Determinants of Travel and Schistosomiasis Prevalence in Sichuan. China

Sacha Ferguson

Abstract This project aims to characterize travel in villages exhibiting a re-emergence of the parasitic disease schistosomiasis in Sichuan Province, China and investigate the relationship between travel among these villages and schistosomiasis prevalence. The relationships between characteristics of travel, such as time, cost and frequency of trips, were investigated in five villages in Sichuan using a social survey designed to evaluate travel patterns. The survey data were used to explore determinants and patterns of travel in the study region. Relationships were found between several characteristics of reported travel, as well as whether people travel, their destination, frequency of travel and activities of travel associated with schistosomiasis transmission. In order to characterize the relationship between schistosomiasis prevalence and social connectivity between villages, the data from the social survey was used to create a metric of social connectivity to quantify travel between the five villages. A preliminary metric entered into a regression analysis revealed no statistically significant relationship with village prevalence.

Introduction

Schistosomiasis is a parasitic worm that infects people who come into contact with contaminated bodies of water. The World Health Organization (WHO) estimates more than 200 million people are infected with schistosomiasis, and 650 million people live in endemic areas throughout the world. Morbidity associated with schistosomiasis is estimated to contribute to the loss of 1.7 million disability adjusted life years (DALYS) per year (WHO 2001). Researchers debate the means by which morbidity due to schistosomiasis is calculated, some claiming morbidity is often underestimated because of unexamined health effects of the disease (King *et al.* 2005). Over the second half of the twentieth century, the Chinese government engaged in major efforts to achieve control of Schistosoma japonicum, the species of the parasite endemic to mainland China. Despite this effort, schistosomiasis is still present in rural areas throughout the country, including Sichuan Province, the region investigated in this study (Ross *et al.* 2001).

Although schistosomiasis has been the target of a major control effort by local public health practitioners in Sichuan Province, it continues to reemerge in previously controlled regions (Liang *et al.* 2006). The re-emergence of disease in a previously controlled area must be preceded by an introduction event; that is, either an infected mammalian or molluscan host, or contaminated waste or water, must bring the disease to the area. Research has found that agricultural work in general and more specifically the application of night soil fertilizer and contact with irrigation ditch water are related to schistosomiasis prevalence (Spear *et al.* 2004).

This project strives to understand how villages interact with each other in ways that both prevent and promote introduction events. Specifically, this project aims to contribute to the understanding of introduction events by investigating human travel between villages as a possible mechanism of introduction of schistosomiasis into a village. This inter-village travel is referred to here as “social connectivity” between villages. This study uses a social survey to record reported human movements between villages. These movements, referred to in this study as “connections,” were analyzed to understand motivation for and characteristics of travel, such as cost or duration of trips. The characterization of travel will be a crucial step in exploring the travel characteristics of residents in areas re-emerging with schistosomiasis.

Previous studies have linked village characteristics similar to social connectivity to disease prevalence in the cases of HIV and diarrheal pathogens. Although schistosomiasis has a different mode of transmission from HIV and diarrheal pathogens, previous research investigating the relationship between disease prevalence and social connectivity may help to understand social connectivity as a potential method for the introduction of schistosomes into a community. Bloom *et al.* (2002) related four village characteristics to the prevalence of HIV in Tanzania. These four factors included social/economic activity, population mobility, the distance to the nearest urban center, and the ratio of bar workers within the community in comparison to the ratio of bar workers within the other study communities. Social and economic activity was classified relative to other communities in the study and population mobility was measured by the percentage of the members of the population that had lived in their homes less than five years. In Uganda, higher rates of HIV infection were found in the main road trading centers than in the rural villages (Wawer *et al.* 1991), implying that increased social and economic activity is linked to infection there as well. In South Africa, Tanser *et al.* (2000) discovered a similar relationship: homes closer to primary and secondary roads had higher disease prevalence. In Ecuador, remoteness of a village, measured in time and cost to travel to a larger, central city, was inversely linked to the risk of infection/disease in the case of diarrheal pathogens (Eisenberg *et al.* 2006).

Schistosomiasis is a water-related disease transmitted via bodies of water contaminated with cercariae, the larval form of a schistosome. In order to complete its life cycle, the parasite must infect both mammals and snails. The schistosome burrows through human skin and enters the blood stream. Then, it travels through the body until it reaches the mucosal branches of the inferior mesenteric and superior hemorrhiodal veins, where the female begins egg production. A portion of the eggs then pass through the mammal's intestine wall and are excreted in feces. The eggs then hatch in fresh water and infect snails of the genus Oncomelania. The form of the parasite hatched from the eggs can only infect snails; the parasite must infect a snail and then be released as cercariae in order to complete its life cycle. The cercariae are released from the snail into the water and can infect a new mammalian host (Ross *et al.* 2001).

The negative health effects of schistosomiasis in humans are caused mostly by the secreted eggs of the schistosome, rather than by the organism itself. The female worm produces up to 3,500 eggs a day, each ranging from 60 to 100 micrometers. The human body reacts to the presence of the eggs that it does not excrete into the intestine wall and expel in feces through a series of inflammatory responses, which form granulomas and lesions in various organs, but with most serious effect on the spleen, liver, and intestines. Chronic cases of the disease are associated with developmental problems in children, and can lead to eggs spreading to the brain and lungs, leading to death (Ross *et al.* 2001). Schistosomiasis has also been significantly linked to anemia, chronic pain, diarrhea, exercise intolerance, and under-nutrition (King *et al.* 2005).

Since schistosomiasis is not transmitted directly between humans, an important question is whether community characteristics, such as social connectivity, which have been shown to be important in the transmission of HIV and diarrheal pathogens could also be useful in conceptualizing and responding to schistosomiasis outbreaks. Similar to other diseases, in the case of schistosomiasis, higher social connectivity could result in higher infection rates in villages. Increased social connectivity between each village and all other villages in the study was hypothesized to be positively correlated with disease prevalence in that village.

In order to study the relationship between social connectivity and schistosomiasis prevalence, this study also explores the characteristics of travel in five villages in Sichuan Province where schistosomiasis is re-emerging. Understanding the characteristics of travel in these villages will assist future studies in their ability to better understand the target population. The survey of five villages presented here provides information about the determinants and characteristics of travel, such as time spent traveling, cost of travel and time spent at the destination. The survey also reveals information on activities in which the respondents reported participating when they traveled. This information enables the characterization of travel that may include activities related to schistosomiasis transmission, such as entering irrigation ditches or participating in agricultural work (Spear *et al.* 2004). Understanding the relationship between these variables is the first step in exploring the relationship between social connectivity and schistosomiasis transmission.

Methods

Study site The study was carried out in five villages[1] in Sichuan Province in South Western China. The villages were selected from a larger study ongoing in these villages carried out by the Spear research group from the School of Public Health at University of California at Berkeley. All five villages were classified as re-emerging with schistosomiasis as determined by the local

[1] The term village used in this study is sometimes referred to as a production group by the Chinese government. The word village is often used by the Chinese government to refer to what this study will call an administrative village.

schistosomiasis control initiative. The average population of a village is around 80 people, with farming being the primary occupation in the villages.

The region has a subtropical climate with an annual average temperature of 17°C and annual rainfall greater than 900 mm. The region is characterized by hilly, irrigated agriculture. Residents grow rice, corn, vegetables, and grains, and there is also some small-scale fish cultivation in ponds in the area.

Study design Villages were visited in July and August, 2007. A Garmin Global Positioning System (GPS) unit was used to map distances between these locations. Road characteristics, such as material and width of the road, was also recorded, in conjunction with the GPS mapping. The distance between the villages was measured with ArcMap (ESRI, Redlands, CA) Geographic Information System (GIS), which was also used to visualize the study villages and the intervening roads that connect them to each other (Fig. 1).

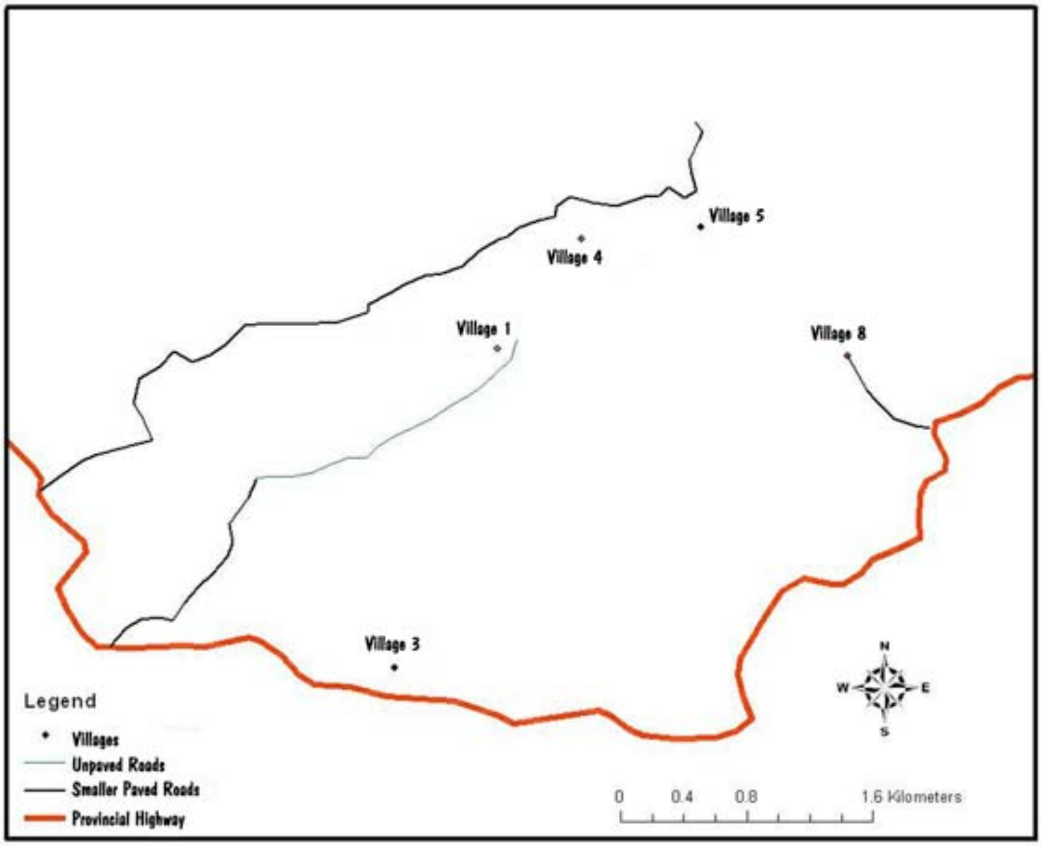
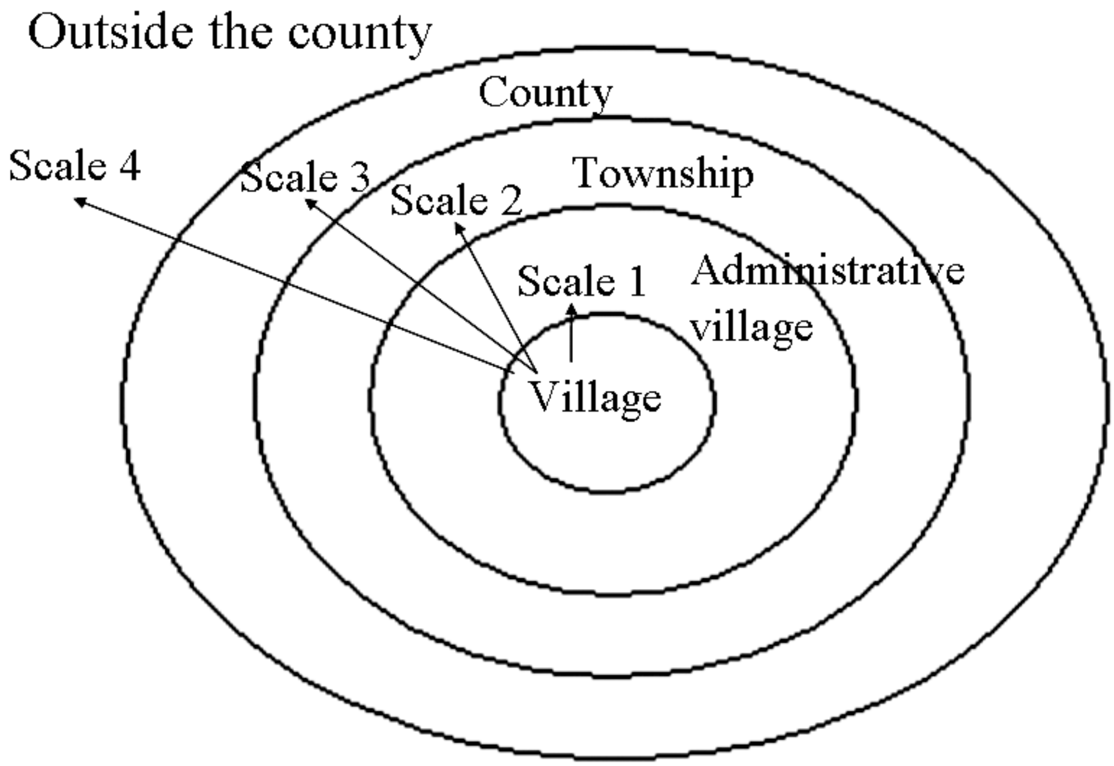


Figure 1. Map of the five surveyed villages. Village 1 is the only village to not have a paved road in the village. Village 3 has a large provincial highway running through it.

The survey contained questions about common travel patterns of participants. Thirty study participants were randomly selected and then stratified by age and gender, with ten men, ten women and ten children participating from each village. Children were over sampled to ensure understanding of their movements to school. The survey included two parts: the first assessed the movement between villages participating in the survey and, the second, the movement to locations not included in the study. Movement outside of the study villages was grouped into four scales. These four scales were defined as travel outside of the village but within the administrative village (the administrative village is an administrative group of villages defined by the Chinese government), outside of the administrative village but within the township, outside of the township but within the county and outside of the county (Fig. 2). All villages in the study are within the same county. Villages 4 and 5 are within the same administrative village and villages



1 and 3 are within the same township.

Figure 2. Diagram of the four scales of survey used in the survey. The first scale is the travel outside of the village and inside the administrative village. The second scale is travel outside the administrative village and inside the township. The third scale is travel outside the township and inside the county. The fourth scale of travel is any travel outside of the county.

Specifically, the survey asked if the participant had traveled to any of the other four participating villages or among the defined four scales of travel. If the participant reported traveling within the last year, he or she would then be asked a series of questions to characterize his or her travel patterns. Information collected included the name of the destination, time spent traveling to the destination, cost of travel, most frequent purpose of traveling to the specified destination, frequency of travel, time spent at the location, and whether the respondent had contact with irrigation ditch water at any time during the trip.

Wilcoxon-Mann and Kruskal-Wallis tests were used to determine differences between the time spent traveling, cost of travel and the time spent at the destination between the scales of travel.

The distance, time and cost data collected from the survey were incorporated into a metric of social connectivity, calculated between villages and from villages to township centers. The metric, following the example of Eisenberg *et al.* 2006, measures the social distance between two locations; if the metric is higher it implies a lower degree of social connectivity between the villages (Fig. 3).

$$\text{Social Distance} = \frac{Dij}{\sum_{i=1}^{24}\sum_{j=1}^{i-1} Dij} + \frac{\frac{\sum_{1}^{n} Cij}{n}}{\sum_{i=1}^{24}\sum_{j=1}^{i-1}\left(\frac{\sum_{1}^{n} Cij}{n}\right)} + \frac{\frac{\sum_{1}^{n} Tij}{n}}{\sum_{i=1}^{24}\sum_{j=1}^{i-1}\left(\frac{\sum_{1}^{n} Tij}{n}\right)}$$

Key:

D = Distance to travel between location *i* and *j*

C = Cost to travel between location *i* and *j*

T = Time to travel between location *i* and *j*

Figure 3: Metric of social connectivity between villages

This metric sums the distance from *i* to *j* divided by the sum of the distances (on primary roads) between all seventeen villages, the average cost to travel between *i* and *j* divided by the sum of the average costs between all the villages and the average time to travel between *i* and *j* divided by the sum of all the average times to travel between the villages.

Village prevalence was collected from local health officials and was entered into a linear regression analysis with the connectivity metric, where the model predicts prevalence of schistosomiasis infection in village x by the sum of the social connectivity between village x and all other villages scaled by the prevalence of each village.

Nominal logistic regression was used to investigate the relationship between whether a participant travels, his or her home village, and the scale at which the travel occurs. The same technique was used to determine the relationship between the scale of travel and whether a participant has irrigation ditch water contact when he or she travels.

Of individuals who reported travel at any scale, negative binomial models using robust variance estimates adjusted for repeated measures (multiple responses) of an individual at multiple scales were used to evaluate factors that affected the reported travel frequencies. Models were fit in Stata/SE version 8.1 (Stata Corporation, College Station, Texas).

Results

Few connections were reported between villages. The respondents reported just nineteen connections between the 5 villages (3% of respondents). Fifteen of the nineteen connections involved village 1 and fourteen of these were from village 1 to another village. Ten of the connections reported behavior associated with schistosomiasis transmission, including agricultural work or irrigation ditch water contact. Three of the respondents reported staying longer than 10 hours at the destination. A simple linear regression model found no statistically significant relationship between the prevalence in a village of schistosomiasis and the metric of social connectivity to neighboring villages scaled by their prevalence (Chi-squared=0.164, p=0.792).

Wilcoxon-Mann and Kruskal-Walis were used to determine if there is a difference in the means of time spent traveling, cost of travel and time spent at the destination between scales of travel (Tables 1, 2 and 3). Statistically significant differences were found between several scales in all three variables.

Table 1. Includes mean, SD and range of time spent traveling to the reported destination at each scale of travel and the differences between the means at each scale. P-values were reported from the Kruskal-Wallis test and correspond to the means of both the indicated scale and the scale below it.

	Mean (minutes)	SD	Range	Differ-ences	P-value
Scale 1	16.5	9.42	[1,30]	A	.0006
Scale 2	30.8	22.5	[0,9]	B	.016
Scale 3	53.8	113.1	[10,1045]	C	.0005
Scale 4	102.3	65.6	[5,240]	D	

Table 2. Includes mean, SD and range of cost of travel to the reported destination at each scale of travel and the differences between the means at each scale. P-values were reported from the Kruskal-Wallis test and correspond to the means of both the indicated scale and the scale below it.

	Mean (yuan)	SD	Range	Differ-ences	P-value
Scale 1	0.08	0.36	[0,2]	A	.008
Scale 2	0.69	1.13	[0,5]	B	.224
Scale 3	2.92	10.6	[0,75]	B	<.0001
Scale 4	59.3	123.9	[0,450]	C	

Table 3. Includes mean, SD and range of the time spent traveling to the destination at each scale of travel and the differences between the means at each scale. P-values were reported from the Kruskal-Wallis test and correspond to the means of both the indicated scale and the scale below it.

	Mean (minutes)	SD	Range	Differ-ences	P-value
Scale 1	4.28	2.51	[1,8]	A	.156
Scale 2	15.4	37.0	[1,168]	AB	.189
Scale 3	20.8	64.3	[2,460]	B	.016
Scale 4	34.9	49.3	[0,168]	C	

Overall, the amount of reported travel increased with scale, until the fourth scale where it decreased, with some variation among villages (Table 4).

Table 4. Percent of respondents who reported travel in each of the four scales of travel by village of the respondent.

	Scale 1	Scale 2	Scale 3	Scale 4
Village 1	57%	40%	37%	10%
Village 3	16%	53%	50%	27%
Village 8	29%	50%	71%	13%
Village 4	13%	30%	53%	7%
Village 5	20%	20%	87%	0
Total	27%	57%	88%	17%

Logistic regression predicting whether people travel based on the scale of travel and the village of the respondent gave unstable results, related in part to the decreased amount of travel at the fourth scale. The fourth scale of travel was removed from the analysis in order to create a stable modeling investigating the relationship within the first three scales of travel (all travel within the county). Statistically significant predictors of whether people travel were found (Table 5). Irrigation ditch water contact can be predicted with statistically significant results between scales 1 and 2 (p=.02 and p=.01 respectively; table 6).

Table 5. Results of nominal logistic regression predicting whether people travel by the first through third scales of travel and the village of the respondent.

	Odds ratio	95% Confidence Interval		P-value
Intercept				<.0001
Scale[2-1]	0.548	0.319	0.926	0.026
Scale[3-2]	0.377	0.225	0.620	0.0001
Village1	0.064	0.016	0.251	<.0001
Village3	2.75	0.562	17.6	0.240
Village4	4.65	0.873	36.2	0.097
Village5	1.76	0.382	9.89	0.488
Village1*Scale[2-1]	12.8	1.93	89.3	0.009
Village1*Scale[3-2]	9.34	1.40	63.7	0.021
Village3*Scale[2-1]	0.102	0.011	0.810	0.037
Village3*Scale[3-2]	9.20	1.43	60.3	0.020
Village4*Scale[2-1]	0.430	0.038	3.98	0.470
Village4*Scale[3-2]	0.991	0.139	6.69	0.992
Village5*Scale[2-1]	3.33	0.350	31.9	0.290
Village5*Scale[3-2]	0.010	0.0008	0.097	0.0002

Table 6. Results of nominal logistic regression predicting whether the respondent has irrigation ditch water contact when they travel by the scale of travel.

	Odds Ratio	95% Confidence Interval		P-value
Intercept				0.019
Scale[2-1]	14.3	1.39	14.3	0.014
Scale[3-2]	30.2	0.868	30.2	0.094
Scale[4-3]	7.53			0.912

Of individuals who reported travel at any scale (n=154), negative binomial regression revealed that time and cost of reported trips were significantly associated with the frequency of travel (Table 6). In multivariate models including individual demographic characteristics, there was no difference between the frequency of travel in males and females (IRR: 0.99, 95% CI: 0.56-1.72, p=0.974), nor did age did significantly alter the reported frequency (IRR: 0.98, 95% CI: 0.97-1.01, p=0.134). Reported travel frequencies did not conform to the assumption of Poisson regression, being highly over dispersed (Wald Chi-Squared= 17.55, p=0.0002) (Table 7).

Table 7. Results of negative binomial regression exploring the influence of trip characteristics on frequency of travel.

	IRR	Robust Std. Err.	95% Confidence Interval		P-value
Time (minutes)	0.99	0.0003	0.98	0.99	0.019
Cost (yuan)	0.74	0.077	0.60	0.91	0.004

Discussion

No statistically significant relationship was found between the prevalence of schistosomiasis in a village and the social connectivity of that village to other villages in the study as measured by the proposed metric. Travel between villages participating in the study was infrequent and the simple linear regression model found no statistically significant relationship between the connectivity metric and prevalence. These results could indicate that travel between the study villages is not related to village prevalence. Alternatively, the results may indicate that the metric as proposed does not capture the transmission-relevant features of connectivity. What is more, this study was limited to five villages within the study region and it is possible that in an expanded study more connections between villages may exist and a relationship between social connectivity and schistosomiasis may be found.

In previous studies investigating the relationship between disease prevalence and connectivity to other locations, (Eisenberg *et al.* 2006 and Tanser *et al.* 2000) relationships existed and they indicated that travel was related to levels of disease. Tanser *et al.* 2000 related distance to the nearest health clinic to HIV prevalence. Eisenberg et al. 2006 measured village connectivity to a central location and investigated the relationship to prevalence of diarrheal pathogens. These studies both related measures of connectivity to a common travel destination or central location and did not attempt to relate inter-village movements to disease outcomes. In contrast, this study was designed to investigate inter-village movement and therefore lacked thorough investigation into the presence of central locations and travel to these locations. Since this study is part of a larger effort to understand schistosomiasis, the study sites were already participating in a larger study and new production groups and other towns could be included. As a result, the villages chosen may not have been ideal subjects for studying inter-village movements. Motivations for travel were not completely understood before the study. It would be useful in future studies to investigate travel to central locations and collect infection data in those locations. In addition, while overall the amount of travel increased with scale until the fourth scale, some villages did not follow this pattern. Specifically, the only village without a paved road, village 1, had reported travel decrease with scale. This phenomenon calls for further study on how the distance to the nearest paved or larger road might affect travel patterns.

Despite the inability to find a relationship between prevalence and travel between the villages in this study, the results indicate that several characteristics of travel in the study region have statistically significant relationships. Time spent traveling, cost of travel and time spent at the destination all appear to vary by the scale of travel, indicating that these variables change according to distance of travel. The relationship found between frequency of travel and time and cost of travel indicates that these variables may have an impact of a respondent's decision to travel. If a location is too far or the trip is too costly, it may deter a person from making the trip. In some cases, scale of travel and the village of a respondent also have statistically significant relationships with whether or not the respondent may travel. It was also found that whether or not a respondent has irrigation ditch water contact when he or she travels is related to the scale of travel. These results imply the distance a respondent chooses to travel, the village of the respondent and the purpose for that travel may impact his or her decision to travel.

These characterizations of travel may seem straightforward: for example, if a trip is more expensive or it takes longer to get somewhere it will impact how often a person travels. However, these characterizations are necessary in order to begin to understand how these movements may impact the levels of schistosomiasis in the region. In order to begin to understand introduction events facilitated by human movement, we must first understand motivations for and activities related to this movement. Characterizing motivations for travel may permit future research to model human movement in the study area and further explore connectivity between villages. Understanding when activities might occur that are considered high risk behavior for schistosomiasis infection is also crucial for future researchers. In this study, we were able to incorporate distance, time and cost of travel into the metric of social connectivity with confidence that it might reflect an accurate level of social connectivity between the villages.

Despite the inability to find a relationship between prevalence and travel between the villages in this study, social connectivity could still account for part of the transmission process in schistosomiasis. This study investigated the relationship between schistosomiasis prevalence and social connectivity, however there was no investigation of whether social connectivity might sustain transmission of the disease or if it may be a method of introduction of the disease into a village. Social connections may account for the introduction of the disease, but levels of schistosomiasis prevalence may be determined by other characteristics of the village that impede or promote the spreading of disease within a village. This hypothesis could be supported by the finding that, while inter-village movements are rare, they often involve behavior that could allow for transmission of the disease. These behaviors include agricultural work, contact with irrigation ditch water or staying at the location for longer than 10 hours (one could imagine the traveler would need to use the restroom in this amount of time). This could be a possible route of introduction of the disease, but the level of prevalence in the village is actually determined by the village's potential to sustain transmission, such as degrees of social networking within the village or other village level characteristics. Future work might incorporate social network analyses within villages similar to the method employed by Bates *et al.* (2007) in the case of diarrheal pathogens. Residents visiting neighbors and family or sharing agricultural work and night soil fertilizers may sustain schistosomiasis within communities.

This study has contributed to the characterization of travel in five re-emerging villages in Sichuan Province. This information will be important for future research wishing to investigate the contribution of human movement to disease vectors in the region. While no relationship was found between schistosomiasis prevalence and the proposed metric of social connectivity, an exploration of alternative metrics, and an extension of the study beyond the five surveyed villages may reveal more about the relationship between schistosomiasis transmission and connectivity. Hopefully, the findings presented on characteristics of travel in this study will help inform future studies aimed at understanding the complex transmission network associated with schistosomiasis.

References

Bates, S.J., J. Trostle, W.T. Cevallos. A. Hubbard and J. N. Eisenberg. 2007. Relating diarrheal disease to social networks and geographic configuration of communities in rural Ecuador. American Journal of Epidemiology 166:1088-95.

Bloom, S.S., M. Urassa, R. Isingo, J. Ng'weshemi, and J.T. Boerma. 2002. Community effects on the risk of HIV infection in rural Tanzania. Sexually Transmitted Infections 78: 261-266.

Eisenberg, Joseph N. S., William Cevallos, Karina Ponce, Karen Levy, Sarah J. Bates, James C. Scott, Alan Hubbard, Nadia Vieira, Pablo Endara, Mauricio Espinel, Gabriel Trueba, Lee W. Riley, and James Trostle. 2006. Environmental change and infectious disease: How new roads affect the transmission of diarrheal pathogens in rural Ecuador. Proceedings of the National Academy of Sciences of the United States of America 103: 19460-19465.

King, Charles H., Katherine Dickman, and Daniel J. Tisch. 2005. Reassessment of the cost of chronic helmintic infection: a meta-analysis of disability-related outcomes in endemic schistosomiasis. The Lancet 365:1561-9.

Liang S., C. Yang, B. Zhong, D. Qui. 2006. Re-emerging schistosmiasis in hilly and mountainour areas of Sichuan, China. Bulletin of the World Health Organization 84: 139-44.

Liang S., Edmund Y. W. Seto, Justin V. Remais, Bo Zhong, Changhong Yang, Alan Hubbard, George M. Davis, Xueguang Gu, Dongchuan Qiu, and Robert C. Spear. 2007. Environmental effects on parasitic disease transmission exemplified by schistosomiasis in western China. Proceedings of the National Academy of Sciences of the United Stated of America 104: 7110-7115.

Ross, Allen G. P., Adrian C. Sleigh, Yuesheng Li, George M. Davis, Gail M. Williams, Zheng Jiang, Zheng Feng, and Donald P. McManus. 2001. Schistosomiasis in the People's Republic of China: Prospects and Challenges for the 21st Century. American Society for Microbiology 14: 270-295.

Spear, Robert C., Edmund Seto, Song Liang, Merrill Birkner, Alan Hubbard, Dongchuan Qiu, Changhong Yang, Bo Zhong, Fashen Xu, Xueguang Gu and George M. Davis. 2004. Factors influencing the transmission of Schistosoma japonicum in the mountains of Sichuan Province of China. American Journal of Tropical Medicine and Hygiene 70: 48-56.

Tanser, Frank, David LeSueur, Geoff Solarsh, and David Wilkinson. 2000. HIV heterogeneity and proximity of homestead to roads in rural South Africa: an exploration using a geographical information system. Tropical Medicine and International Health 5: 40-46.

Wawer, Maria J., David Serwadda, Stanley D. Musgrave, Joesph K. Konde-Lule, Maako Musagara, and Nelson K. Sewankambo. 1991. Dynamics of spread of HIV-1 infection in a rural district of Uganda. British Medical Journal 303: 1303-1305.

World Health Organization. 1996. Retrieved March, 21 2007 from, http://www.who.int/mediacentre/factsheets/fs115/en/.