animals that are successfully smuggled out of the country without passing through the open markets cannot be accounted for. The actual number of tortoises removed from their natural habitat is therefore likely to be significantly higher than can be observed or accounted for here. Likewise, the turnover represented here is a conservative estimate as we only included instances in which we could be certain turnover had taken place.

Conclusions and recommendations

Considering the potentially high profit margins if exported, low risk of detection or prosecution and ease with which source animals can be purchased, there is a strong incentive for people to engage in the illegal transport of spur-thighed tortoises within and out of Morocco. The cessation of large-scale export undoubtedly gave the species some room to recover but until the significant numbers of animals traded within-country are addressed, tortoise populations in the wild remain at risk from over-harvesting.

While conservation of any species must be multi-faceted and take into account a variety of threats, combatting the offtake for the pet trade is a significant step that can be taken swiftly and will likely strengthen the conservation outlook of wild populations. New laws enable Moroccan authorities to protect biodiversity in the country like never before. The average cost of a tortoise is a fraction of the cost of the fine for keeping one and is not an easily absorbed cost for vendors, increasing the potential effectiveness of these laws. Decisive, consistent and clear measures along with effective and sustained enforcement leading to prosecution of offenders are therefore required to enforce the current laws if they are to positively impact wildlife in the country. Market surveys such as the ones undertaken here help focus enforcement efforts, efficiently utilizing police time and resources.

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