Location and Setting of Zoonotic Gastrointestinal Parasites in the Peruvian Primate Trade

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Background

Peru by Departmento

Zoonotic disease is the biggest source of emerging infectious disease in humans, and "6 out of every 10 known infectious diseases in people are spread from animals"[1]. Most spillovers occur between human and primate because of similarities in physiology. The most recognizable spillovers occurred in the cases of HIV and Ebola, however countless bacterial and viral illness strains have made the jump[2]. Nine diseases are the focus of this project, and all have been shown to transmit zoonotically from primates to humans. They can cause gastrointestinal disease, manifesting in pathologies such as diarrheal disease, dehydration, and malnutrition[3].

Though the trade of wild primates is illegal in Peru, there is a large market of animals caught for use as bushmeat or pets. Primates are accessible and widely dispersed throughout Peru. Law enforcement lacks the resources to effectively combat illegal commerce[4]. Researchers estimate that current rates of trafficking mirror those from prior to the 1973 legal ban on primate trade[4]. These captured wild animals pose significant risk for introducing zoonotic infectious disease into human populations.

Due to the clandestine nature of the topic, particular illegal trade routes and market locations are hard to find. Geospatial analysis is a helpful tool in defining what regions of the country are at risk of zoonotic disease spillover, and which parasites are most common in primates of those areas. This research project focuses on the question: in what areas of Peru do illegally traded primates test positive for various gastrointestinal parasites, and in what settings are these positive primates located? The parasites of interest are stated below. Settings refer to wetmarkets (e.g. meat market), captivity (e.g. zoos), and pet houses (e.g. individual homes).

Methods

Data: Primate gastrointestinal and Peruvian geospatial datasets were merged for this analysis. Both were collected by Marieke Rosenbaum in Peru between 2010 and 2012[5]. Rosenbaum ran all microscopy tests and data validation. Gastrointestinal data included microscopy for 9 parasites: Cryptosporidium, Hookworm, Trichuris trichiura, Ascaris, Blastocystis, Entamoeba, Giardia, Balantidium, and Strongyloides. Missing locations were imputed. The 1984 WGS Zone18S coordinate system was used.

Heat Maps: I selected data by positivity for any of the nine parasites, and exported the selected data as a shapefile. I repeated this step for each setting (wetmarket, pet house, captivity). I created a kernel density map for all parasites, then one for each distinct setting. I used a cell size of 1000 and search radius of 250000km for all parasites, 150000km for individual setting maps.

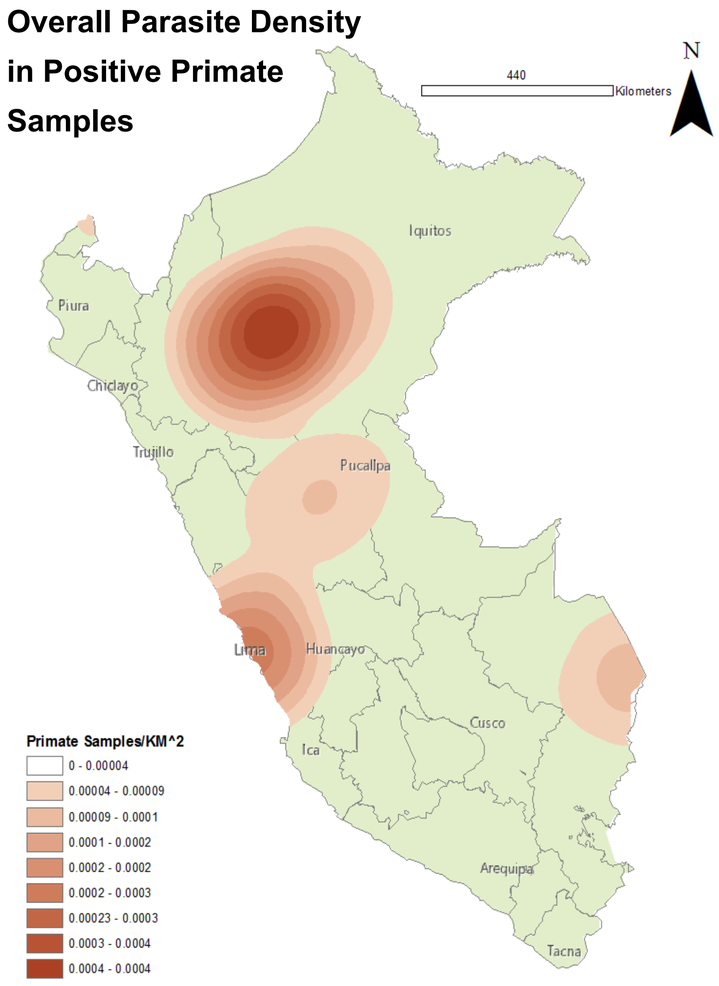
Dot Density Maps: I selected data by positivity for each parasite, creating nine distinct shapefiles. I then joined each individual parasite shapefile with a Peruvian departmento shapefile from ESRI[6]. I ran dot density analysis by departmento with density of 0.02 positive samples per dot for each parasite for ease of visualization.

Samples by Parasite, Setting, and Location

Parasite	*N**
Total Sampled	134
Blastocystis	42
Hookworm	45
Trichuris trichiura	7
Ascaris	9
Balantidium	12
Entamoeba	60
Strongyloides	16
Giardia	9
Setting	*N*
Captivity	70
Pet House	38
Wetmarket	26
City	*N*
Choquepata	2
Iquito	8
Lima	29
San Martin	13
Pulcallpa	28
Puerto Maldonao	11
Tingo Maria	5
Tumbes	5
Yurimaguas	32

*Total parasite-specific N may add up to more than total N due to multiple positive results within one sample.

Overall Parasite Density in Positive Primate Samples



Results

Descriptive statistics: There are a total of 134 primate samples. Entamoeba is the most common parasite found in the primates (N=60), followed by Hookworm (N=45) and Blastocystis (N=42). Trichuris trichiura is the common parasite (N=7), though Ascaris and Giardia were also rare (Ns=9). A majority of the sample primates are found in captivity (N=70), followed by pet houses (N=38) and Wetmarkets (N=26). Most primates are found in Lima (N=29), closely followed by the city of Pulcallpa in departmento Ucayali (N=28). The fewest samples are located in the Southeastern region near Cuzco.

Overall kernel density: The area with the highest concentration (0.0004 primates/Km^2) of primate samples positive for gastrointestinal disease is between the departmentos of San Martin, Amazonas, and Loreto in the north-central part of Peru. The second most dense concentration of is near Lima on the Pacific coast.

Setting kernel density: All three settings have high concentration fo samples near Lima, and Wetmarket clustering is only centralized there. Density of positive primates in captivity mirror those of the full sample, focusing particularly in Peru's north-central. There are two distinct concentrations of positive primates found in pet houses in Tumbes and Pucallpa.

Dot density per parasite: The Amazonas departmento shows the highest concentration of Hookworm, Entamoeba, Cryptosporidium, and Blastocystis. There are high concentrations of Hookworm, Entamoeba, Strongyloides, Giardia, and Cryptosporidium in Tumbes, while the other parasites are nonexistent in that departmento. Ascaris, Balantidium, and Trichuris trichiura are evenly and sparsely distributed throughout Peru.

Conclusion

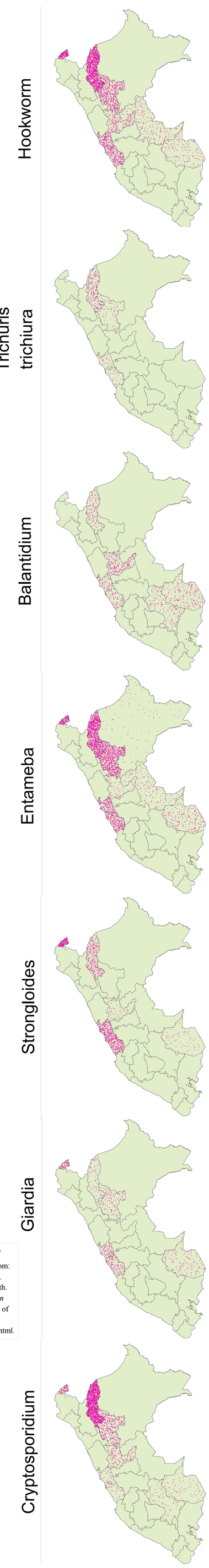
Peru's most populated city, Lima[4], has the highest number of samples and the highest density of positive samples across settings. The nearest city to the overall parasite density map's focal point is Yurimaguas, a port town[6]. Other highly dense spots are found near the Bolivian boarder to the east and the Ucayali river in the middle of the country. This indicates that gastrointestinal parasites may propagate more in primates that exist in areas with high population density or high levels of trade.

A major strength of this project is the data itself, as this population is typically hard to access due to illegality. All points are precise, with information down to latitude/longitude level. However, the sample size is small and some geospatial data had to be imputed. Another limitation is that multiple samples were collected at one site with the same latitude/longitude, making distribution visualization difficult. Parasite density was analyzed on a departmento level, though city polygons may be more appropriate for future studies.

Hypotheses generated from this study could lead to further analysis with this dataset. They are as follows: Is there clustering or correlation between certain parasite types, or between parasites and locations? Are there statistically significant relationships between setting and parasite type, or setting and parasite density How do trade routes relate to these results, and how do patterns of deforestation?

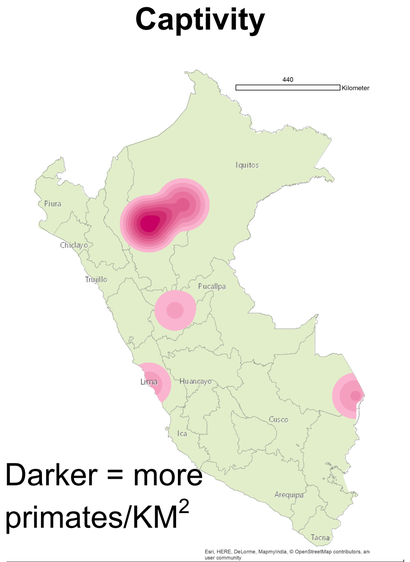
Sources: 1) Zoonotic Diseases | One Health | CDC [Internet]. 2016 [cited 2017 Apr 10]. Available from: https://www.cdc.gov/onehealth/basics/zoonotic-diseases.html. 2) Questions and Answers about Ebola, Pets, and Other Animals [Internet] 2016 [cited 2017 Apr] Available from: https://www.cdc.gov/vhf/ebola/transmission/qas-pets.html 3) Bunnag D, Harinasuta T, Viravan C, Jarupakorn V, Chindanond D, Desakorn V. Clinical trial of flubendazole on hookworm, Trichuris trichiura and Ascaris lumbricoides infections. Southeast Asian J Trop Med Public Health. 1980 Sep;11(3):363–6. 4) Shanee et al. (2015). Diagnostic Overview of the Illegal Trade in Primates and Law Enforcement in Peru. *American Journal of Primatology* 9999:1-12. 5) Rosenbaum M, Mendoza P, Ghersi BM, Wilbur AK, Perez-Brumer A, Cavero Yong N, et al. Detection of Mycobacterium tuberculosis Complex in New World Monkeys in Peru. EcoHealth. 2015 Jun;12(2):288–97. 6) ESRI [Internet]. 2014. [Cited April 2017] Available from: http://www.esri.com/ 6) Yurimaguas Peru. 2015 [Accessed 2017] http://www.virtualperu.net/cities_yurimaguas.html.

Positive Primate Samples by Parasite Type (1 dot/0.2 samples):



Positive Primate Samples by Setting :

Captivity



Darker = more primates/KM^2

Wetmarket

Pet House