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Human–armadillo interaction in Ceará, Brazil: Potential for transmission of *Mycobacterium leprae*

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ABSTRACT

Several factors suggest that armadillos present an important risk for human leprosy infection. This study uses semi-structured interviews to better illustrate how human interaction with armadillos may increase the risk of leprosy transmission. The participants were all residents of the state of Ceará, in northeastern Brazil, all acknowledged contact with armadillos either through hunting, through cooking, or through consumption of its meat. This study raises important issues about contact between human beings and armadillos. The interviews provide evidence of numerous situations in which leprosy transmission via the armadillo is possible. At a minimum, people who hunt armadillos need to be made aware of the risk of infection.

1. Introduction

Leprosy is an infectious disease caused by *Mycobacterium leprae* that attacks the skin and peripheral nerves, causing numerous sequelae. Although person to person infection with leprosy has long been suspected as the most important mode of transmission (van Beers et al., 1999), zoological reservoirs may also play a role in leprosy transmission, necessitating a different approach to the control and prevention of the disease (Truman and Fine, 2010).

In 1971, Kirchheimer and Storrs (Kirchheimer and Storrs, 1971) infected armadillos with leprosy and in 1975 a leprosy like disease was reported among wild nine banded armadillos (*Dasypus novemcinctus*) (Walsh et al., 1975). In 1983, it was confirmed that armadillo caught in the wild were infected with the same *M. leprae* infecting humans (Smith et al., 1983a). More recently it has been shown that wild armadillos in Louisiana, naturally infected with *M. leprae*, harbor the European/North African SNP type 3 strain, found in human leprosy (Monot et al., 2005). The presence of naturally occurring leprosy in armadillos raises the possibility that they play a role in human leprosy infection but this role is not yet clear (Truman, 2005, 2008).

At least 20–40 new cases of the 100–200 cases diagnosed with leprosy every year among native-born US citizens have no history of foreign or human exposure. Those patients reside mainly in Texas, Louisiana and Mississippi, where the highest prevalence rates of infected armadillos are described, and reported no contact with individuals with leprosy (Truman, 2005, 2008). Another study described leprosy cases among three native-born patients from Mississippi with no history of foreign travel, contact with each other or known leprosy patients, but all had a history of armadillo exposure (Abide et al., 2008). More recently, a second zoonotic strain that differed from the strain found in Texas and Louisiana was identified in 10 patients and multiple armadillos from South Florida where armadillos were free from the infection 20 years ago (Sharma et al., 2013).

Because *D. novemcinctus* has been indicated as a carrier of *M. leprae*, both direct and indirect contact with this animal was noted as a possible risk factor for infection. Later, Job et al. (1985) described the presentation and course of the disease in armadillos, confirming the bacteria's presence in a variety of armadillo tissue. Some

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authors found direct exposure to armadillo associated with leprosy, including possible transmission by human consumption of armadillo meat (Abide et al., 2008; Deps et al., 2008a; Thomas et al., 1987; Clark et al., 2008). Other authors did not find association with exposure to armadillo (Kerr-Pontes et al., 2006) including armadillo meat consumption (Schmitt et al., 2010).

Following the empirical confirmation of the presence of *M. leprae* bacteria in naturally infected armadillos using different approaches, including biological markers and histopathological studies, *M. leprae* infected armadillos have been found across a broad geographical range in the Americas, including Texas and Louisiana in the southern United States (Truman, 2005; Smith et al., 1983b; Stallknecht et al., 1987; Walsh et al., 1986; Truman et al., 1991), Mexico (Amezcua et al., 1984), Colombia (Cardona-Castro et al., 2009a,b), Brazil (Deps et al., 2008b; Deps et al., 2007, 2002), and Argentina (Zumarraga et al., 2001). Of note, the distribution of leprosy infected armadillos mirrors the distribution of most human leprosy cases in the US. Recently, naturally infected armadillos were found in Ceará not only in *D. novemcinctus* but also in *Euphractus sexcinctus* (Frota et al., 2012).

Several factors suggest that armadillos present an important risk for human leprosy infection: they are naturally infected in the wild; and the geographic distribution of human leprosy and armadillo leprosy cases is strongly correlated in areas where person-to-person contact cannot be suspected. This correlation is particularly notable because of the armadillo's wide but specific range. Although it has been suggested that armadillos are a vector for leprosy transmission to humans, little work has been done to describe the modes of human and armadillo interaction. This study uses semi-structured interviews conducted in the northeastern Brazilian state of Ceará to better illuminate how human interaction with armadillos may increase the risk of leprosy transmission.

To understand human–armadillo interactions, it is useful to be familiar with the armadillo's habitat and behavior. The armadillo, whose name in Portuguese (*tatu*) means "tough leather" in the indigenous language Tupi (Pereira et al., 2003), possesses several unique characteristics that are relevant to its role as a zoological reservoir for *M. leprae*. It is a nocturnal mammal that lives in burrows throughout the southern United States, Mexico, and South America. Diet consists of mostly invertebrates and plants harvested with its claws and nose, although the animal is an omnivorous and opportunistic feeder, including consuming road kill. Generally not aggressive, armadillos have been known to scratch people when cornered, although they would prefer to flee to dense brush. As implied in their Portuguese name, armadillo have been used for their skin for millennia, and are still hunted for food, using dogs, guns, and traps.

Although both the incidence and prevalence of leprosy have declined over the last century and new-case detection in WHO regions during 2004–2010 continue to decline in all regions except the Eastern Mediterranean (World Health Organization, 2011), leprosy is still an important public health problem in Brazil (Penna and Penna, 2007), which has the second highest prevalence of leprosy in the world. Brazil has encountered difficulty in detecting and controlling the disease. This fact, as well as the incidence of cases in patients under fifteen years of age, point to active and current transmission. A qualitative study such as the one undertaken in this paper can clarify the role of zoologic transmission of the disease to humans, and contribute to the control of this endemic.

2. Material and methods

This study has three principal goals: (1) to review the body of evidence concerning armadillo habitat and interaction with humans; (2) to describe the social implications of the armadillo as well as the importance of armadillo hunting to people in Ceará, Northeastern Brazil; (3) to describe the physical interactions that take place between humans and armadillos that may be related to transmission of *M. leprae*.

2.1. Study area

The participants are all residents of the state of Ceará which is located in northeastern Brazil and one of twenty seven subdivisions of the Brazilian federation, which is comprised of twenty six states and the federal district of Brasilia. The population of the state is 8,448,055 (Instituto Brasileiro de Geografia e Estatística, 2010), with approximately 71.5% living in urban areas. The literacy rate of 76.9% is relatively low compared to other Brazilian states, especially those in the south of the country. The Index of Human Development (IHD) of Ceará varies from 0.551 to 0.786, below the IDH of the country as a whole (Instituto de Pesquisa e Estratégia Econômica do Ceará, 2010). These figures reflect Ceara's recent increases in IHD, the most rapid of all the Brazilian states. However, even these recent increases in the IDH have not been sufficient to substantially reduce social inequality in Ceará.

Although the detection of new cases of leprosy in Brazil is continuously decreasing, the North, Northeast and Midwest regions are considered endemic and responsible for most new cases (Penna et al., 2009). In Ceará, one of the states of the Northeast region, leprosy is still a very important public health problem. From 2001 to 2012, the detection rate varied from 37.4 to 23.6 cases/100,000 inhabitants. The detection rate among children under 15 years of age is also high, varying from 7.3 to 5.0 cases/100,000 (Ceará Secretaria Estadual de Saude, 2013), demonstrating that active transmission is occurring. Because of the epidemiology and an environment conducive to armadillo Ceará was chosen for this study.

2.2. Study population

Although hunting armadillos – mostly for food – was a relatively popular pursuit in the past, this has fallen in recent times as living standards have improved. We met with staff from the State Zoonosis Authority in Fortaleza to recommend individuals that they knew to be authorities on armadillo hunting and cooking. We identified eleven individuals, nine men and two women, and interviewed them for this study. Ages ranged from 33 to 75 years of age. Education level ranged from no schooling to some university. Occupations included farmers, small businessmen, janitors and one veterinary assistant. All acknowledged substantial contact with armadillos either through hunting, through cooking, or through consumption of its meat. While the number of participants in the study was small, they provided a comprehensive and knowledgeable range of information about the habits of armadillos, the tradition of cooking and eating armadillo and current human–armadillo interaction.

2.3. Collection and analysis of data

A semi-structured interview guide was developed exploring social conditions, income, reasons for hunting and hunting practices, including preparing the meat, preferences for armadillo meat, role of armadillo in the diet and historic changes in armadillo hunting. All participants were consented and interviews conducted by an anthropology graduate student from the Federal University of Ceará and recorded with the participants' permission.

2.4. Data analysis

The interviews were analyzed using a qualitative methodology described in Kendall et al. (2005) (Chopra et al., 2006). The pre-defined categories established in the interview guide were

summarized as new interviews were added. The interviewer was supervised daily by the first author. The interviewer and author met twice during the interviews to review all interviews to date and identify themes that were emerging. For example, the effect of government family support programs on armadillo hunting was noted and became a theme to be explored in further interviews.

The goal of this analysis is to provide greater understanding of the relationship between humans and armadillos, and moreover to investigate whether this contact could potentially transmit leprosy from armadillos to humans. Further, this study may improve the means of controlling and preventing leprosy.

2.5. Ethics

This study was approved by the Federal University of Cearás Research Ethics Committee (COMEPE). All wild animals are protected by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) in Brazil and a special license to collect was provided by this institute.

3. Results

3.1. Armadillo habitat

In order to understand the potential transmission of *M. leprae* from armadillos to humans, as well as the events encompassing the armadillo hunt, it is important to be familiar with the characteristics of armadillo habitat.

One of the armadillos unique characteristics is how it constructs its den, which is a cave dug out with its claws. An interview with J.E provided insight into the habitat of the armadillo:

> They live in deep holes that they make themselves, dug out with big, sharp claws, they make underground tunnels, and that's where they make their home... (J.E., 56 yrs old)

In another conversation, we obtained additional information

> It's a burrow... he makes a hole in the dirt, sometimes in the mud, sometimes in a rocky hole... sometimes it's in a "lageiro" and most of the time its right there in the sand, in the mud... the den... two meters, he's got that little entrance a little hole that just fits him and there inside he digs out like a frying pan and he tosses the sand outside and during the day he stays there resting... the pan... maybe forty centimeters in diameter. (D., 62 yrs old)

3.2. Significance of armadillo hunting

Three distinct reasons were identified for hunting armadillo: those who hunt to satisfy physical needs (hunger), those who hunt out of economic need, and those who hunt for pleasure.

Some hunt armadillos for food, due to the lack of money to purchase meat. This was common in the northeastern states during a long period when poverty and misery in large segments of the population was more common. According to two participants, the national economic plans enacted in the past several decades as well as programs intended to raise the income of the lowest socioeconomic classes in the previous and current administration have lessened the necessity of hunting wild animals for subsistence, changing the purpose of hunting:

> After President Lula and this family assistance, food assistance, school assistance (for the poorest people)... ended hunger in the interior of the country... today... everyone gets to eat at least twice a day... so, today people hunt as a hobby, because they like it (D., 62 yrs)

Others hunt so they can sell the meat, which is sought after, and thereby generate an additional source of income for those who live in financially precarious situations. Both these situations can be seen in the following:

> It's not for fun, but sometimes for survival certain people will sell portions (of armadillo)... they get three, four and sell them and buy flour, buy rice, beans to eat... everyone orders the meat... its really good and everyone wants to buy it (L., 59 yrs).

Nonetheless, many have stopped hunting for financial reasons. As a result, those who are more financially stable have begun to see the armadillo as a source of entertainment, pastime or novelty for the family. The following quote demonstrates this idea:

> In my case, where I have my source of income, a way to survive, I go only for sport, for the pleasure of seeing the clear moonlight, the nocturnal landscape, I go with my friends to have fun (J.E., 56 yrs)

Others compare the armadillo to lobster, reinforcing the idea that the armadillo is a unique novelty and a distinct part of the life of people in the interior of northeastern Brazil. D. comments:

> Today, people always get together in the interior on the weekends, from Thursday to Friday or from Friday till Saturday, and get three, four friends that like to hunt and at eight o'clock at night, they go out into the brush (where the armadillos live)... it's like it was really a hobby... it's like fishing... a lot of the time you don't even eat the fish, but you like to fish... armadillos are like a novelty... you guys don't like to eat a lobster every once in a while? (D., 62 yrs)

In some rural areas of Ceará and Rio Grande do Norte states, there are often armadillo hunting tournaments. In these gatherings, friends meet to have fun and compete among themselves. As an example, an interviewee employed as a cowhand told us:

> Sometimes we put together these tournaments ('armadillo round up') and form three groups that leave for the bush... to see who are the best hunters... the prize is fifty *conto* (an antiquated Brazilian currency which is used in the vernacular to signify money), eighty reals (the official currency of Brazil)... and whoever gets more is the best (A.W., 42 yrs)

3.3. The armadillo hunt

The armadillo hunt usually takes place at night during the rainy season, which is also referred to as the winter in the northeastern region of Brazil, although it falls during the months of January through May. The preference for hunting at dawn in the rainy season is because armadillos are just returning to their dens full, slow, and satiated after a night of feeding on roots that become abundant during the season. It is possible that the water and humidity at this time could favor infection with *M. leprae*, creating an excellent environment for survival of the bacteria. The previously cited factors would facilitate increased contact of infected animals with other animals, with the environment and with human beings.

> The rainy season (hunting season) is when the winter starts, January, February, around that time, rainy season. Because he leaves to eat plants... people are planting corn and things like that (A., 54 yrs)

The rainy season creates complications for hunters because of the water and the thick bush. Hunters bring pickaxes, shotguns, traps, machetes, propane, gasoline and dogs. The following illustrates this:

> . . .the armadillo hunt is at night, we take the shotgun and wait for him, go out with the dogs. . . the dogs have the scent and grab him, a lot of the time, he (armadillo) wants to hide himself in a hole and we shoot the shotgun and pull him out by the tail. . ., he's pretty strong, but we capture him just like that. . . its better to just take him with the dog. . . in that season we go by the footprints, we've got those little trails of theirs. . . we follow them. . . with dogs. . . (A., 54 yrs)

Some hunters use traps and propane (cooking gas) to capture armadillos:

> Sometimes in a rocky den. . . we know the location and can't manage to pull it out because. . . we don't have any way to break the rock. . . so we put down traps. . . its an iron trap, with wire, and a cage so that when it leaves, it falls inside the cage, and the cage closes automatically. . . we also capture. . . a lot of the time. . . putting a hose. . . with cooking gas. . . we open the canister a little and put it in there and when it smells the gas it leaves the den (D., 62 yrs)

During the hunt, armadillos and humans are frequently in contact with each other. Being in close quarters with armadillos, being exposed to the cloud of dust raised by a threatened armadillo as it attempts to flee and the direct contact that occurs when the hunter grabs the armadillo with his hands could present a significant risk of infection.

As mentioned above, there are still people who use dogs to spot the armadillos that are then captured by hand. One of the interviewees said:

> The dog corners it and the *cabra* (literally goat, used here to refer to the hunter and emphasize his masculinity) grabs it. . . sometimes the *cabra* pulls it out with his arm, right there with his hand, and sometimes he throws it out and the dog. . . grabs it. . . (A.W., 42 yrs)

After the armadillo is captured, it can have several fates. Some are killed almost immediately, others are transported alive to the hunter's house and are killed to prepare for eating. As previously mentioned, the hunter can also sell the armadillo to third parties, and the contact that these people have with the armadillos can be seen as yet another opportunity for risk of leprosy transmission. The following quote illustrates this:

> When they are captured, sometimes the hunter breaks their necks immediately. . . (if the armadillo is brought alive) to transport the armadillo is easier because its got these big ears and we. . . grab its ears, tie one to another covering its eyes, and pretty quickly he calms down and we put him in a bag. . . sometimes we sell it also. . . to get some extra money. . . (D., 62 yrs)

The intense handling that occurs during the capture of the armadillo is relevant to this study. Direct contact with the armadillo can occur through scratches received during handling. Indirect contact occurs through contact with the sacks used to transport armadillos, which are often reused to store or transport other materials such as food, even though they are sometimes contaminated with armadillo blood.

According to one of the interviewees, it is uncommon to keep armadillos in captivity for long periods of time because they have difficulty adapting to peridomestic circumstances. Furthermore, it is not necessary to clean the armadillo's digestive tract because their gut contents are generally benign. The following discussion refers to this:

> The armadillo. . . when captured. . . has to be killed right away. . . because he doesn't know how to adapt. . . he doesn't eat. . . he dies (A., 54 yrs)

However, other informants report keeping the animals for several days, feeding and watering them to "clean" them prior to slaughter. Cleaning, i.e., feeding and watering armadillo before slaughtering, is required said some informants because popular knowledge holds that armadillos eat dead animals, including cadavers, and these residues need to be cleaned from the digestive system before the armadillo is fit for human consumption. This would extend the time for casual contact.

3.4. Food preparation

Preparing armadillos to eat is another situation in which people risk infection, because there is contact with the armadillo's blood (principally when the viscera of the animal are removed), its skin and its body secretions. One of the interviewed, J.E., explains:

> First, we take off its shell, the outer bony part, we throw out the guts, head and then we cut it into pieces. . . if you want you can grill it on a spit like a barbeque. . . and if you want you can make it cooked or fried using the same spices as chicken, goat, sheep, etc. . . (J.E., 56 yrs)

Another hunter further reinforces the contact that occurs with the viscera:

> The hunter opens it, bleeds it, well it's already been bled in the bush, and then he throws away the guts. . . with his hands. . . he throws the guts out. . . or gives them to the dogs. . . and in the kitchen he can fry it up, it's a tender, tasty meat (D., 62 yrs)

As can be seen, armadillo is a relatively rare and valued meat, attracting hunting. Furthermore, many see the hunt as entertainment. Overall, this relationship with the armadillo creates a real possibility of leprosy transmission, since the relationship is characterized by frequent contact with the animal and, potentially, the bacteria.

4. Discussion

This study raises important issues about contact between human beings and armadillos. The interviews provide evidence of numerous situations in which leprosy transmission via the armadillo is possible.

Contact with the armadillo begins when hunters seek out the animal for a variety of reasons. Three principal motivations for armadillo hunting are reported as hunger, financial necessity, and pleasure. Differences notwithstanding, the appreciation of the taste of armadillo meat represents an important commonality across all three of these motivational categories.

Armadillo are hunted at night, especially in the rainy season when the armadillo is very active. The humid environment contributes to the survival of *M. leprae* (Desikan and Sreevatsa, 1995), since the bacteria does not survive for long periods in hot, dry environments. This also suggests that the environment in which armadillos are hunted could be contaminated with *M. leprae*, and thus presents another risk of infection to the hunters (Truman, 2005; Kazda et al., 1986, 1980).

During the act of hunting itself, additional situations are reported that are conducive to leprosy infection. Hunters, and others in the Northeast live in the *sertão*, a dry, shrubby ecosystem characteristic of the interior of northeastern Brazil. When armadillos escape or are pursued, they flee to an area better suited to their survival. When fleeing, armadillos often raise a cloud of dust that contains *M. leprae bacilli*. They move through shrubs often covered with thorns that can scratch pursuers. Apart from indirect contact, direct contact occurs through the handling of the animal, resulting in increased risk of infection.

Studies (Job et al., 1985) have shown that *M. leprae* can be disseminated through the tissues and organs of the armadillo, including the spleen, liver, and skin. As such, the organs could be natural reservoirs for the bacteria. In this light, the interviews report that hunters handle armadillo viscera without any form of protection, maintaining contact with the blood, body secretions and organs which are potentially contaminated with *M. leprae*.

Whether killed at the site or transported home, the animals are carried in sacks that are often reused for the storage of food items and tools. This behavior can potentially generate increased risk, since *M. leprae* can remain infectious for up to seven days in dry secretions (Desikan and Sreevatsa, 1995; Walsh et al., 1981).

Another potential occasion for infection is the preparation of the armadillo for consumption. Apart from the contact with viscera mentioned earlier, the consumption of armadillo meat was found to be an additional mode of transmission (Rodrigues et al., 1993).

A range of more speculative associations between armadillo and leprosy can be found. As mentioned above, the consumption of infected human cadavers is mentioned (but not observed) by our respondents. Corpses in Brazil are not normally embalmed or otherwise treated beyond wiping with a wet cloth, and are required to be buried within 24 h of death. The six-banded or yellow armadillo (*E. sexcinctus* known in Brazil as *Peba*) has an opportunistic diet. Larvae of necrophagous flies (Sarcophagidae) were found in stomachs of this species. Furthermore, we recently found evidence of *E. sexcinctus* naturally infected with *M. leprae* (personal communication, Frota, C.C.).

It is important to note here that additional factors such as an individual's environment, hygiene, nutritional status, and socioeconomic situation may influence his or her susceptibility to the development of leprosy (Kerr-Pontes et al., 2006; van Beers et al., 1996; Kerr-Pontes et al., 2004; Rees, 1981). *M. leprae* does not infect all people who are exposed to the bacteria, and the gravity of the disease varies among those who are infected. For example, malnutrition, especially protein malnutrition, results in reduced immune capacity. Consequently, people who need to hunt armadillos for food are probably more susceptible to leprosy infection.

This study has shown the diverse situations surrounding armadillo hunting in which leprosy infection is possible. At a minimum, people who hunt armadillos need to be made aware of the risk of infection.

Conflicts of interest

The authors declare no conflicts of interest

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