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Assessment of a Leishmaniasis Reporting System in Tropical Bolivia Using the Capture-Recapture Method

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Abstract. This study evaluates the level of underreporting of the National Program of Leishmaniasis Control (NPLC) in two communities of Cochabamba, Bolivia during the period 2013–2014. Montenegro skin test-confirmed cases of cutaneous leishmaniasis (CL) were identified through active surveillance during medical campaigns. These cases were compared with those registered in the NPLC by passive surveillance. After matching and cleaning data from the two sources, the total number of cases and the level of underreporting of the National Program were calculated using the capture-recapture analysis. This estimated that 86 cases of CL (95% confidence interval [CI]: 62.1–110.8) occurred in the study period in both communities. The level of underreporting of the NPLC in these communities was very high: 73.4% (95% CI: 63.1–81.5%). These results can be explained by the inaccessibility of health services and centralization of the NPLC activities. This information is important to establish priorities among policy-makers and funding organizations as well as implementing adequate intervention plans.

INTRODUCTION

Leishmaniasis disease is a parasitic infection transmitted by the bites of infected sandflies. These parasites are transmitted from wild animals to humans when its natural environment is invaded. Among all forms of leishmaniasis, cutaneous leishmaniasis (CL) is the most common. The disease is endemic in 98 countries and it is estimated that two million people are infected every year, of which 1.5 million are CL.[1] Bolivia, a country located in South America, has more than 70% of its territory covered by the Amazon forest which is considered an endemic area for CL. Between 1983 and 2006, 35,724 new cases of CL were reported and it is estimated that 2,300 people are infected every year nationally. Within the country, Cochabamba is the fourth department with the highest number of CL cases according to national reports. Subtropical areas in Cochabamba have been the preferred site for immigration from the highlands to settle and work in agriculture, thereby increasing exposure to vectors and the risk of leishmaniasis disease.

Surveillance of leishmaniasis depends on local and national health authorities. These data are necessary to estimate the disease burden in each country[2,3] and to establish priorities among policy-makers and funding organizations. However, the scarce and poor quality of national registers of leishmaniasis are constant barriers to the design of adequate intervention plans.[4]

Of the 98 countries where leishmaniasis is endemic, only two-thirds have presented incidence reports from the last 5 years.[2] Furthermore, it is well known that registers have a significant level of underreporting. For instance, studies from Brazil, Argentina, India, Jordan, and Tunisia have observed underreporting ranging from 4 to 40 times the real figures.[5–9]

In Bolivia, the National Program of Leishmaniasis Control (NPLC) is responsible for reports of the disease. NPLC gathers, analyzes, and disseminates data generated from notification cases at departmental and country levels. NPLC is organized into two levels, a central office dependent on the Ministry of Health for national-level coordination and nine departmental health offices. The notification system of NPLC depends entirely on passive surveillance. CL patients are registered when the confirmed laboratory case requests specific treatment (Glucantime®). Treatment delivery is exclusively a responsibility of the NPLC offices. The NPLC notification system is the only reliable register because CL cases are included when they have laboratory diagnostic confirmation.

It is well known that the passive surveillance method used by the NPLC has a significant level of underreporting, bearing in mind the requirements for inclusion in the register. Most CL patients are settled in isolated and distant communities with poor transport systems. Primary health services in the communities are not capable of performing diagnosis, so patients must travel to the laboratory. In this scenario, only a fraction of patients have access to laboratory diagnosis and in consequence to the specific treatment.

There are several limitations, in terms of human resources and funds, of directly evaluating the extent of the underreporting problem. However, alternative approaches to overcome these problems have been proposed. One of them is the capture-recapture method that estimates the extent of incomplete reporting using information from overlapping lists of cases from different sources.[10] This method was initially developed to measure species populations in biology.[11,12] Nowadays, it has been used more frequently in epidemiology to estimate the number of cases of specific illnesses such as tuberculosis,[13–17] cancer,[18,19] human immunodeficiency virus infected patients,[20–23] injury cases,[24–27] and leishmaniasis.[6,9]

The aim of this article is to evaluate the extent of underreporting by the NPLC between January 1, 2013 and December 31, 2014 in tropical communities of Bolivia, using the capture-recapture approach.

METHODS

Study area and population. The study was conducted in two communities, Ichoa and Tacopaya, located in the Isiboro Sécure National Park (ISNP) that belongs to the Chapare

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province of the Cochabamba department in Bolivia. Chapare is a tropical area located in the Amazon basin where primary hosts and vectors of leishmaniasis have their ecological niche. Even though most of the area is part of the protected ISNP, it has seen constant farming colonization with a disregard of settlement restriction laws.[28,29] In the 2012 census, the Chapare population consisted of 262,639 inhabitants. This population is distributed in more than 150 communities, 50 of which have colonized the ISNP.

Sources of data. Two sources of data were used to assess the registration system of the NPLC. The first source was NPLC registers of the Cochabamba department. Information included full name, age, sex, year of infection, community of residence, and the healthcare center where treatment was provided. All cases had been confirmed by parasite identification using direct microscopic examination.

The second data source included a list of patients who were recaptured using an active surveillance method through medical campaigns in 2015. The whole population living in these communities was invited to the medical campaigns. Multiple invitations were made by the community authorities, the medical staff of the health posts, and by the researchers during their monthly Labor Union meetings before the campaigns. A total of 743 people attended to the calls corresponding to a response rate of 55% in Ichoa and 61% in Tacopaya.

Medical campaigns consisted on medical examinations performed by senior researchers from the Tropical Medicine Center of the Medicine School in San Simon University of Cochabamba, for 3 days in Ichoa and 5 days in Tacopaya.

All participants received a comprehensive physical examination of skin and mucous membranes focused on the detection of present or past CL. Even though the main goal of the medical campaigns was to identify patients with skin scars of CL developed during 2013 and 2014, whenever ulcers were present, a sample was taken for parasitological examination. All patients who were positive to CL received treatment free of charge.

The criteria used to identify CL skin scars was a history of skin ulcers that lasted more than 2 weeks before healing and those who had a positive reaction to the Montenegro skin test (MST). This test has been successfully used in several epidemiological studies to assess exposition to the leishmaniasis parasite and leishmaniasis infection.[30–35] The MST sensitivity and specificity to detect parasite exposure were reported at over 97% and 93%, respectively, which improves with increased exposure time.[36–38] People showing a reaction diameter greater than 5 mm, 48 hours after the application of the test, were considered positive. The antigens used for the MST test were produced by the Institute of Tropical Medicine in Cayetano Heredia University, Peru.

Patients with positive MST and self-reported CL skin scars in 2013 and 2014 were included in a second list, in which the name, age, sex, year of infection, community of residence, attendance at a healthcare center, and treatment received were recorded. These 2 years were considered to avoid reporting bias.

The strategy of searching cases during the community meetings was chosen instead of house-to-house visits because it was not always feasible to find people in their houses. People use to be working on their farms during the day far from their households. In addition, the sylvatic geography where

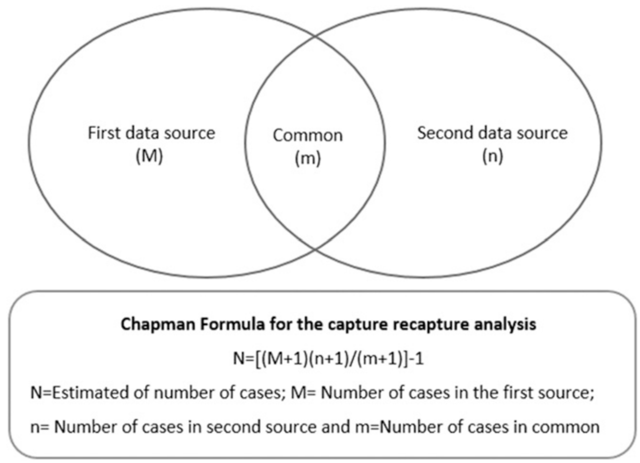

FIGURE 1. Two-sample capture–recapture method diagram and Chapman's formula.

they are settled as well as the scattered distribution of the households made it complicated to find the participants at night. On the other hand, the trade union organization of the farmers has regular monthly meetings in these communities to discuss their local issues where health is an important concern.

Matching procedure. For each of the sources, a database was created containing variables relating to CL characteristics as well as key variables for matching: name, age, sex, community of residence. Names were then indexed and sorted to identify duplicate cases. Later, both files were merged and two new variables were added to identify sources. After the data were cleaned and matched, the names were removed and replaced by codes for data security and to protect anonymity.

Data analysis. To estimate the total cases of CL, the capture-recapture method was applied using Chapman's formula[10] to calculate the *N* value, its variance, and the 95% confidence interval (CI) (Figure 1).

To assess the completeness of the CL NPLC registers, the total number of cases in the NPLC list was divided by the estimated total number of CL cases identified by the capture-recapture analysis and expressed as a percentage with 95% CI.

Ethical consent. Approval of the study was obtained from the Ethical Committee of the School of Medicine in San Simon University.

The research team attended monthly community meetings organized by the board of the Local Farmers Union. The community received information on leishmaniasis disease, as well as the nature and importance of the study. The researchers asked for permission from the population to proceed with the study. Individual written consent was signed by each participant, and for children, written consent was also sought from their parents.

RESULTS

The capture–recapture results are presented in two ways: first, the overall comparison between NPLC and medical campaigns; second, comparisons between the NPLC and the medical campaigns disaggregated by sex, community, age, and year.

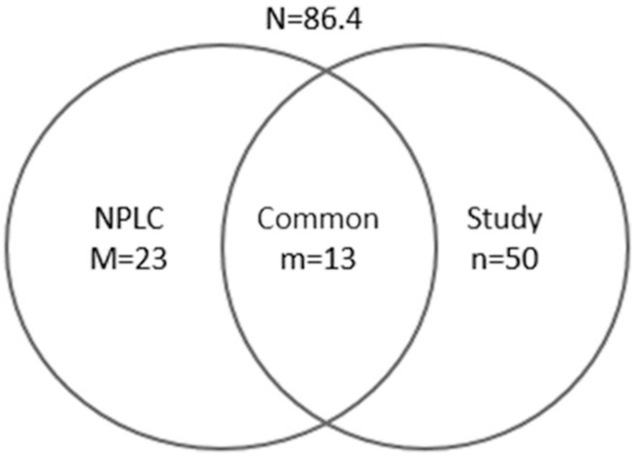

FIGURE 2. Distribution of cutaneous leishmaniasis cases after linking both data sources.

The total number of CL cases captured by the two data sources was 60, with 47 cases captured only once. Thirteen (21.7%) of the total cases found were captured by the two data sources. Thirty-seven (61.7%) of the 60 cases found in both data sources were not present in the NPLC registers (Figure 2).

Applying the two-sample capture–recapture method to this information, a total figure of 86.4 CL cases (95% CI: 62.1–110.8) were achieved, corresponding to an NPLC underreporting of 73.4% (95% CI: 63.1–81.5%).

NPLC underreporting was higher among men (80.0%) than women (64.4%). Ichoa, which is the farthest community from the main town Villa Tunari, had a higher underreporting rate (75.6%) than Tacopaya (64.3%). Comparing age groups, underreporting in people older than 15 years was slightly higher (75.7%) than those younger than 15 years (72.4%). Finally, worse notification was observed in 2014 (76.9%) than in 2013 (69.3%) (Table 1).

DISCUSSION

Level of underreporting. The capture–recapture analysis identified a large extent of NPLC underreporting (73.4%) in the two communities of Cochabamba. This figure is higher than a similar study in Argentina (55%),[9] but lower than another undertaken in Guatemala (97.5%).[5] There are two explanations for this finding. First, there is a problem of access to laboratory diagnosis for CL patients, a requirement to be included in NPLC registers. There are more than 90 communities in the ISNP area but during the study period, laboratory diagnostic testing for leishmaniasis was only available in the Hospital of Villa Tunari, the main town of Chapare province. This hospital is separated from the ISNP area by more than 200 km, the public transport is scarce and expensive, the roads are in bad condition, and traveling is difficult during the rainy season. These accessibility factors partly explain the underreporting levels in these communities. The second explanation is related to the method used to identify cases, the MST, which has a great capacity to detect cases. MST can be positive even in patients with mild CL lesions that have cured spontaneously and that patients themselves fail to recognize. These patients might have not visited the health services and in consequence, they were not registered by the NPLC.

Methodological considerations. The applicability of the capture-recapture method is based on four assumptions that are described elsewhere.[10,12,39–42] Firstly, the violation of the appropriate matching assumption was avoided, as record linkage between data sources was conducted through two different processes: a manual review of all matched and nonmatched records, and by verification of near-matches by nurses and community leaders. Secondly, the closed population assumption has been followed as most residents live permanently in the two communities, although a small number of people moved from the community for occupational reasons. Thirdly, the assumption of homogeneous population was evaluated by the stratified capture–recapture analysis. This confirmed no differences in capture probabilities among groups. Finally, a violation of the fourth assumption of independent sources was avoided as the active surveillance through medical campaigns was unrelated to the NPLC registers.

An important limitation of the study was related to the possible selection bias. People who consider themselves as healthy did not attend our medical campaigns. These campaigns evaluated 207 subjects in Ichoa and 332 in Tacopaya, representing less than 50% of the populations registered. Probably, the number of cases confirmed would have increased underreporting if the whole populations had attended the medical campaigns.

Another issue to be considered is related to the calculation of the incident cases. While the NPLC captured the new cases diagnosed by direct microscopic examination of the parasite,

TABLE 1
Capture–recapture analysis and NPLC under-reporting estimation

	Notified* (M) No.	Medical campaigns (n) No.	Common (m) No.	Aggregated registry	Ascertainment-corrected estimate (95% CI)† $N = (M + 1 \times n + 1/(m + 1))-1$	Estimated under-reporting (95% CI) % = $1 - (N/M) \times 100$
(a) Overall registers comparison						
Total	23	50	13	60	86.4 (62.1–110.8)	73.4% (63.1–81.5%)
(b) Disaggregated registers comparison						
Men	11	27	5	33	55.0 (29.0–81.0)	80.0% (67.6–88.5%)
Women	12	23	8	27	33.7 (24.2–43.1)	64.4% (47.9–78.5%)
Ichoa	15	38	9	44	61.4 (41.9–80.9)	75.6% (63.3–84.5%)
Tacopaya	8	12	4	16	22.4 (12.6–32.2)	64.3% (43.0–80.3%)
< 15	3	9	2	10	12.3 (6.9–17.8)	75.7% (46.8–91.1%)
> 15	20	41	11	50	72.5 (50.4–94.6)	72.4% (61.4–82.0%)
2013	14	27	8	33	45.7 (30.6–60.7)	69.3% (55.2–80.9%)
2014	9	23	5	27	39.0 (22.8–55.2)	76.9% (61.7–87.4%)

CI = confidence interval; NPLC = National Program of Leishmaniasis Control.
* Cases notified by NPLC.
† Chapman's formula used to calculate the estimator.

we also included as new cases those identified by the MST and where lesions were reported by the participants to have occurred within the last 2 years before the study. Despite this short time period, we cannot reject the risk for some possible recall bias.

CONCLUSION

Leishmaniasis is a very common disease in the tropical region of Chapare. The underreporting observed is significant (73.4%) and warrants an urgent improvement of the notification system. Health care accessibility is likely to be the main problem for patients with leishmaniasis, and the real burden of disease will remain unknown if the economic investment and programs for disease control remain restricted to the main municipalities far from isolated communities.

Reliable information on the real burden of leishmaniasis in Bolivia is crucial in developing more efficient plans that provide improved medical attention to patients with leishmaniasis.

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REFERENCES

1. Desjeux P, 2004. Leishmaniasis: current situation and new perspectives. *Comp Immunol Microbiol Infect Dis 27:* 305–318.
2. Alvar J, Velez ID, Bern C, Herrero M, Desjeux P, Cano J, Jannin J, den Boer M, 2012. Leishmaniasis worldwide and global estimates of its incidence. *PLoS One 7:* e35671.
3. Ault SK, 2007. Pan American Health Organization's Regional Strategic Framework for addressing neglected diseases in neglected populations in Latin America and the Caribbean. *Mem Inst Oswaldo Cruz 102 (Suppl 1):* 99–107.
4. Mathers CD, Ezzati M, Lopez AD, 2007. Measuring the burden of neglected tropical diseases: the global burden of disease framework. *PLoS Negl Trop Dis 1:* e114.
5. Copeland HW, Arana BA, Navin TR, 1990. Comparison of active and passive case detection of cutaneous leishmaniasis in Guatemala. *Am J Trop Med Hyg 43:* 257–259.
6. Maia-Elkhoury AN, Carmo EH, Sousa-Gomes ML, Mota E, 2007. Analysis of visceral leishmaniasis reports by the capture-recapture method. *Rev Saude Publica 41:* 931–937.
7. Mosleh IM, Geith E, Natsheh L, Abdul-Dayem M, Abotteen N, 2008. Cutaneous leishmaniasis in the Jordanian side of the Jordan Valley: severe under-reporting and consequences on public health management. *Trop Med Int Health 13:* 855–860.
8. Singh SP, Reddy DC, Rai M, Sundar S, 2006. Serious under-reporting of visceral leishmaniasis through passive case reporting in Bihar, India. *Trop Med Int Health 11:* 899–905.
9. Yadon ZE, Quigley MA, Davies CR, Rodrigues LC, Segura EL, 2001. Assessment of Leishmaniasis notification system in Santiago del Estero, Argentina, 1990–1993. *Am J Trop Med Hyg 65:* 27–30.
10. Brittain S, Böhning D, 2009. Estimators in capture–recapture studies with two sources. *AStA Adv Stat Anal 93:* 23–47.
11. Borchers DL, Buckland ST, Zucchini W, 2002. *Estimating Animal Abundance: Closed Populations*. London: Springer.
12. Seber GAF, 1982. The estimation of animal abundance: and related parameters. New York: Macmillan Pub. Co.
13. Bassili A, Grant AD, El-Mohgazy E, Galal A, Glaziou P, Seita A, Abubakar I, Bierrenbach AL, Crofts JP, van Hest NA, 2010. Estimating tuberculosis case detection rate in resource-limited countries: a capture-recapture study in Egypt. *Int J Tuberc Lung Dis 14:* 727–732.
14. Cojocaru C, van Hest NA, Mihaescu T, Davies PD, 2009. Completeness of notification of adult tuberculosis in Iasi County, Romania: a capture-recapture analysis. *Int J Tuberc Lung Dis 13:* 1094–1099.
15. Dunbar R, van Hest R, Lawrence K, Verver S, Enarson DA, Lombard C, Beyers N, Barnes JM, 2011. Capture-recapture to estimate completeness of tuberculosis surveillance in two communities in South Africa. *Int J Tuberc Lung Dis 15:* 1038–1043.
16. Huseynova S, Hashim DS, Tbena MR, Harris R, Bassili A, Abubakar I, Glaziou P, Floyd K, van Hest NA, 2013. Estimating tuberculosis burden and reporting in resource-limited countries: a capture-recapture study in Iraq. *Int J Tuberc Lung Dis 17:* 462–467.
17. VAN Hest NA, Story A, Grant AD, Antoine D, Crofts JP, Watson JM, 2008. Record-linkage and capture-recapture analysis to estimate the incidence and completeness of reporting of tuberculosis in England 1999–2002. *Epidemiol Infect 136:* 1606–1616.
18. Fararouei M, Marzban M, Shahraki G, 2016. Completeness of cancer registry data in a small Iranian province: a capture-recapture approach. *HIM J 46:* 96–100.
19. Khodadost M, Yavari P, Khodadost B, Babaei M, Sarvi F, Khatibi SR, Barzegari S, 2016. Estimating the esophagus cancer incidence rate in Ardabil, Iran: a capture-recapture method. *Iran J Cancer Prev 9:* e3972.
20. de Lemos LM, Duarte GS, Martins NG, da Silva FJ, Ilozue C, Gurgel RQ, 2013. Estimating the number of HIV-positive pregnant women in Sergipe, Brazil, using capture-recapture. *AIDS Care 25:* 691–694.
21. Heraud-Bousquet V, Lot F, Esvan M, Cazein F, Laurent C, Warszawski J, Gallay A, 2012. A three-source capture-recapture estimate of the number of new HIV diagnoses in children in France from 2003–2006 with multiple imputation of a variable of heterogeneous catchability. *BMC Infect Dis 12:* 251.
22. Mastro TD, Kitayaporn D, Weniger BG, Vanichseni S, Laosunthorn V, Uneklabh T, Uneklabh C, Choopanya K, Limpakarnjanarat K, 1994. Estimating the number of HIV-infected injection drug users in Bangkok: a capture–recapture method. *Am J Public Health 84:* 1094–1099.
23. van Leth F, Evenblij K, Wit F, Kiers A, Sprenger H, Verhagen M, Hillebregt M, Kalisvaart N, Schimmel H, Verbon A, 2016. TB-HIV co-infection in the Netherlands: estimating prevalence and under-reporting in national registration databases using a capture-recapture analysis. *J Epidemiol Community Health 70:* 556–560.
24. Chokotho LC, Matzopoulos R, Myers JE, 2013. Assessing quality of existing data sources on road traffic injuries (RTIs) and their utility in informing injury prevention in the western Cape Province, South Africa. *Traffic Inj Prev 14:* 267–273.
25. Janstrup KH, Kaplan S, Hels T, Lauritsen J, Prato CG, 2016. Understanding traffic crash under-reporting: linking police and

medical records to individual and crash characteristics. *Traffic Inj Prev 17:* 580–584.
26. Kraemer JD, Benton CS, 2015. Disparities in road crash mortality among pedestrians using wheelchairs in the USA: results of a capture-recapture analysis. *BMJ Open 5:* e008396.
27. Short J, Caulfield B, 2016. Record linkage for road traffic injuries in Ireland using police hospital and injury claims data. *J Safety Res 58:* 1–14.
28. Pacheco P, Nazaré A, 2004. Las fronteras agrícolas en el trópico boliviano: entre las situaciones heredadas y los desafíos del presente. CEP 66035: 170.
29. Weil J, Weil C, 1993. Verde es la esperanza: colonización, comunidad y coca en la Amazonia. Editorial: Los Amigos del Libro.
30. Bettaieb J, Toumi A, Chlif S, Chelghaf B, Boukthir A, Gharbi A, Ben Salah A, 2014. Prevalence and determinants of *Leishmania major* infection in emerging and old foci in Tunisia. *Parasit Vectors 7:* 386.
31. Sordo L et al., 2012. Low prevalence of Leishmania infection in post-epidemic areas of Libo Kemkem, Ethiopia. *Am J Trop Med Hyg 86:* 955–958.
32. Silveira FT, Lainson R, Pereira EA, de Souza AA, Campos MB, Chagas EJ, Gomes CM, Laurenti MD, Corbett CE, 2009. A longitudinal study on the transmission dynamics of human *Leishmania* (*Leishmania*) *infantum chagasi* infection in Amazonian Brazil, with special reference to its prevalence and incidence. *Parasitol Res 104:* 559–567.
33. Oliveira F et al., 2009. Discrepant prevalence and incidence of *Leishmania* infection between two neighboring villages in central Mali based on leishmanin skin test surveys. *PLoS Negl Trop Dis 3:* e565.
34. Ampuero J, Urdaneta M, Macedo Vde O, 2005. Risk factors for cutaneous leishmaniasis transmission in children aged 0 to 5 years in an endemic area of *Leishmania* (*Viannia*) *braziliensis*. *Cad Saude Publica 21:* 161–170.
35. de Oliveira-Neto MP, Mattos MS, Perez MA, Da-Cruz AM, Fernandes O, Moreira J, Goncalves-Costa SC, Brahin LR, Menezes CR, Pirmez C, 2000. American tegumentary leishmaniasis (ATL) in Rio de Janeiro State, Brazil: main clinical and epidemiologic characteristics. *Int J Dermatol 39:* 506–514.
36. Hashemi SN, Mohebali M, Mansouri P, Bairami A, Hajjaran H, Akhoundi B, Charehdar S, 2011. Comparison of leishmanin skin test and direct smear for the diagnosis of cutaneous leishmaniasis. *Acta Med Iran 49:* 136–141.
37. Marques MJ, Volpini AC, Machado-Coelho GL, Machado-Pinto J, da Costa CA, Mayrink W, Genaro O, Romanha AJ, 2006. Comparison of polymerase chain reaction with other laboratory methods for the diagnosis of American cutaneous leishmaniasis: diagnosis of cutaneous leishmaniasis by polymerase chain reaction. *Diagn Microbiol Infect Dis 54:* 37–43.
38. Skraba CM, de Mello TF, Pedroso RB, Ferreira EC, Demarchi IG, Aristides SM, Lonardoni MV, Silveira TG, 2015. Evaluation of the reference value for the Montenegro skin test. *Rev Soc Bras Med Trop 48:* 437–444.
39. Begon M, 1979. *Investigating Animal Abundance: Capture-Recapture for Biologists*. Baltimore, MD: University Park Press.
40. Chao A, Tsay PK, Lin SH, Shau WY, Chao DY, 2001. The applications of capture-recapture models to epidemiological data. *Stat Med 20:* 3123–3157.
41. Pollock KH, 1980. Capture-recapture models: a review of current methods, assumptions and experimental design. North Carolina: North Carolina State University, Institute of Statistics.
42. Wittes J, Sidel VW, 1968. A generalization of the simple capture-recapture model with applications to epidemiological research. *J Chronic Dis 21:* 287–301.