Turtles on the Brink in Madagascar: Proceedings of Two Workshops on the Status, Conservation, and Biology of Malagasy Tortoises and Freshwater Turtles
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Long-Term Monitoring and Impacts of Human Harvest on the Radiated Tortoise (*Astrochelys radiata*)

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Abstract. – The Radiated Tortoise (*Astrochelys radiata*) is endemic to the spiny forest along Madagascar's southern coastline. It is listed as Critically Endangered by the IUCN Red List due to local consumption, collection for the illegal pet trade, and habitat loss. Surveys were conducted at five widespread locations to determine the current status of tortoise populations for comparisons with data collected 10–15 years earlier. Interviews were conducted at each location to better understand the factors influencing recent harvest trends—such as drought, poverty, political instability, and the erosion of protective native taboos. Tortoises occurred at high densities at the Cap Sainte Marie Special Reserve, Lavanono, Nisoa-Ambony, and Lavavolo. However, very few individuals were observed at Ankirikirika; this was coincident with the discovery of a nearby tortoise poaching camp that contained the remains of about 600 tortoises. Tortoise densities have increased at both protected locations, the Cap Sainte Marie Special Reserve and Nisoa-Ambony, and decreased at Ankirikirika and Lavavolo, when compared to previous years. Tortoise density at Lavanono was similar to earlier reports. According to interviewees, an increase in the illegal harvest was mostly associated with: 1) regional development that has attracted tortoise-eating people to the region that do not respect the local taboo against consuming this species; 2) poverty, motivating people to collect tortoises for money, or to trade for rice; 3) drought that has led to crop failure and hunger; and 4) the consumption of tortoise meat as a delicacy for special occasions and religious holidays. It was also determined that tortoise collection is mainly conducted by Antanosy people from Fotadrevo and that most of the harvesting activity is concentrated along the Menarandra River in the Marolinta, Ankirikirika, and Androka regions. Community conservation programs should target villages that drive tortoise collection, including Fotadrevo, Beloha, Tsiombe, Ft. Dauphin, and Tulear. A long-term monitoring program for the tortoise populations at the five survey locations has been established. However, these populations are extremely vulnerable to collection and require a substantial increase in protection.

Key Words. – Reptilia, Testudines, Testudinidae, community conservation, harvest, Madagascar, population density, taboo erosion

Humans are altering biodiversity in many ways and at faster rates than generated and maintained by natural processes (IPCC 2007; Pressey et al. 2007). The most unfortunate result of biodiversity alteration is extinction and conservationists are particularly concerned with species that may be lost in the very near future. Indeed, finite resources for conservation management dictate the need for prioritizing efforts towards species that are the most imperiled (Joseph et al. 2009).

Two critical pieces of information should precede major conservation efforts to protect declining species: quantitative evidence for the decline and knowledge of the threatening processes. Evidence of declines is crucial because observations of mortality do not necessarily translate into population level losses (Houlahan et al. 2000; Doody et al. 2009). Identifying the major threatening processes is important for conservation programs aimed at eliminating, or reducing threats; and reintroducing, repatriating, or translocating individuals for conservation purposes (Griffith et al. 1989; Dodd and Seigel 1991; Lambeck 1997).

Long-term monitoring provides a robust identification of population trends using quantitative data. It is generally superior to short-term monitoring because it can capture perturbations against a background of annual variation in abundance generated by 'natural' factors that vary across years, such as rainfall amounts or food availability. Identifying potential or probable threatening processes responsible for a species' decline is often difficult;

however, qualitative evidence in tandem with declines in population abundance can pinpoint a major threatening process.

The iconic tortoises of southern Madagascar are highly endangered. It has been predicted that the Radiated Tortoise (*Astrochelys radiata*) may go functionally extinct within the next 20 years (Hudson and Horne 2010), and the species has been listed as Critically Endangered by the IUCN Red List since 2008 due to local consumption, collection for the illegal pet trade, and habitat loss (Leuteritz and Rioux Paquette 2008). Over-collection is considered to be the main threatening process behind this decline, as tortoises are intensely harvested for local consumption by the Malagasy and also exported for the international trade (O'Brien et al. 2003). Increased poverty, prolonged drought, erosion of local taboos (fady) protecting the tortoises, and most recently, ineffective law enforcement related to political instability are thought to be driving the harvest even further (O'Brien et al. 2003; Bohannon 2009).

We examined the status of the Radiated Tortoise within its core range by assessing long-term changes in abundance at five locations that were surveyed 10–15 years prior to our surveys. We also addressed the impact of human harvest by interviewing key locals to determine their views on 1) whether the collection for human harvest has increased; and 2) what social factors underpinned any increase—including poverty, drought, and recent political instability. We also measured tortoises to investigate any effects of the harvest on size structure in each population. Our discovery of an active tortoise poaching camp near Ankirikirika provided insight into the details of the harvest. We conclude by making recommendations for the future protection of the Radiated Tortoise.

METHODS

Study Species. — The Radiated Tortoise (*Astrochelys radiata*) is a large terrestrial species that is endemic and restricted to the spiny forest of southwest Madagascar (Fig. 1; Leuteritz 2002; Glaw and Vences 2007; Pedrono 2008). It is the most conspicuous and iconic of the Malagasy tortoises due to its size and the attractive starred pattern on its shell. It was once very common throughout its range, but has been subject to heavy collection for many years and has now been extirpated from some areas (Lewis 1995; Leuteritz 2002; O'Brien et al. 2003). Its historic distribution extended from the area north of the village of Morombe located in the Toliara Province on the west coast, southward to the Cap Sainte Marie Special Reserve, and east nearly to Fort Dauphin (Glaw and Vences 2007). Currently, it exists south of Toliara and west of Ambovombe, which signifies an estimated range reduction of about 65% (Rafeliarisoa et al. 2013 [this volume]).

Study Locations and Historical Data. — Five widespread localities (Fig. 2; Cap Sainte Marie Special Reserve, Lavanono, Ankirikirika, Nisoa-Ambony, and Lavavolo) were surveyed for tortoises between October and November 2009. These sites were chosen because they were surveyed previously in 1995 (Lewis 1995) and 1999 (Leuteritz 2002). A description of each survey location follows.

Figure 1. Radiated Tortoise (*Astrochelys radiata*) at the Cap Sainte Marie Special Reserve. Photo by C. Castellano.

Cap Sainte Marie Special Reserve (CSM). — This reserve of 1750 ha is located at the southern-most tip of Madagascar, approximately 200 km west of Fort Dauphin (Fig. 2). The dominant vegetation is *Alluaudia comosa*, *Euphorbia* sp., and *Fernando madagascariensis* (Fig. 3) (Leuteritz 2002). Radiated Tortoise density at CSM was previously estimated at 563.0 tortoises/km^2 (Lewis 1995) and 653.7 tortoises/km^2 in 1999 (Leuteritz 2002). The mean carapace length (CL) for tortoises (n = 23) at CSM was 24.6 cm (range = 9.6-36.3) and the percentages of males:females:juveniles in the population were 39.1:8.7:52.2 (Leuteritz 2002).

Lavanono. — This area is located about 30 km west of CSM (Fig. 2). The dominant vegetation is *Euphorbia stenoclada* and *Opuntia* sp. (Leuteritz 2002). The forest

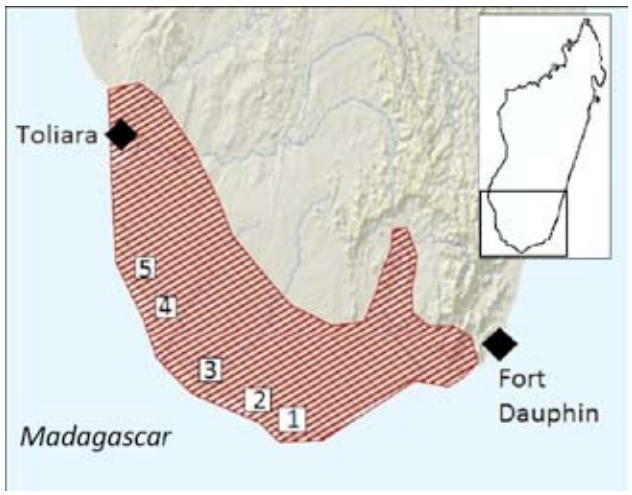

Figure 2. Map of survey locations in southern Madagascar (not to scale). 1 = Cap Sainte Marie Special Reserve, 2 = Lavanono, 3 = Ankirikirika, 4 = Nisoa-Ambony, and 5 = Lavavolo. Cross hatched area = historic distribution of the Radiated Tortoise (from Leuteritz and Rioux Paquette 2008).

Figure 3. Typical spiny forest vegetation at the Cap Sainte Marie Special Reserve. Photo by C. Castellano.

Figure 4. Degraded habitat at Lavanono dominated by large stands of non-native *Opuntia* sp. Photo by C. Castellano.

is degraded as a result of livestock grazing and burning for agriculture (Fig. 4). Density estimates for tortoises at Lavanono were previously 713.8 tortoises/km^2 (Lewis1995) and 953.1 tortoise/km^2 (Leuteritz 2002). The mean CL of 28 individuals was 18.5 cm (range, 6.4–33.5) and the percentages of males:females:juveniles in the population were 14.3:17.9:67.9 (Leuteritz 2002).

Ankirikirika. — This forest is located about 49 km northwest of Lavanono (Fig. 2). It is considered to be a sacred forest and a traditional ceremony must be conducted before commencing work. *Alluaudia ascendens*, *Euphorbia stenoclada*, and *Obetia sp*. dominate the forest (Leuteritz 2002). Ankirikirika was described by Leuteritz (2002) as having been a beautiful gallery forest in 1999. In contrast, we observed considerable evidence that timber was being illegally harvested. Large piles of wood chips were found along many of the survey transects. Density estimates for tortoises at this location were previously 1076.7 tortoises/km^2 (Lewis 1995) and 1884.6 tortoises/km^2 in 1999 (Leuteritz 2002). The mean CL for 15 tortoises was 30.9 cm (range, 4.6–36.6) and the percentages of males:females:juveniles in the population were 20.0:66.7:13.3 (Leuteritz 2002).

Nisoa-Ambony. — This site is located about 65 km northwest of Ankirikirika (Fig. 2). The dominant vegetation is *Alluaudia comosa*, *Comiphora sp*., *Euphorbia* sp., *Jatropha mahafaliensis*, and *Kalanchoe beharensis* (Leuteritz 2002). The forest is protected as a reserve by the local people. Tortoise density at this location was estimated to be 3484.5 tortoises/km^2 in 1999 (Leuteritz 2002). The mean CL for 28 tortoises measured was 25.0 cm (range, 5.3–36.7) and the percentages of males:females:juveniles in the population were 35.7:28.6:35.7 (Leuteritz 2002).

Lavavolo. — This area is located about 20 km northwest of Nisoa-Ambony (Fig. 2). The vegetation is dominated by *Adansonia* sp., *Alluaudia ascendens*, *Didierea trollii*, *Euphorbia* sp., *Jatropha mahafaliensis*, and *Kalanchoe beharensis* (Leuteritz 2002). Tortoise density was estimated at 602.0 tortoises/km^2 (Lewis 1995) and 4908.3 tortoises/km^2 (Leuteritz 2002). The mean CL for 38 tortoises measured was 19.2 cm (range, 4.8–34.9) and the percentages of males:females:juveniles in the population were 26.3:18.4:55.3 (Leuteritz 2002).

Data Collection in the Present Study. — Two 80 m-wide transects at least 400 m apart were surveyed for tortoises at each of the five locations between 28 October and 16 November 2009. Each transect was surveyed by 7–9 people spaced approximately 10 m apart. Transects ranged in length from 400–1000 m depending on the number of tortoises observed and the handling time required to measure them. Transects were walked once per day over two days during peak tortoise activity periods (0630–1000 and 1530–1900 hrs). Transects were alternated each day between these periods to ensure a morning and afternoon survey was completed for each site.

Time, air temperature, cloud cover, precipitation, wind speed, and GPS location were recorded at the beginning and end of each survey. Air temperature was recorded with a rapid register thermometer held in the shade at 1 m above the ground. Cloud cover was recorded as clear sky, some clouds, or no blue sky visible. Precipitation was recorded as none, light, moderate, or heavy. Wind speed was recorded as 0 = calm (smoke rises vertically), 1 = light breeze (wind felt on skin), 2 = gentle breeze (wind motion visible in leaves), 3 = moderate wind (dust raised, small branches moving), and 4 = strong wind (large branches in motion, whistling). GPS locations were recorded using a Magellan hand-held unit in the datum WGS 84.

We searched for tortoises by scanning left and right for both moving individuals and those that were inactive under bushes. Data on size, weight, age, and sex were collected for each individual tortoise encountered. Carapace and plastron lengths were measured using a 45 cm caliper rule and mass was determined using Pesola spring scales. Age was estimated by counting growth annuli, but was clearly inaccurate for older individuals with worn annuli. Sex was

determined according to secondary sexual characteristics: males have thicker and longer tails, deeper anal notches, and more protruding gular scutes (Leuteritz 2002). Individuals < 26 cm CL were considered juveniles (Leuteritz 2002). In order to distinguish among individuals in future surveys, the shell of each tortoise was permanently notched with a square file using a standardized system (Cagle 1939). The five survey locations were also reflected in the notch pattern; for example, all individuals observed at CSM were notched L8 in addition to their unique code. This was done in order to be able to identify the origin of confiscated or displaced tortoises in the future. The Lincoln-Peterson method was used to estimate population size for each transect based on all original captures on day 1 and all recaptures on day 2. Density was determined based on the population estimate and the total area of the survey site (i.e., transect length and width).

Training Program. — Three Malagasy graduate-level students from the University of Antananarivo (UA) and one from the University of Tulear participated in the training program. The primary goal of the program was to teach the methods used to survey and monitor tortoises, and to provide them with the skills needed to implement a community-based tortoise monitoring program. The students that participated were selected based on their academic program and level of field experience.

Students attended a project orientation session at UA before the fieldwork was conducted. The orientation session included a presentation of the project's objectives and a demonstration of the monitoring techniques and data collection procedures that were to be employed. In addition, each student received a "conservation toolbox" with the equipment needed to conduct the surveys and collect the appropriate data (i.e., GPS, compass, file, scales, maps, notebook, etc.). Moreover, an all-day training session was conducted at the first survey location before the surveys were initiated.

Road Surveys. — Road surveys for tortoises were conducted opportunistically when traveling by vehicle during the hours of peak tortoise activity. Date, location, time, GPS coordinates (UTMs), weather, and speed (km/hr) were recorded at the beginning and end of each survey. Total lengths of roads traveled and numbers of tortoises observed were determined at the completion of each survey.

Community Interviews. — The perception of the conservation community at the time of the study was that an increase in the illegal harvesting of natural resources throughout the country had transpired due to the ousting of the former president in February 2009. The belief was that government agencies in Antananarivo were less able to regulate or monitor illegal activities. To gauge the credibility of this perception interviews were conducted with members of each of the five communities that were associated with the survey locations. Questions were asked with regards to whether the collection of tortoises had increased, and what factors may have underpinned any increase, including poverty, drought, and the lack of law enforcement due to political instability associated with the change in government.

RESULTS

Surveys. — Twenty-one surveys were conducted for Radiated Tortoises from 28 October to 16 November 2009. The average transect length was 515 m (range, 100–900). Transect length varied due to number of tortoises observed; for example, the high density of tortoises at Cap Sainte Marie required a large portion of the survey period to be spent processing individuals. The mean search effort (person-hours) per survey was 17 hrs (range, 10–32). The mean air temperature recorded during the surveys was 26ºC (range, 22–37ºC). Weather conditions were mostly slightly overcast, with little or no rain. More specifically, partly cloudy skies were recorded for 42% of the surveys followed by 34% clear skies and 24% with no blue sky visible. Light precipitation was recorded for 12% of the surveys and no precipitation for 88%. Wind speed was recorded as gentle breeze for 46% of the surveys followed by 27% light breeze, 21% moderate wind, and 3% for both calm and strong winds.

The number of tortoises and the percentages of males, females, and juveniles observed at each survey location are summarized in Table 1. The mean number of individual tortoises observed across locations was 40 (range, 3–106). The greatest number of individuals were found at Nisoa-Ambony transect 1 (n = 106) and the fewest at Ankirikirika transect 2 (n = 3). The mean proportions of males, females, and juveniles captured across all locations were 28.2% (range, 0.0–53.5), 36.7% (range, 19.2–66.6), and 34.9% (range, 6.6–75.0), respectively. Females outnumbered males by a considerable margin at 7 of the 10 sites (Table 1). A contingency test revealed that sex ratios were not independent of location when the data from the two transects were pooled for each location ($X^2 = 43.973$, $p < 0.001$).

Table 1. Total numbers, sex, and age class of tortoises captured and processed during the present study in 2009, compared to those observed at the same locations in 1999 by Leuteritz (2002) (italics*). 1,2 = survey transects in the present study; T = transect from Leuteritz study. CSM = Cap Saint Marie. Nis-Am = Nisoa-Ambony.

Location	Transect	N	% Males	% Females	% Juveniles
CSM	1	90	12.2	24.4	63.3
CSM	2	36	5.5	19.4	75.0
CSM*	T	23	39.1	8.7	52.2
Lavanono	1	41	14.6	19.5	65.8
Lavanono	2	26	46.1	19.2	34.6
Lavanono*	T	28	14.3	17.9	67.9
Ankirikirika	1	13	38.4	53.8	7.6
Ankirikirika	2	3	0.0	66.6	33.3
Ankirikirika*	T	15	20.0	66.7	13.3
Nis-Am	1	106	41.5	51.8	6.6
Nis-Am	2	34	20.5	47.0	32.3
Nis-Am*	T	28	35.7	28.6	35.7
Lavavolo	1	30	50.0	33.3	16.6
Lavavolo	2	28	53.5	32.1	14.2
Lavavolo*	T	38	26.3	18.4	55.3
	Mean	40	28.2	36.7	34.9

Table 2. Carapace lengths from transects in the present study (2009) compared to those obtained in 1999 by Leuteritz (2002) (*). Data are means ± 1 SD.

Location	Transect	N	Mean CL (cm)	Range
CSM	1	90	22.6	8.6-36.6
CSM	2	36	22.5	13.2-34.5
CSM*	T	23	24.6	9.6-36.3
Lavanono	1	41	21.6	5.6-32.0
Lavanono	2	26	26.8	2.0-37.0
Lavanono*	T	28	18.5	6.4-33.5
Ankirikirika	1	13	31.6	20.3-34.4
Ankirikirika	2	3	20.3	10.8-27.6
Ankirikirika*	T	15	30.9	4.6-36.3
Nisoa-Ambony	1	106	31.0	5.5-37.4
Nisoa-Ambony	2	34	25.6	2.3-36.4
Nisoa-Ambony*	T	28	25.0	5.3-36.7
Lavavolo	1	30	30.1	8.6-38.4
Lavavolo	2	28	30.4	6.7-37.2
Lavavolo*	T	38	19.2	4.8-34.9

We used CL as an index of body size for comparisons among locations, transects within locations, and between transects in the present study and that of Leuteritz (2002). Mean CL differed significantly among locations (Table 2; non-parametric ANOVA on ranks: $H = 132.08$, $p < 0.001$) and between most transects (Dunn's pair-wise method, $p < 0.05$). The examination of CL distributions revealed considerable variation in size structure among survey locations (Fig. 5). For example, CL distributions were essentially normally distributed at both CSM transects and at Lavanono transect 1, while CL distributions were skewed towards larger animals at Lavanono transect 2, both transects at Nisoa-Ambony, and both transects at Lavavolo. Size structure distributions for the Ankirikirika transects are not shown due to low sample size.

Table 3. Population density estimates (tortoises/km^2) at the five survey locations between transects and among years studied. CSM = Cap Sainte Marie; 1995 = study by Lewis (1995); 1999 = study by Leuteritz (2002); 2009 (T1 and T2) = transects surveyed in the present study.

Location	1995	1999	2009		
			T1	T2	Mean
CSM	563.0	653.7	23600.0	2850.0	13225.0
Lavanono	713.8	953.1	710.0	1031.0	870.5
Ankirikirika	1076.7	1884.6	870.0	60.0	465.0
Nis-Ambony	N/A	3484.5	10450.0	760.0	5605.0
Lavavolo	602.0	4908.3	925.0	970.0	947.5

Population Densities. — Population density estimates for tortoises varied considerably between transects at each location with the exception of Lavavolo (Table 3). The highest densities were recorded at Cap Sainte Marie (2859–23,600 tortoises/km^2) and Nisoa-Ambony (760–10,450 tortoises/km^2), while the lowest density was recorded at Ankirikirika (60–879 tortoises/km^2). Population density estimates also varied considerably among years (Fig. 6). Tortoise density has increased over time at the Cap Sainte Marie Special Reserve and Nisoa-Ambony and decreased at Ankirikirika

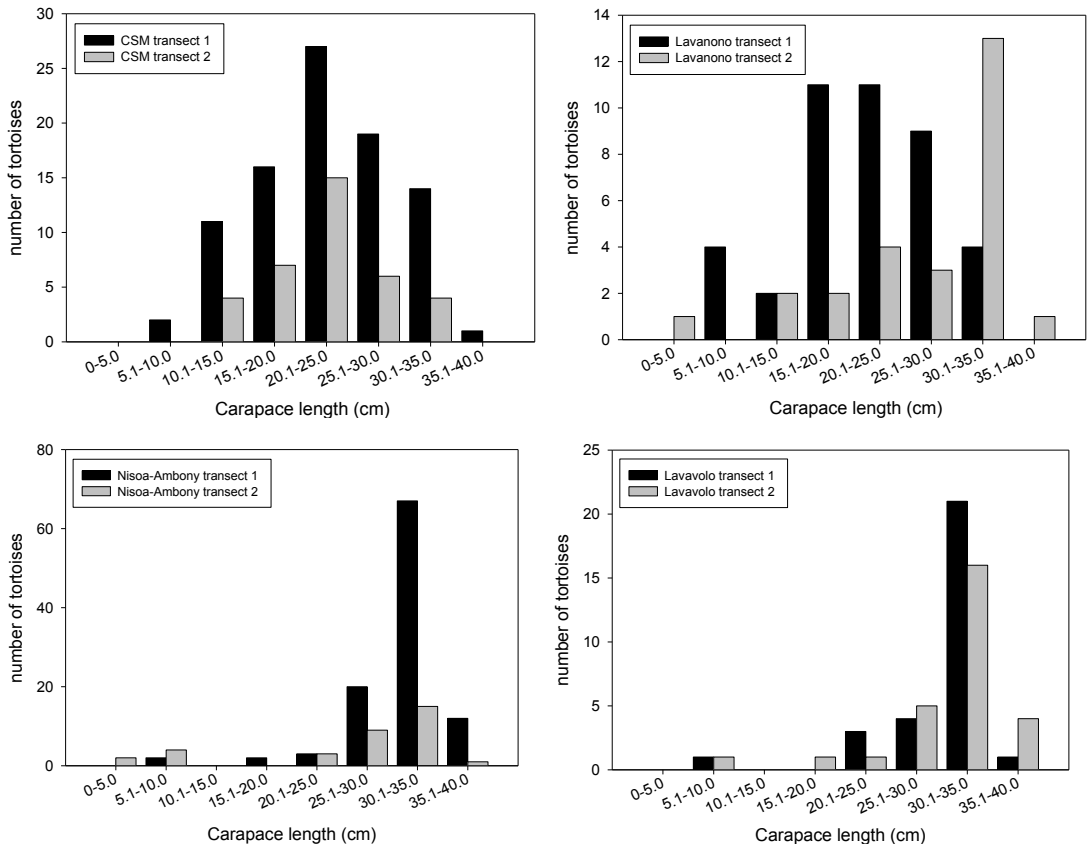

Figure 5. Carapace lengths of Radiated Tortoises at four survey locations, showing variation in the shapes of the size distributions among sites and between transects within sites.

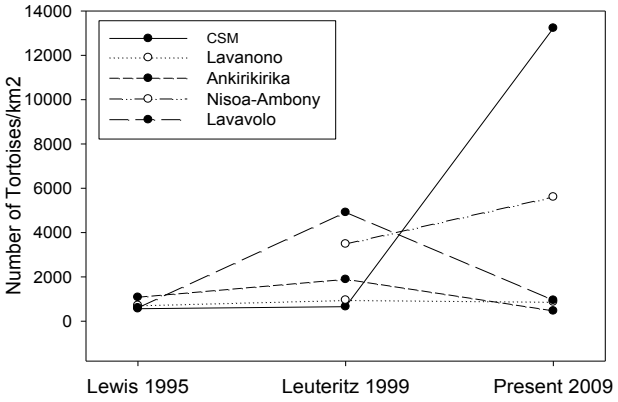

Figure 6. Comparisons of density estimates of *A. radiata* among studies, sites, and years.

and Lavavolo, while the density of tortoises at Lavanono has remained relatively constant.

Road Surveys. — Six opportunistic road surveys for Radiated Tortoises were conducted during the last week of October 2009. Survey transects ranged from 5–40 km in length. The number of tortoises observed per survey ranged from 7–105. Linear densities ranged from 0.88–3.13 tortoises per road km. Two tortoises were found dead on the road between Cap Sainte Marie and Lavanono. The ruptured shells of both individuals indicated that they were struck by vehicles.

Threats to Survival. — On 4 November 2009 we encountered a poaching camp about 11 km south of Ankirikirika. The camp was within 50 m of the Menarandra River on a road that had been closed to traffic a week earlier. About 10 of the approximately 30 total poachers (estimated by the number of carry sticks) who were in the camp when we arrived fled into the forest. On the road were six large blankets covered with cooked tortoise limbs (Fig. 7). The limbs were being dried in the sun in preparation for transport. It was estimated that each blanket had approximately 170 limbs, or the meat of over 40 tortoises. Together, the meat on the six blankets represented more than 250 individuals.

When we arrived, poachers were in the process of slaughtering tortoises, cleaning shells, and removing entrails in preparation for cooking (Fig. 8). There were dozens of small charcoal pits that were used for cooking. Cast iron pots filled with vegetables were found along with pieces of burned shells. Primitive hatchets used for slaughtering tortoises were also observed, and plastic bottles filled with tortoise liver oil were discovered in transport sacks (Fig. 9). One live tortoise was observed hanging in a tree. A rope had been sewn through a hole drilled in the carapacial edge. Three sacks filled with dried tortoise meat were also discovered. We estimated that each sack contained the meat of about 100 tortoises, which brought the total estimated number of poached tortoises to about 600. The sacks were tied to carry sticks used for transport.

At the recommendation of the government official in our group (ZR), we released the tethered tortoise and disposed of the tortoise limbs, most of the weapons, and cooking utensils by throwing them into the river. Villagers who had seen the camp told us that the poachers were from the Antanosy tribe. We filed a police report in Itampolo and submitted several hatchets and bottles of liver oil to the police as evidence (Fig. 9).

Two tortoise shells were found crushed on the road between Cap Sainte Marie and Lavanono. Tortoises were

Figure 8. Tortoises being slaughtered and entrails removed in preparation for cooking at poaching camp. Photo by C. Castellano.

Figure 7. One of six blankets covered in tortoise limbs at poaching camp near Ankirikirika. Photo by C. Castellano.

Figure 9. Primitive weapons used to slaughter tortoises and bottles of tortoise liver oil used for cooking. Photo by C. Castellano.

regularly observed crossing the road and eating cactus fruit on road edges. This behavior makes them susceptible to death or injury through collisions with vehicles. Eight burned tortoise shells were observed at Lavanono. The tortoises may have been burned to death while sheltering in vegetation. Fire is commonly used to clear vegetation. Timber has been illegally harvested from the forest at Ankirikirika and the habitat has been significantly degraded as a result. Four fire pits were also discovered while conducting surveys at this location. Each had three to four tortoise shells present. The shells had been hacked open from the top of the carapace and the plastrons were removed with visible hatchet marks on the bridge. The local villagers were aware that people enter the forest to harvest the timber, and that these harvesters eat tortoises to sustain themselves while collecting timber.

Four tortoise nests that had been destroyed by predators were discovered at transect 2 at Nisoa-Ambony. In addition, two 2-year-old tortoises were found with their heads and forelimbs missing. Both individuals had teeth and/or claw marks on their shells. Two dead hatchlings with intact heads and limbs were also found at this location. They may have been victims of ant predation. One dead juvenile with puncture wounds in its shell and one adult tortoise with a missing limb were observed along transect 1 at Lavavolo.

Interviews. — Seventeen local Malagasy people were interviewed at five locations. According to interviewees, the increase in the illegal harvest was not due to the political unrest, but was mostly associated with: 1) regional development that has attracted tortoise eating tribes to the region that do not respect the local taboo against consuming this species; 2) poverty, motivating people to collect tortoises for money, or to trade for rice; 3) drought that has led to crop failure and hunger; and 4) the consumption of tortoise meat as a delicacy for special occasions and religious holidays. It was also determined that tortoise collection is mainly conducted by the Antanosy tribe from Fotadrevo.

Interview 1. — The first interview was conducted on 29 October at the Cap Sainte Marie Special Reserve. The people interviewed included a village elder (male, 65 years old), camp cook (male, 40), and three representatives (males, 25–55) from Madagascar National Parks (MNP). It was stated that very little harvesting is occurring within the park. Tortoises are harvested for food north of Marovato, transferred to Ft. Dauphin through Beloha and Tsiombe, and sold in restaurants in Ft. Dauphin.

It was agreed that there had been no increase in the collection of tortoises since the change in government. Collection is random and mainly for local consumption. In March, one ranger chased a man with 10 tortoises tied to his bicycle. The man dropped his bicycle and fled. In July, another man was found carrying a few tortoises, but he also fled when confronted, leaving the tortoises behind.

Once tortoises were extremely abundant and could be seen throughout the area. The decline began when the lighthouse was built in 1971. With the lighthouse came people from many different tribes, including those that did not respect the local taboo (fady) against consuming tortoises. Tsiombe was mentioned as a place with a mixture of these tribes. A tortoise can be purchased in the local market for 20,000 Ariary (currently equivalent to about US $10) in Tsiombe. Collectors that live there are asked to gather tortoises when patrons request them. (Note: Before the lighthouse was erected, people in the community built fires in stone pits to guide ships around the cape. Nevertheless, a commercial fishing boat sank and the people on board said that they saw a vision of the Virgin Mary appear above them on the cliff's edge. To honor this vision, nuns erected a statue of the Virgin Mary and named this location Cap Sainte Marie.)

Interview 2. — This interview was conducted at Lavanono on 1 November. Three male fishermen aged between 20–25 years were interviewed. There is awareness of the political situation in the capitol city Antananarivo, but it has had very little effect on their community. The people of Lavanono respect the fady and do not harm tortoises. They were unaware of any collectors entering the village since they moved there about three years ago. They were aware that collectors live in Beloha and tortoises can be found in the markets there.

Interview 3. — This was conducted at Lavanono on 1 November. The male owner of a hotel aged 50 was interviewed. Fewer tortoises are seen in the village since he and his family arrived in 2003. The forest habitat has been reduced since then. There is awareness that other tribes collect and eat tortoises. Tortoises are collected from Lavanono when people from these tribes travel through on their way to other villages or cities. One family will eat around five tortoises. The hotel owner has never seen anyone collect tortoises in large numbers, but has heard stories of tortoises being collected for restaurants in Ft. Dauphin. In 2007, he saw about 20 tortoises in the markets at Beloha. He also witnessed a politician and his companions collecting tortoises. The people in the village told them that it was forbidden, but they took them regardless.

Interview 4. — This was conducted in Beloha on 2 November. A male military commander aged 40 was interviewed. He was travelling from Tongobory to Tulear where he was stationed. He reported that the dried meat of fifty tortoises was located two weeks earlier in Androka, a place that had not been targeted previously by poachers. The poachers were Antanosy women that were camping in the forest. After collecting the tortoises they dried the meat in preparation for transport to Fotadrevo. Dried tortoise limbs are considered to be a delicacy by some tribes. The Antanosy trade the meat for rice, which they can no longer afford to buy. The people in Androka protested, but the women would not leave; although they eventually fled when the police arrived. The commander also reported that the shells of five hundred tortoises had been found near Marolinta two days before this interview. (Note: We attempted to find this site in order to document this massacre, but the river could not be crossed due to overnight flooding).

Interview 5. — This was conducted in Beloha on 3 November. A deputy of the former administration was interviewed (male, age 70). Tortoises have been collected

around Beloha for the last 40 years, but there has been a decrease in the rate of collection over the past two. Two years ago he saw 10 oxcarts filled with tortoises in Beloha. Antanosy people from Fotadrevo collect tortoises, dry the meat, and transport it back to their village. Both live tortoises and dried meat are sent to Tulear and Ft. Dauphin. In these cities, tortoise meat is considered to be a delicacy and is served for special events and holidays, especially Christmas. Tortoises are also sent to restaurants on Reunion.

Interview 6. — This was conducted at the Sacred Forest of Ankirikirika on 3 November. The brother of the King (70 years old) and his son (35) were interviewed. Protection for the tortoises has increased since the change in the administration. The government committee that is in charge of protecting the environment is now working properly. In the past collectors were unafraid; now they are afraid and run from the police. The people who collect tortoises for food are very hungry. They have been suffering through drought for several years and have had little success with their crops. Both the prince and his son were very sympathetic because these people need food and they are very poor. They were both born in this forest and have seen a decline in tortoises over the past several years. Antanosy people have collected most of the tortoises from the forest at Ankirikirika. They also cut down the trees and the forest and tortoises are dying. There is a local law to punish collectors; it states that if someone is seen killing a tortoise they must purchase a six-year-old zebu for 200,000 Ariary (US$ 100), spread its blood at the site where the tortoise was killed, and give the zebu meat to the villagers. The event is documented and the person's name is sent to the government. It is believed that this deters people from collecting tortoises.

Interview 7. — This was conducted at Itampolo on 6 November. Two male police officers (age 35–40) were interviewed. A sailboat had been docked in the bay for over a week and they had just returned from inspecting it. No tortoises were found on-board. Earlier that week, they located poachers with sacks of dried meat from approximately 800 tortoises and 95 live individuals between Itampolo and Androka. Eight poachers identified as Antanosy people from Fotadrevo, which included four men, three women, and one young boy, had been arrested and were currently jailed in Itampolo. The law states that the confiscated meat has to be destroyed and was therefore burned. The officers said that collection was on the rise as Christmas was approaching.

Interview 8. — This was conducted at Itampolo on 8 November. Two male farmers (age 30) were interviewed. Tortoise collection has not increased with the change in administration. Tortoises are not being collected by locals because of the fady and Antanosy do not come here because it is too close to the police station. Also, the community protects the tortoises in this area. Tortoise numbers have not declined because the forest is not harmed. If someone is caught eating, or taking a tortoise they have to kill a six-year-old zebu, spread its blood at the site, and give the zebu meat to the villagers (same law as in Ankirikirika). People travelling through the area do collect tortoises to eat during their journey.

Interview 9. — This last interview was conducted in Itampolo on 8 November. A local man (60) was interviewed. Collection was increasing, but not because of politics. A Chinese man living in Antananarivo sends people to collect tortoises for their livers. They prefer males because they have larger livers than females. The tortoises are slaughtered and the livers are sent to Ampanihy and then to Japan. These men are very dangerous and carry guns. Tortoises are also collected during religious holidays especially around Christmas and during periods of drought when food is scarce.

DISCUSSION

Population Density. — Despite the high estimates of tortoise abundance reported here, the populations at the survey locations are extremely vulnerable to collection and require immediate and substantial protection. Illegal collection of tortoises is widespread and will eventually reach these locations as other populations become depleted. Compared to historical surveys in 1995 and 1999, tortoise densities were lower at two localities (Ankirikirika and Lavavolo), higher at two sites (Cap Sainte Marie and Nisoa-Ambony), and relatively unchanged at a fifth locality (Lavanono). Tortoise density may have increased at the Cap Sainte Marie Special Reserve and the forest at Nisoa-Ambony because both locations receive protected area status. An MNP office has been erected at Cap Sainte Marie since Leuteritz completed his research in 2002. This office provides a significant law enforcement presence, which has likely limited tortoise poaching in the reserve. Similarly, the forest at Nisoa-Ambony is near to Itampolo, which is the location of the Gendarmerie (military police). As a result, there is a strong police presence in this area that may serve to deter tortoise collection. Density estimates for the population at Nisoa-Ambony may be somewhat inflated, however, as the tortoises at this location were aggregated at a communal drinking site (Doody et al. 2011). Nevertheless, our data suggest that these locations, with the exception of Ankirikirika, support dense populations of Radiated Tortoises, which makes them critical for the survival of the species and therefore require significant protection.

The tortoise population at Ankirikirika has suffered greatly from illegal harvest and possibly habitat destruction. This population remains in jeopardy because it is within an area that is being targeted by poachers. Urgent action is needed at Ankirikirika to prevent further losses. The community at Ankirikirika respects tortoises, is aware of illegal poaching, and wants to prevent further harm. This community can contribute greatly to tortoise conservation because of their strong presence in the forest, but require support from the police. At Lavavolo, habitat degradation may be contributing to a slow decline in tortoises, although this species is known to live in degraded landscapes (O'Brien et al. 2003). Livestock grazing occurs throughout the area and the survey sites were located near to settlements.

Demography. — Radiated Tortoise populations at Cap Sainte Marie and Lavanono had relatively higher numbers of smaller individuals present than Nisoa-Ambony and Lavavolo. This suggests that the populations at CSM and Lavanono are expanding. The size distributions at Nisoa-Ambony and Lavavolo suggest that those populations are contracting. However, the vegetation among the survey locations was variable. The dwarf vegetation at Cap Sainte Marie and exposed sandy substrate at Lavanono may have made it easier to locate both large and small individuals. The forests at Nisoa-Ambony and Lavavolo were dense compared to the others; nevertheless, the vegetation was relatively sparse at all locations as it was the very beginning of the wet or growing season.

Leuteritz (2002) reported that the population at Cap Sainte Marie was composed mainly of small individuals. When compared to the size structure reported for this location in the present study, it appears that the juvenile tortoises observed by Leuteritz have grown into the larger size classes. This could reflect a decrease in harvesting between these study periods, or some other factor.

Illegal Harvest. — The perception of the people interviewed in the local communities was that there was an increase in tortoise harvest, but this increase was not associated with the political situation. The four primary reasons given for the apparent increase in collection were:

1. Development in the region has attracted peopled from tribes that do not respect the local taboo (fady) that prevents people from harming the tortoises.

2. Tortoise meat is considered to be a delicacy and is served for special occasions; consequently, collection increases before religious holidays, especially Christmas.

3. People collect tortoises in order to earn money.

4. Prolonged periods of drought has led to years of crop failure; as a result, people trade tortoise meat for rice.

Collectively, both our results and observations suggest that tortoise harvesting is primarily driven by Antanosy people from Fotadrevo. They hunt tortoises and dry the meat before transporting it back to Fotadrevo. Villages associated with the tortoise trade for local consumption include Fotadrevo, Beloha, Tsiombe, Marolinta, Androka, and Ankirikirika. Tortoises are collected for restaurants in Tulear and Ft. Dauphin. None of the people interviewed had any information on tortoises being collected for the international trade.

The apparent increase in harvest of tortoises is related to the erosion of taboos across human generations (Lingard et al. 2003). Cultural taboos play a critical role in species conservation by guiding human conduct toward the natural environment in many of the world's traditional societies (Colding and Folke 2001). A system of taboos is central to Malagasy culture and strict taboos offer undeniable protection for threatened species (e.g., lemurs and chameleons) especially where capacity to enforce external conservation laws is restricted (Tengo et al. 2007; Jones et al. 2008). Consuming or harming tortoises in southern Madagascar is considered taboo by three of the four Malagasy tribes that span their range. Historically, this has resulted in "safe havens" for these species (Lingard et al. 2003). These taboos are not respected by outside tribes (e.g., Antanosy) that travel to the safe havens to collect tortoises. Moreover, young members of the tribe respecting the taboos maintain that they mainly uphold the taboos out of respect for their elders, rather than for traditional (supernatural) reasons. Tortoise abundance is lower in areas nearest to the Antanosy and urban centers with greater ethnic mixing (Lingard et al. 2003). Recent severe drought and political instability have increased poverty and reduced law enforcement, respectively, throughout the nation (Bohannon 2009). Opinions of the locals we interviewed notwithstanding, these phenomena may be further exposing the taboo as an ever-weakening institution for conservation of tortoises even within the safe havens.

Recommendations

We make the following recommendations based on the findings noted.

1. Protected locations, which include a law enforcement presence, support the highest densities of Radiated Tortoises.

a) Provide support to the MNP office and the presence of Park Rangers at the Cap Sainte Marie Special Reserve to deter poaching; and,

b) Establish reserves with a law enforcement presence at Nisoa-Ambony, Lavanono, Ankirikirika, and Lavavolo.

2. Radiated Tortoises at Ankirikirika are declining drastically due to illegal collection and also potentially due to habitat loss. The community at this location can contribute to tortoise conservation.

a) Develop a community-based conservation program to be facilitated by the royal family;

b) Establish a law enforcement presence to prevent tortoise collection and timber harvesting; and,

c) Determine the impacts of poaching and timber harvesting on tortoises.

3. Current tortoise density (in 2009) has increased at Cap Sainte Marie and Nisoa-Ambony, decreased at Ankirikirika and Lavavolo, and remained stable at Lavanono, as compared to 1995 and 1999 when previous surveys were conducted.

a) Continue long-term monitoring programs at these locations in order to determine population trends through time; and,

b) Use the data provided here (including sex ratios, age class structure, size distributions, sources of mortality, potential for community-based conservation programs, etc.) to develop tailored conservation strategies for each location as these factors vary among sites.

4. Tortoise meat is considered to be a delicacy and is served for special occasions; consequently, collection increases before religious holidays, especially Christmas.

a) Develop a conservation campaign to raise awareness about overharvesting that can be implemented throughout the year, but especially during the months that precede religious holidays. Target villages that contribute to the demand for

tortoise meat, including Fotadrevo, Beloha, Tsiombe, Tulear, and Ft. Dauphin.

5. Development in the south and southwest has attracted people from outside tribes that do not respect the local fady to move into villages within the tortoise's range, including Beloha and Tsiombe.

a) Conduct surveys to establish the status of tortoises at these and surrounding locations;

b) Use these data to identify and develop areas of protection for the remaining populations; and,

c) Identify barriers to tortoise conservation at these and surrounding locations and develop community-based conservation program to eliminate those barriers.

6. People are very poor and collect tortoises for money, or trade the meat for rice. The ongoing drought has led to years of crop failure; as a result, people collect tortoises to eat because they are starving.

a) Develop partnership with USAID, or similar organizations, to develop alternate food sources for villagers that respect the fady and those that do not, particularly in the region between Faux Cap and Ft. Dauphin.

7. The Antanosy people from Fotadrevo are driving the illegal harvest. They hunt tortoises and dry the meat before transporting it back to Fotadrevo.

a) Target Fotadrevo for a community-based conservation program; and,

b) Develop and implement an awareness and education campaign at this location.

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Résumé

La tortue radiée (*Astrochelys radiata*) occupe naturellement les forêts épineuses de la zone littorale du sud de Madagascar. L'espèce est classée En Danger Critique d'Extinction conséquemment à non seulement une consommation locale accrue, mais aussi aux collectes que ses populations subissent pour le marché des animaux exotiques et de compagnie, ainsi que la perte de son habitat originel. Des inventaires ont été effectués dans cinq localités éparses pour réévaluer le statut des populations naturelles de tortues radiées, en comparaison avec des données datant de 10 à 15 ans. Des interviews ont été réalisées dans chaque localité pour mieux comprendre les facteurs à l'origine des récentes tendances de collecte de tortues comme la sécheresse, la pauvreté, l'instabilité politique et la perte progressive des tabous ancestraux. La tortue radiée se trouve encore en grand nombre dans la Réserve Spéciale de Cap Sainte-Marie, de même qu'à Lavanono, Nisoa-Ambony, et Lavavolo. Toutefois, très peu d'individus ont pu être observés à Ankirikirika. Ceci est probablement lié à la découverte par la suite d'un campement de braconniers à proximité. Les restes d'environ 600 tortues y ont été constatés. Comparée aux données antérieures, la densité des tortues a augmenté dans les zones protégées que sont Cap Sainte-Marie et Nisoa-Ambony et elle a diminué à Ankirikirika et Lavavolo. La densité trouvée à Lavanono était similaire à celle évoquée dans de précédents rapports. D'après les personnes interviewées, l'augmentation de la collecte illicite de tortues était principalement due à: 1) un développement local qui a attiré des personnes de tribus différentes et pour lesquelles consommer la tortue n'est pas tabou; 2) une pauvreté croissante qui pousse les gens à vendre des tortues ou à les échanger contre du riz; 3) la sécheresse qui a corrompu les récoltes et ramené la famine; et 4) la viande de tortue est toujours considérée comme un mets des grandes occasions. La collecte des tortues est souvent effectuée par les Antanosy venant de Fotadrevo et les «foyers» des collectes se situent le long de la rivière Menarandra dans les environs de Marolinta, Ankirikirika, et Androka. Les programmes de conservation mis en place avec les communautés locales devraient cibler les localités qui dirigent les collectes de tortues, comprenant Fotadrevo, Beloha, Tsiombe, Ft-Dauphin, et Toliara. Un programme de suivi à long terme des populations de tortues dans les cinq sites inventoriés a été mis en place. Toutefois, ces populations sont extrêmement vulnérables par rapport à la collecte. De ce fait, une accentuation des mesures de protection est requise.

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