Title: The illegal pet trade is driving Madagascar's ploughshare tortoise to extinction

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Abstract The illegal wildlife trade is driving declines in populations of a number of large, charismatic animal species but also many lesser known and restricted-range species, some of which are now facing extinction as a result. The ploughshare tortoise (*Astrochelys yniphora*), endemic to the Baly Bay National Park of north-western Madagascar, is being heavily impacted by poaching for the international illegal pet trade. To quantify this we estimated population trends between 2006 and 2015, using distance sampling surveys along line transects, and recorded national and international confiscations of trafficked tortoises from 2002 to 2016. The results suggest the ploughshare tortoise population declined by over 50% during this period, falling to around 500 adults and sub-adults in 2014–2015. Prior to 2006 very few tortoises were seized either in Madagascar or internationally but confiscations appeared to increase sharply from 2010. Since 2015, poaching on the ground has intensified with field reports suggesting that two of four sub-populations are extinct, leaving an unknown but almost certainly perilously low number of adult tortoises in the wild. This study has produced the first reliable ploughshare tortoise population estimates and shows that the species has declined rapidly due to poaching to supply the international pet trade. There is an urgent need for increased action both in Madagascar and along international trade routes if the extinction of the ploughshare tortoise in the wild is to be avoided.

Keywords: *Astrochelys yniphora*, chelonian, illegal wildlife trade, anti-poaching, distance sampling, line transect surveys, population monitoring

Introduction

Illegal wildlife trade (IWT) involves the collection, transportation, and distribution of living or dead animals, animal parts and derivatives, both domestically and internationally, in

contravention of foreign and domestic laws and treaties (Wyler & Sheikh, 2013). IWT is a major and growing challenge for conservation. While global volumes of IWT have been difficult to quantify accurately (Rosen & Smith, 2010), its financial value is estimated at USD 8–10 billion per annum (Lawson & Vines, 2014). IWT is pushing many high-profile species such as tigers, *Panthera tigris*, African elephant, *Loxodonta africana*, and white and black rhinoceroses, *Diceros bicornis* and *Ceratotherium simum*, toward extinction (Bennett, 2011; CITES Secretariat, 2012; Underwood et al., 2013; Biggs et al., 2013; TRAFFIC, 2016a).

In addition, IWT affects a wide range of lesser-known species (Rosen & Smith, 2010) that often receive little international attention. Reptiles, and chelonians in particular, are trafficked in high volumes, accounting respectively for 69% and 38% of seizures of live animals recorded in TRAFFIC Bulletins in 1996-2008 (Rosen & Smith, 2010) and 95% in 2010-2014 (D'Cruze & Macdonald, 2016). Levels of collection for illegal trade are rarely sustainable and are causing declines in wild reptile populations (Zhou & Jiang, 2004; Natusch & Lyons, 2012; Nijman et al., 2012) with turtles and tortoises being particularly heavily impacted (Jenkins, 1995; Cheung & Dudgeon, 2006; Horne et al., 2012). Linked to traditional rites, beliefs, food preferences and medicinal uses, tortoise trafficking has been observed mostly into Southeast and Eastern Asia in recent decades, with a high number of exports originating from Africa (Jenkins, 1995; Nijman & Shepherd, 2007; Nijman & Shepherd, 2015).

All four of Madagascar's endemic tortoise species, the radiated tortoise *Astrochelys radiata*, ploughshare tortoise *Astrochelys yniphora*, spider tortoise *Pyxis arachnoides* and flat-tailed tortoise *Pyxis planicauda*, are listed on Appendix I of CITES (2017) and classified as

Critically Endangered on the IUCN Red List (Leuteritz & Rioux-Paquette, 2008; Leuteritz & Pedrono, 2008; Leuteritz et al., 2008; Leuteritz & Walker, 2014). All have been, or are currently, affected by illegal collection from the wild for the international pet trade (O'Brien et al., 2003; Pedrono, 2008a; Walker & Rafeliarisoa, 2012).

The ploughshare tortoise has long been considered one of the world's rarest tortoises (Decary, 1934; Juvik & Blanc, 1974; Curl et al., 1985), perhaps in part due to a long history of exploitation. Vaillant & Grandidier (1910) describe a naval archive from the 17th century which notes that stores in the region were full of tortoises, many of which were purchased by Arab sailors. This historical commerce in ploughshare tortoises was for food, but demand has shifted in the latter part of the 20th century to supply the international pet trade, primarily in Southeast Asia (Kiester et al., 2013; Raghavan et al., 2015). The ploughshare tortoise has been protected by Malagasy law since 1960 (the law was revised in 2006), which prohibits any collection or harvesting from the wild, transportation, keeping in captivity as pets, consumption, selling, and exporting of live individuals.

Currently found only in the bamboo scrub habitats around Baly Bay on the north-western coast of Madagascar, there is no evidence, either from the historical or sub-fossil record, to suggest that the species was ever found outside of this highly restricted locality. All known ploughshare habitats are now legally protected as core zones of the Baly Bay National Park, established in 1997. All entry to them, except for conservation and research purposes, is forbidden.

A number of ploughshare tortoise population surveys have been previously carried out. In the mid-1980s, Curl (1986) estimated 100–400 individuals in the wild and a more precise estimate of 605 ± 166 individuals was reported by Pedrono (2000). The survey methods used to produce these estimates did not account for biases arising from imperfect detection, nor did they cover the species' full range, and therefore reliable information on historical and current population sizes is lacking.

Over the past decade, a noticeable decline in numbers of the ploughshare tortoise is suspected to have occurred, however this has not been quantified. In this paper, we present the results of species range-wide surveys conducted between 2006 and 2015 with the first robust estimates of ploughshare tortoise population size and trend. We report data from anti-poaching patrols conducted since 2015 to understand more recent population changes and also examine data from seizures of ploughshare tortoise over the same 10-year period as an indicator of the level of trafficking of this species.

Methods

Study area

We carried out line transect surveys at Ambatomainty, Betainalika, Beheta and Cap Sada, the four known sites supporting extant ploughshare tortoise sub-populations within the Baly Bay National Park (Fig. 1). There is also a reintroduction site at Beaboaly, where a known number of released tortoises are intensively monitored. The Park is located around Baly Bay in the Region of Boeny on the north-western coast of Madagascar. This region has two distinct seasons: a rainy, hot period from December to March, and an extended dry, cooler season

125 from April to November. The former coincides with the ploughshare's active season during
126 which breeding occurs and the latter with a long period of low activity and aestivation.
127
128 Ploughshare tortoise habitat comprises dense patches of bamboo thicket *Perrierbambos*
129 *madagascariensis*, scrub-shrub, and palm savannah (Smith et al., 1999a). Of these habitats,
130 bamboo thicket is the most inaccessible and difficult to survey (Juvik et al., 1981). The
131 suitable habitat patches are isolated, separated from each other by grass savannahs, seasonal
132 rivers, lakes, mangroves, marshes, salt marshes and the Bay of Baly (Fig.1). Two patches of
133 habitat, Cap Sada (235ha) and Beheta (688 ha) are located on the eastern side of the bay and
134 two others, Betainalika (2,905 ha) and Ambatomainty (10,645 ha) on the western side
135 (Mandimbihasina & Woolaver, 2014).
136
137 ***Line transect population surveys and analyses***
138 Distance sampling (Buckland et al., 2001) is widely used for monitoring land tortoises (e.g.
139 Swann et al., 2002; Leuteritz et al., 2005; Young et al., 2008; Smith et al., 2009; Walker &
140 Rafeliarisoa, 2012) and has been carried out by Durrell Wildlife Conservation Trust (Durrell)
141 periodically since 2005 (with a pilot study in 2003-04) to estimate ploughshare tortoise
142 densities. Line transects were surveyed in October–April in the periods 2006-08, 2011-13 and
143 2014-15, between 08.00–11.00 and 15.00–17.00, as tortoises were more active during these
144 cooler hours. For a given transect, a team of 3–11 surveyors walked in parallel lines 10 m
145 apart, with a team leader in the middle responsible for navigating and measuring the length of
146 the transect. The survey team consisted of a professional biologist acting as team leader and
147 trained local community members. All team members walked along the line transect at the

same speed, 0.5–0.7 km/h, and in the same direction (either east–west or north–south). The leader and the surveyors at the ends of the line used GPS units to ensure that precise travel distance was recorded and the walked lines were as straight as possible. The transect length was then calculated as the distance walked by the survey team multiplied by the number of people in that team.

When a tortoise was found, all observers stopped surveying whilst data were recorded. The perpendicular distance from the tortoise to the line of the surveyor that found it was measured. Sex of adults (based on plastron curvature and anal fork opening), identification number of previously marked animals, and body measurements were recorded for each tortoise encountered. Individuals were assigned to one of two age categories based on their size; individuals were considered an adult or sub-adult if they had a carapace length > 20 cm, and a juvenile if < 20 cm.

For each survey session, line transects typically 0.6 – 1.6 km in length were randomly placed (a minimum of 500 m apart) to cover all four sites of ploughshare tortoise habitat. Due to difficulty of access, there was an unsampled area of approximately 50 km^2 within the centre of the largest site of tortoise habitat in Ambatomainty. Eighty-eight transects with a total length of 563.9 km were surveyed in 2006–2008, followed by 514.2 km (82 transects) in 2011–2013, and 552.1 km (72 transects) in 2014-2015.

The accuracy of this transect methodology was tested during a pilot study in Cap Sada during 2003–2004. Cap Sada is the best studied of the wild subpopulations of ploughshare tortoise,

with research carried out at this site since the 1970s (e.g. Juvik & Blanc, 1974; Juvik et al., 1981; Smith et al., 1999b). Nearly all adult and sub-adult tortoises in Cap Sada had been permanently marked as of 2003 and therefore the total numbers of this cohort was known. Twenty-seven transects, arranged in a systematic grid to ensure good coverage of the entire area of suitable habitat, totalling 90.2 km, were surveyed in 2003–2004, and the results from the distance sampling compared to the known population size of adults in the subpopulation.

In an attempt to understand the status of the ploughshare tortoise population since 2015, we collated data on any tortoises seen in the wild during anti-poaching patrols conducted in Baly Bay National Park. The patrols covered the sites of all four wild sub-populations plus the reintroduced sub-population, searching for signs of poaching activity (mainly illegal camps, campfires, paths) as well as recording numbers and locations of any ploughshare tortoises seen. Patrol teams carried GPS units to measure distances walked and recorded start and finish times of their daily patrols. We calculated the effort (number of kilometres walked and hours patrolling) of the anti-poaching patrols conducted between January 2016 and May 2017 and attempted to calculate encounter rates (tortoises encountered per kilometre walked). Data analyses were carried out using Distance® version 6.2 (Thomas et al., 2010).

Although population size was estimated at the sub-population level, here we report global population estimates, to avoid providing traffickers with information about potential numbers at each site which may influence poaching activity. For both the Cap Sada pilot study and the wider survey, the data were truncated to exclude the 5% of distances furthest from the transect line, to discard unusual observations (Thomas et al., 2010). Based on lowest AIC

values and visual inspection of the detection functions, we selected the half-normal cosine model for density estimation in both cases.

National and international confiscation data

We collated records of ploughshare tortoises seized by authorities outside Madagascar as reported in TRAFFIC Bulletins from June 1998 to December 2016 (TRAFFIC, 2014; TRAFFIC, 2016b), and accessed from the TRAFFIC website (http://www.traffic.org/Bulletin). The age of individuals was not always reported, so we recorded only the number of individuals confiscated. Numbers of juveniles and adults were known for all confiscations in Madagascar, so these were used to explore which age classes are most targeted by poachers. We also collated all available anecdotal and reported evidence of trafficking, sales and demand in order to better understand the dynamics of IWT of ploughshare tortoises.

Results

Tortoise population trends

In our Cap Sada pilot study in 2003–2004, we observed 14 adults along 27 transect lines totalling 90.2 km. Despite the small sample size, the detection function provided a good fit to the data (Chi-square value = 3.81; P = 0.43) and we estimated a density of 0.19 adult tortoises ha^{-1} (95% CI: 0.11-0.33 adult tortoises ha^{-1}) and a population size of 34 individuals (95% CI: 20–58 tortoises). This matches reasonably closely with the 41 adults believed to be in the sub-population at the time, as determined through a long-term mark-recapture study (Smith et al., 1999b) which was initiated in 1993 and ran until 2004.

Despite a survey effort of over 500 km per survey session, and therefore 1720.4 km of line transects over the 10-year monitoring period, it was not possible to meet the target number of tortoise observations required (60–80 data points per period; Buckland et al., 2001) to reliably model a detection function for each of the three sampling periods. Therefore the data were pooled to estimate a global detection function (i.e. applied to all three survey periods; Obbard et al., 2015), which showed no signs of avoidance of the line or heaping at any distance, which was post-stratified to generate population abundance and density estimates for each survey period. The detection function provided a good fit to the data (Chi-square value = 10.76; df = 11; P = 0.46), and was used to estimate density because it had the lowest AIC value across all possible models.

Ploughshare tortoise encounter rates, and population density and size estimates for each survey session are presented in Table 1. The confidence intervals around the mean population sizes were large, but the difference in the mean estimates strongly suggest a rapid decline in wild ploughshare tortoises between 2006–2008 and 2011–2013, and a negligible difference between 2011-2013 and 2014–2015. The overall decline in the mean population estimates over the 10 year period is 54%.

However, reports from anti-poaching patrols and conservation NGO field teams between January 2016 and May 2017, suggest the situation has deteriorated further and rapidly. Multiple visits by both groups during this period covered all four main sites of suitable habitat, plus the reintroduction site, in both the active and low activity seasons. Quality-

controlled data of patrol effort were only available for Beaboaly, where the joint anti-poaching teams conducted 3,815 km and 6,019 hours of patrolling to protect the reintroduced population. For the other four sub-populations, patrols totalled 14,400 hours. This effort is at least equal to the entire effort (in terms of time spent on the ground searching for tortoises and surface area covered) expended to conduct the 1,700 km of surveys during the period 2006-2015. Despite this large-scale and intensive search effort, no animals have been seen in two of the wild sub-populations since end of 2016. The situation is less clear for the other two sub-populations, but given the extremely low encounter rates that were observed, we strongly suspect that both have been severely depleted from 2015 levels and (based on only one individual being found) one sub-population perhaps now only consists of a handful of individuals.

Trends in confiscations

The first ploughshare tortoise confiscation reported from outside Madagascar was three individuals seized in Belgium in 1998. The next was one individual confiscated in Japan in 2004. The number seized each year outside Madagascar has increased since 2006 (Fig. 2) with peaks in 2010 (39 tortoises) and 2013 (58). A total of 162 ploughshare tortoises have been confiscated outside of Madagascar in 35 separate seizures in 2002–2016 (see Fig. 3 for photographs of example seizures).

The first confiscation recorded inside Madagascar was in 2002, of nine adults in a single seizure. A single juvenile was confiscated in 2002–2005. Since 2006 the number of confiscated ploughshare tortoises in Madagascar each year has increased (Fig. 2) with peaks

in 2011 (54 tortoises) and 2014 (28). The total number of ploughshare tortoises confiscated within Madagascar between 2002 and 2016 was 172 individuals (26 adults and 146 juveniles), in 36 separate seizures. The total number of seizures (international and national) was highest in 2009-11 (11, 14, 9 seizures) and 2016 (7), compared with 0–4 seizures in all other years.

Additional evidence of IWT

During the period of rapid population decline, NGO field teams in Baly Bay observed an escalation in the reported price being offered to local poachers by collectors for an adult ploughshare tortoise from around $2 USD in 2009, to $62 in 2015 and $620 USD in 2016 (Jinoro Delphin, pers. comm.). To place this in context, the mean local wage in the villages adjacent to Baly Bay National Park is US$1.5-2 per day (Andrianandrasana, 2017).

The main intended destinations for ploughshare tortoises, based on confiscation patterns, are Thailand, Malaysia, Singapore, Indonesia, and Hong Kong, with animals transiting through Kenya and Abu Dhabi from Madagascar (TRAFFIC, 2014; TRAFFIC, 2016b). While data are lacking on trade routes into China, it is suspected that many trafficked animals are destined for collectors there (Turtle Conservancy, 2015). Ploughshare tortoises have been reported to command very high prices in demand countries, with recent reports of tortoises for sale in Indonesia at prices from US$509 for a small individual to US$47,000 for a large animal (Morgan & Chng, 2017).

The use of the internet and social media platforms appear to be now facilitating IWT of ploughshare tortoises (Morgan & Chng, 2017), which first started appearing for sale online

around 2008 (Walker, 2012; Kiester et al., 2013). We suspect there may have been a recent spike in online sales. For example, five adult ploughshare tortoises were on sale on a Hong Kong website in 2015, and seven others for sale online in 2016 (R. Lewis, pers. comm.). Nine of these were confirmed (based on identification markings observed on the photos online) as having been recently stolen from the wild populations.

Discussion

Our study provides the first estimates of ploughshare tortoise population size and trend based on range-wide surveys, and using a method that takes imperfect detection into account. Our results reveal that the ploughshare tortoise probably declined by over 50% between 2006 and 2015, but more recent field patrols point to an even larger decline, with some sub-populations (at least the adults and sub-adults) now likely extinct. Concurrent data on escalating confiscations in Madagascar and in Southeast Asia, as well as anecdotal evidence of high and increasing levels of poaching activity in Baly Bay, clearly identify the illegal international pet trade as the driver of this rapid and severe decline.

Given the low population density of this species, over 1,700 km of survey effort was required to obtain reasonable sample sizes for analyses. Despite this, the remote and at times inaccessible study area, combined with the cryptic nature of the species and short active season, means the survey had a number of limitations. Firstly, due to lower than anticipated numbers of tortoise detections, our population estimates had relatively wide confidence intervals. However, our pilot-test of the line transect method using the Cap Sada population

307 produced a population estimate similar to the known population size, despite the low numbers
308 of observations. Secondly, we were not able to access the central portion of Ambatomainty,
309 the western-most and largest patch of suitable habitat. In the analysis, we therefore assumed
310 that tortoise density in this area was equivalent to the mean density across the rest of the
311 species' range. Given its inaccessibility, due to its remoteness and dense vegetation, this may
312 be an important site for ploughshares and requires continued intensive protection and
313 monitoring. Thirdly, the low numbers of observed juveniles was problematic, meaning we
314 were limited to estimating population size and density for adults and subadults only. Smaller
315 individuals are very hard to detect within the dense bamboo scrub, but the lack of sightings of
316 juveniles in some sub-populations in 2011–2013 and 2014–2015, compared with earlier
317 years, suggests a decline in the number of individuals in this age class. Most of the
318 ploughshare tortoises confiscated have been juveniles, which can be more easily concealed
319 and transported in large numbers (Fig. 3) and this could explain in part the lack of juvenile
320 sightings in the wild.

321

322 Despite these survey limitations, we believe the evidence presented here points to a
323 catastrophic decline in the ploughshare tortoise. In 2014-15, the estimated density of
324 individuals of, or near, breeding age was only 3.5 individuals km^{-2}. To put this into context,
325 the density (of all age classes) of the Sonoran desert tortoise *Gopherus agassizii*, a species
326 considered rare and threatened, at an arid mountain site in the southern USA, was an order of
327 magnitude higher at 30 individuals km^{-2} (Zylstra et al., 2010). The lack of ploughshare
328 tortoise observations since January 2016, despite repeated field visits, leads us to strongly
329 suspect that only one of the four wild sub-populations contains more than a handful of adults

330 and sub-adults, and two are likely to have been extirpated. Given its long generation time
331 (approximately 20 years) and therefore very limited capacity to recover from population
332 declines, this species is now in a perilous situation and its survival is at severe risk.

333

334 At the time of writing, there have been 334 ploughshare tortoises reported as confiscated
335 (both within and outside of Madagascar) during trafficking attempts since 2002, 280 of these
336 since 2009. Seizure data consistently and substantially underestimate absolute numbers of
337 animals poached (D'Cruze & Macdonald, 2016), therefore the numbers of adults and
338 juveniles taken from the wild and trafficked since 2009 may be in the low thousands
339 (probably mostly juveniles which aren't represented in the reported population estimates).
340 While it is not possible to evaluate temporal trends in enforcement effort, there has been an
341 increase in corruption in Madagascar since the political instability commencing in 2009,
342 driving a reduced capacity to control illegal smuggling of goods out of the country
343 (Randriamalala & Liu, 2010; Gore et al., 2013). This ties up with the survey results, which
344 suggest a particularly dramatic drop in numbers between the first and second survey periods,
345 indicating that intensive poaching started around 2009.

346

347 As the ploughshare tortoise rapidly declined, increasing effort will have been required by
348 poachers to locate tortoises in the wild, which may have been a disincentive. However, the
349 Anthropogenic Allee effect predicts that increasing species rarity drives up desirability which
350 in turn drives up the amount people are willing to pay (Hall et al., 2008; Lyons & Natusch,
351 2013). This is reflected in the 300-fold increase since 2009 in the local price paid to poachers

for tortoises taken from the wild. Given that ploughshare tortoises have been witnessed for sale for nearly $50,000 in a demand country we anticipate that these local price escalations may continue, sustaining the poaching intensity even as the global wild population of the ploughshare tortoise declines to just a few individuals.

Prior to the recent increase in poaching, the ploughshare tortoise conservation programme appeared to be on track to achieve its goals, with successful habitat protection, reduction of threats from fire and cattle encroachment and a promising reintroduction programme (Durbin et al., 1996; Wallis, 2009; Mandimbihasina & Woolaver, 2014). However, the upsurge in their international demand, facilitated by weakening governance and limited law enforcement in Madagascar, has meant that conservation agencies have had to adapt and diversify their responses rapidly to include anti-poaching actions, judicial capacity development and national and international advocacy. It is clear that these interventions have not been enough in either scale or intensity to reduce the rapid surge in poaching. Perhaps most surprisingly, a campaign of engraving the carapaces of all wild, released and captive ploughshare tortoises appears to have failed in sufficiently reducing demand, with engraved animals now for sale online. A lack of enforcement action against traders or buyers of these engraved tortoises (which are obviously illegal) is likely to have contributed to the lack of success of this campaign.

There is an immediate need to take further action to safeguard the remaining wild, released and captive populations. Current anti-poaching actions in Baly Bay must be scaled up and

374 improved, including better detection of poachers (e.g. using patrol dogs), tortoise protection
375 (e.g. fences), and rapid response enforcement techniques that have been developed elsewhere
376 to combat poaching (O'Donoghue & Rutz, 2015; Moreto & Lemieux, 2015; Avery, 2016).
377 Captive populations are being established outside of Madagascar as assurance colonies using
378 internationally confiscated animals (Kiester et al., 2013) and new breeding centres are also
379 required in Madagascar with high-security measures to prevent break-ins and animals being
380 stolen. Strategies to reduce the demand for wild animals should also be considered, in order
381 to secure the long-term future of the species. Demand reduction initiatives for other species,
382 particularly in Southeast and East Asia, have met with limited success (Challender et al.,
383 2014), and are poorly evidenced (Olmedo et al., 2017). The consumers driving the trade in
384 this species (and many other rare reptiles) are a relatively small number of dealers and
385 hobbyists, predominantly in eastern Asia, who seek out the rarest animals and for whom the
386 illegality of owning the species appears not to be a deterrent. More research is required to
387 understand the psychology of collectors and to identify the messaging to which this group
388 would be responsive (Veríssimo et al., 2012; Hinsley et al., 2016).
389
390 We conclude that the imminent extinction of the ploughshare tortoise in the wild is
391 unavoidable unless the current level of poaching for the illegal pet trade is stopped
392 immediately. Even if poaching ceases today, we suspect that given the extent of the
393 demographic collapse of the ploughshare tortoise, its recovery is unlikely to happen without
394 intensive management such as large-scale reintroductions and, even with such actions, is
395 likely to take many decades.
396

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Author contributions

AM carried out the data collection, data analysis and wrote the first draft of the manuscript. NF has helped on data collection/fieldwork. LW, REL and LLR coordinated the field research. LW and AM compiled the confiscation data. LC and RY assisted with the data analysis. LW, LC, EJMG, REL and AT assisted the writing and editing of the manuscript. RY led the design of the field research, and wrote and edited later drafts of the manuscript.

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Biographical sketches

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Richard Lewis is director of Durrell's Madagascar programme and has led the ploughshare tortoise conservation programme for the past 15 years.

Andrew Terry is Durrell's Head of Field Programmes and is interested in management and policy interventions to combat the illegal wildlife trade.

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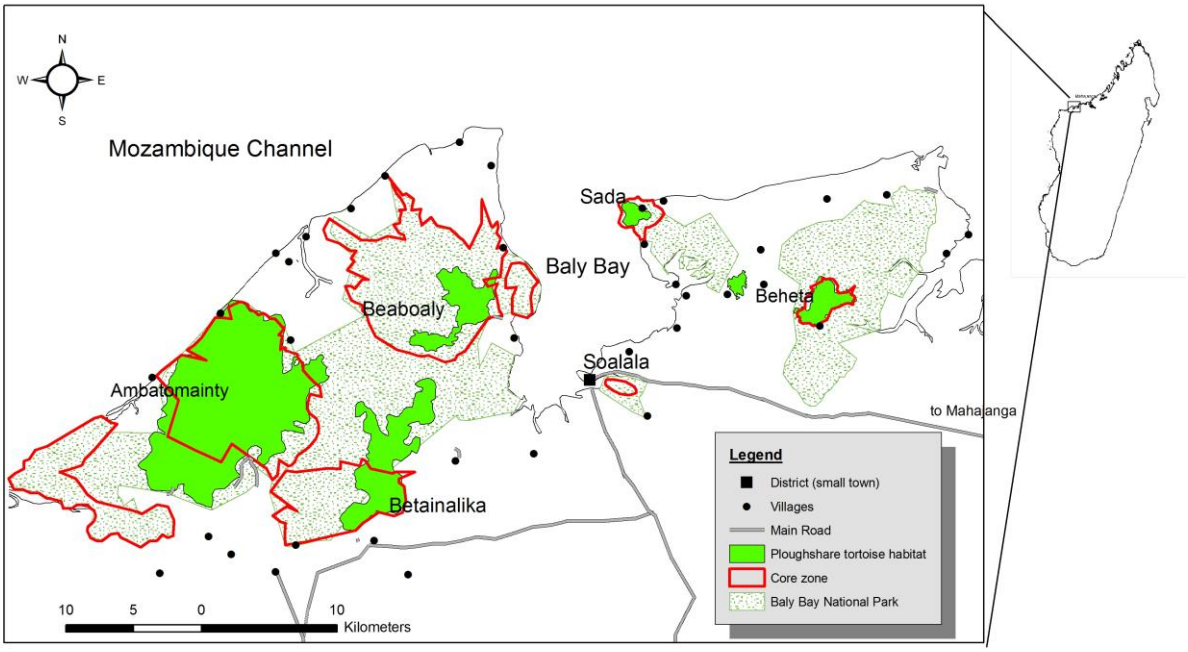
652 TABLE 1 Number of individuals recorded (A=adults, SA=subadults, J=juveniles) during the
653 surveys, encounter rates, ploughshare tortoise population density and size estimates with
654 lower and upper 95% confidence limits.

Time period	Distance surveyed (km)	Tortoises recorded A+SA/ J	Encounter rate A+SA / J (tortoises km^{-1})	Density (tortoises ha^{-1})*	Population size*	Lower 95% CL	Upper 95% CL
2006–2008	563.9	43 / 15	0.076 / 0.027	0.076	1,105	709	1,722
2011–2013	514.2	26 / 18	0.056 / 0.035	0.036	517	174	1,535
2014–2015	552.1	38 / 13	0.067 / 0.024	0.035	506	188	1,359

655 *Population density and size estimates are for adults and sub-adults only.

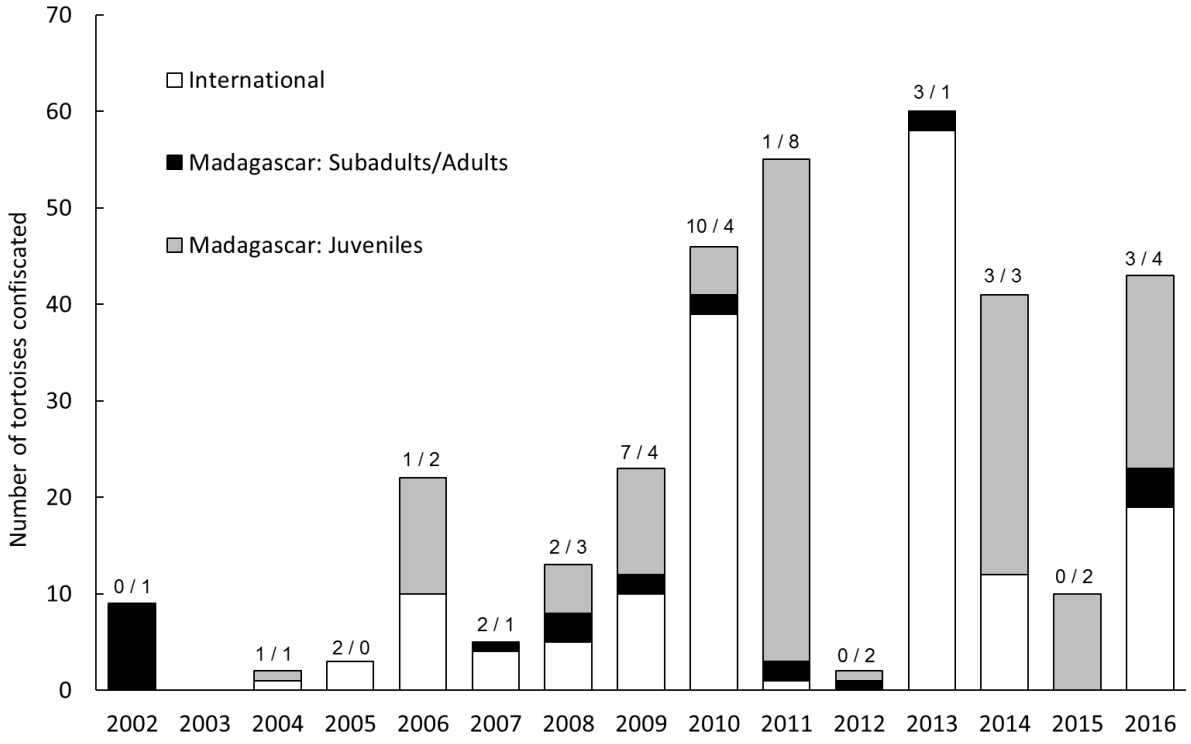
656



657

658 FIG. 1 Map of Baly Bay National Park, Madagascar, showing sites of suitable habitat for
659 ploughshare tortoises. The red polygons describe the strict conservation zones of the National
660 Park. The Ambatomainty, Beheta, Betainalika and Sada sites were surveyed in three survey
661 periods: 2006-08, 2011-13 and 2014-15.

662



663

664 FIG. 2 Number of ploughshare tortoises confiscated internationally and in Madagascar in
665 2002–2016 (age-specific data were only available for national confiscations). Numbers above
666 each column indicate number of seizures (International / Madagascar) for that year. Juveniles
667 are classed as tortoises with a carapace length < 20 cm.

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672 FIG. 3 Photos of the illegal trade in ploughshare tortoises *Astrochelys yniphora*: top) A
673 shipment confiscated in Madagascar at Ivato International Airport in July 2011 included 27
674 juvenile and 1 adult ploughshare tortoise, as well as 169 radiated tortoises and a spider

675 tortoise *Pyxis arachnoides* (Durrell Wildlife Conservation Trust, 2011) middle) A seizure of
676 Malagasy tortoises in Thailand in 2013 included 54 ploughshare tortoises and 21 radiated
677 tortoises *Astrochelys radiata* (Panjit Tansome, TRAFFIC 2013); bottom) Five adult
678 ploughshares, two of which are clearly engraved, for sale on a Chinese website in June 2015.
679