Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Social Science & Medicine 129 (2015) 87–95

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

An expanded One Health model: Integrating social science and One Health to inform study of the human-animal interface

Sara Woldehanna*, Susan Zimicki

FHI 360, 1825 Connecticut Ave NW, Washington DC 20009, USA

ARTICLE INFO

Article history:
Available online 1 November 2014

Keywords:
Lao PDR
Hmong
Lao-Tai
One Health
Emerging zoonoses
Social factors
Human-animal interface
Mixed-methods study

ABSTRACT

Zoonotic disease emergence is not a purely biological process mediated only by ecologic factors; opportunities for transmission of zoonoses from animals to humans also depend on how people interact with animals. While exposure is conditioned by the type of animal and the location in which interactions occur, these in turn are influenced by human activity. The activities people engage in are determined by social as well as contextual factors including gender, age, socio-economic status, occupation, social norms, settlement patterns and livelihood systems, family and community dynamics, as well as national and global influences. This paper proposes an expanded "One Health" conceptual model for human-animal exposure that accounts for social as well as epidemiologic factors. The expanded model informed a new study approach to document the extent of human exposure to animals and explore the interplay of social and environmental factors that influence risk of transmission at the individual and community level. The approach includes a formative phase using qualitative and participatory methods, and a representative, random sample survey to quantify exposure to animals in a variety of settings. The paper discusses the different factors that were considered in developing the approach, including the range of animals asked about and the parameters of exposure that are included, as well as factors to be considered in local adaptation of the generic instruments. Illustrative results from research using this approach in Lao PDR are presented to demonstrate the effect of social factors on how people interact with animals. We believe that the expanded model can be similarly operationalized to explore the interactions of other social and policy-level determinants that may influence transmission of zoonoses.

1. Introduction

The current Ebola outbreak in West Africa (CDC, 2014), and to a lesser extent the outbreak of Middle East Respiratory Syndrome (MERS), first identified in Saudi Arabia in 2012 (Cunha and Opal, 2014) have galvanized the world's attention on the dangers posed by zoonotic infections. However, these are only the latest in a series of outbreaks of novel diseases in humans during the last decade of the 20th century highlighting the need for focus on the zoonotic (animal) origin of viral infections. For instance, avian influenza H5N1 was identified in Hong Kong in 1997 (Mounts et al., 1999); Rift Valley fever caused an estimated 27,500 human infections and reported loss of approximately 70% of livestock (primarily sheep and goats) in Garissa District, Kenya, in 1997–1999 with reports of disease in four other provinces in Kenya as well as in Somalia and Tanzania (Woods et al., 2002); an outbreak of Nipah virus in Malaysia in 1998–1999 caused at least 283 human cases of encephalitis and 109 deaths (Chua, 2003) with an estimated 1.1 million pigs culled in efforts to stop transmission (FAO and APHCA, 2002); and outbreaks of West Nile virus occurred in Europe from 1996 to 1999 (Hubalek and Halouzka, 1999) and the United States beginning in 1999 (WHO, 2012). In 2001 Taylor and colleagues (Taylor et al., 2001) inventoried known human infectious disease pathogens and pointed out that 61% of all pathogens and 75% of emerging disease pathogens were zoonotic in origin. About 80% of human viral pathogens are zoonotic (Morse et al., 2012; Taylor et al., 2001).

The importance of viral zoonoses was emphasized with the emergence of SARS coronavirus in 2002–2003 and the reappearance of H5N1 in Hong Kong in 2003, followed by its spread throughout Asia, the Middle East, Europe and sub-Saharan Africa by 2006 (WHO, 2012). The pace of new outbreaks led to increasing recognition that emerging infectious diseases originate at the interface of human and animal ecosystems.

This recognition underscored the need for an inter-disciplinary approach to dealing with transmission and was one of the main

* Corresponding author.
E-mail address: swoldehanna@gmail.com (S. Woldehanna).

http://dx.doi.org/10.1016/j.socscimed.2014.10.059
0277-9536/

factors leading to creation of the One World One Health™ movement. At a conference convened by the Wildlife Conservation Society at the Rockefeller University in 2004, the movement gained its trademarked name and issued a call to action, embodied in the "Manhattan principles" for preventing emerging diseases in human and animal population and maintaining ecosystem integrity (WCS). By 2008, the UN Agencies and the World Bank had drafted a strategic framework, introduced at the "One World, One Health: From Ideas to Action" Conference in Winnipeg, Canada, in 2009 (PHAC, 2009). The premise of One Health is that people, animals and the environment form an interdependent ecosystem that needs to be considered in a coordinated manner (FAO et al., 2008; Frank, 2008). It rests on a conceptually simple model that focuses on contact – and therefore the potential for transmission of disease – between wild and domestic animals and humans (usually depicted as three overlapping circles) in the context of the environment.

This model has worked well as an advocacy tool to present the case for coordination in detecting and responding to outbreaks. It has also fostered discussions on the factors that are contributing to spillover of diseases from animals to humans, the first step in an outbreak. Most of the discussions to date about drivers of emergence (Daszak et al., 2000; A. Dobson and Foufopoulos, 2001; Karesh et al., 2012; Patz et al., 2004; Smolinski et al., 2003) have focused on anthropogenic land use changes – essentially resource exploitation (logging, mining, establishment of plantations, dam building) and associated road building and pollution. These factors are fundamental drivers of disease emergence in wildlife through their effects on habitat fragmentation, biodiversity and host-pathogen dynamics. A second set of frequently mentioned drivers focuses on movement of hosts and pathogens through travel and the transport and trade of animals and animal products. Finally, increased human-animal contact occurs because of increasing human population density and its consequences – encroachment of humans into previously undisturbed areas and the development of larger scale or more intensive animal production systems (Slingenbergh et al., 2004).

While these large-scale changes and interactions may provide the potential for contact between humans and animals, opportunities for transmission – that is, the initial spillover event – also depend on specific human activity at the local level: if, how, where and when people interact with animals (K. A. Alexander and McNutt, 2010). For example, Chua et al. (2002) suggested that the first documented outbreak of Nipah virus in Malaysia was precipitated by a combination of ecological and social factors. The ecological factors included El Niño-cycle related drought, land use change (deforestation and reduced habitat for fruit bats due to logging) and fire arising from slash and burn agriculture that displaced bats to orchards in Ipoh. In addition, key factors included local practices regarding location of piggeries in and near fruit orchards and pigsties constructed so that water run-off from roofs – and fruit dropped by bats – was directed into the pigsty. The result was that pigs were able to eat bat-saliva-contaminated fruit, became infected and then infected their handlers.

This example supports the importance of the land use change drivers, but also suggests the importance of other, more proximate determinants of contact – in this example, the siting of piggeries and pigsty construction. For preventing, or at least slowing, the emergence of new diseases – and for more efficient response to outbreaks – we need to have a better understanding of these proximate determinants. One route to preventing recurrence of Nipah virus at pig farms would be to implement policies and regulations addressing the "upstream" land use changes that eventually led to emergence. A second, complementary route is through interventions affecting what Chua calls "the pattern of pig and orchard farming" (Chua et al., 2002); that is, human activities at the local level. A first step in this approach is discerning those patterns. Having a model of proximate determinants facilitates this activity.

In this paper we propose an expanded One Health model that highlights the social determinants of human-animal exposure, describe a study approach that operationalizes the model to explore factors that influence the risk of transmission at the individual and community level and present some results that illustrate the effect of social factors on how people interact with animals.

2. An expanded one-health model

The expanded One Health model we propose gives serious consideration to all the factors, both social and ecological, that can contribute to disease emergence at the local level. In the expanded model (Fig. 1), the probability of zoonotic disease spillover is a function of contact between humans engaging in different activities and infected animals they encounter during those activities. As our primary interest is emerging pandemic threats, in developing the model we considered what we know about emerging viral diseases transmitted from animals to humans by direct or indirect contact; these comprise about a quarter of all emerging zoonotic diseases (calculated from Table 2 in Taylor et al. (2001). The model would need further expansion to account for proximate determinants of the emergence of other kinds of diseases of zoonotic-origin: vector-borne diseases, drug resistance, bacterial, fungal or helminthic infections.

Any specific spillover event involves one or a small number of animals and one or a small group of individuals (e.g., family members or a hunting party). From the animal side, the probability of transmission to humans is primarily affected by the prevalence of infected animals, which could be wild or domestic. There is a lively debate about the proximate determinants of prevalence, which may include animal biology, pathogen ecology, animal density, biodiversity and animal movement, among others (Keesing et al., 2010). On the human side of the model the probability of spillover transmission from animals is primarily affected by the likelihood of someone encountering an infected animal or its excreta, determined by the frequency with which people come in contact with specific types of animals that might carry infections and the type of contact they have with animals; that is, by the types of activities in which they engage.

Human activity is influenced by a complex range of factors along the socio-ecological continuum (Riekert et al., 2008) which may act separately or in tandem. Key categories include: biological characteristics of individuals; social characteristics of individuals, households and communities, including norms, livelihood systems and settlement patterns; and finally, at the public policy level, local and international governance and politics (see Table 1 for examples of key elements in each category).

Complex social dynamics determine the type and frequency of engagement of any individual, family or community in specific activities involving possible interactions with animals, as well as the intensity of interactions and thus potential exposure to pathogens. At the simplest level, socially-determined roles for individuals of specific gender, age and education affect both the range of possible occupations and division of labor; for instance, women may cook and men slaughter. Individuals engaged in occupations related to animals (hunting, butchering and caring for animals, etc.) or working in agricultural areas or forests are obviously at increased risk compared to the general population.

Household characteristics, including family structures and socio-economic status, can determine if and how families are exposed. These relationships can be complex. For example, while families that hunt for food tend to be poorer and less educated than families that purchase food, poverty is a predictor of only one kind

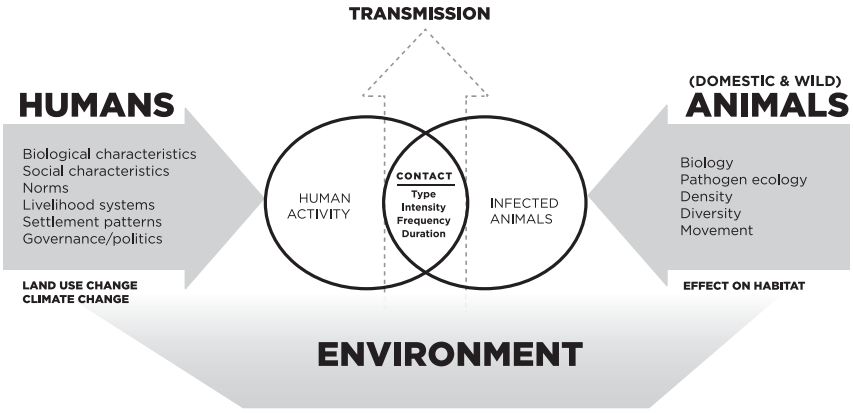

Fig. 1. Expanded One Health model of zoonotic disease transmission.

of interaction with specific types of wild animals. Wild animal meat purchased in markets is frequently more expensive than domestic animal meat; a market survey carried out by WCS and FHI360 in Laos (unpublished) showed that brush-tailed porcupine meat cost three times as much as domestic pork per kilogram. In addition, within-family dynamics can affect who gets exposed and with what frequency and intensity. As an example, family type – e.g. single parent, nuclear family or extended – will affect whether and how intensely children are socialized to hunting or what food allocation rules are practiced to determine who gets to eat what part of the animal (Whitehead, 2000).

Availability of markets, goods and services, the strength and type of social networks, and proximity to natural resources can affect community dynamics leading to greater or less exposure to animals. For instance, a study conducted in several African countries showed that while more wealth was associated with less bush meat consumption in rural communities closer to source of wild life harvest, it was associated with more bush meat consumption in urban communities (Brashares et al., 2011). Various social forces such as conflict or forced or voluntary migration can also change peoples' relationships to the environment and animals (de Merode et al., 2007; Fauna and Flora, 2013).

Social norms can affect interactions with animals and potential exposure to zoonotic pathogens in many ways (e.g., which if any animals are preferred for eating and what types of preparation are acceptable, or what kinds of animals are considered suitable for pets – or for children to play with). Various customs with regards to specific animals may serve different social functions that can shed light on other determinants of exposure. For instance, hunting some animals may confer certain social standing in the community and sharing the products of a hunt maybe used as a way of incurring favors (Gurven and von Rueden, 2006). Food taboos related to animals, often applied differentially to subgroups (e.g. children, pregnant women, individuals from different castes), can serve several purposes including protecting health, marking special events, protecting or allocating scarce resources, or creating group cohesion (Meyer-Rochow, 2009).

Settlement patterns affect the variety and number of animals to which people might be exposed. For example, how houses are constructed, which may be associated with ethnicity and/or socio-economic status, may determine risk of rodent infestation (Bonner et al., 2007). Rodent abundance is also affected by location of housing relative to different types of animal habitat and open water sources and to waste disposal sites (Bonner et al., 2007; Masi et al., 2010; Promkerd et al., 2008). It is important to note that while increasing urbanization produces habitats unsuitable for many species of animals, urban-adapted wild animals can occur at higher densities in urban and peri-urban areas than in more rural areas (Bradley and Altizer, 2007). Finally, governance and politics, from local to international levels, can affect not only the extent and impact of some of the anthropogenic land use changes mentioned above but also social dynamics at all levels to influence who gets exposed and with what frequency and intensity.

Our expanded model increases the level of detail of the One Health framework and strengthens the foundation for understanding the interplay of factors that lead to disease emergence. Below we describe a research approach based on this expanded model.

3. Operationalizing the expanded model: the human-animal exposure study

The human-animal exposure study was developed to document the extent of human exposure to animals and begin to explore the interplay of social and environmental factors that influence risk of transmission at the individual and community level. The study aims to identify groups who are at particular risk of transmission of infections and the (potentially modifiable) factors contributing to that risk.

In Southeast Asia the human-animal exposure study has been conducted in selected locations in Thailand and Lao PDR. In Thailand the study was implemented in urban and rural locations inhabited by the same ethnic group (the I-San). In Lao PDR, the study examined differences in exposure between two culturally different ethnic groups (Hmong, Lao-Tai) living in the same location. Both of these studies received formal ethical approval from the FHI360 Protection of Human Subjects Committee (FHI 360's IRB) and an IRB in the country in which they were conducted. Informed consent was obtained from all participants; in the case of children, we obtained the child's assent and informed consent from a parent. Below we use examples from these settings to illustrate our discussion of the factors important in implementing such an approach.

3.1. A standardized study approach

One research objective suggested by the model is to improve understanding of the interaction between culture and ecology in determining potentially risky human-animal exposure. Fully addressing this objective will requires in-depth exploration of the multitude of factors mediating risk of exposure that are affected by social dynamics at the international, national, community, familial and individual level. As a first step, we chose to start this endeavor simply, by comparing groups distinguished by different social determinants of human activity involving animals, e.g., gender, age,

Table 1
Social determinants of human activities that affect human-animal exposure.

Category	Examples of key elements
Biological characteristics	• Age • Sex • Immune status • Comorbidities
Social characteristics	• Individual's social characteristics such gender, age, education affect who hunts, markets, butchers, prepares food, handles animal fertilizer • Household characteristics including family structure (e.g. female headed, nuclear or extended), household head educational level, SES – food security status, how are children are taught to hunt or cook, house maintenance • Community characteristics such as location, homogeneity, resilience, level of prosperity or poverty, access to employment, availability and access to resources such as health workers or veterinarians, market types • Ethnicity, class, race and caste often determine who in society engages in which activity or can access which resources • Migration or conflict can change the way people interact with animals
Norms	• Acceptability of e.g., animals in the house, eating uncooked food, different animals as pets • Food preferences (demand/aversion regarding specific types) • Hygiene and sanitation • Expectations about religious and medicinal rituals • Slaughter and food preparation practices • Beliefs e.g., about disease, risk
Livelihood systems	• Agricultural practices (e.g., field clearing practices, animal conflict, use of animal fertilizer) • Animal husbandry practices, especially those related to diversity, density and diet, transport of domestic animals and their potential interaction with wildlife • Hunting – methods used, locations • Gathering – methods used (tree climbing), locations •Trade in animals/animal products
Settlement patterns	• Construction of housing • Density of housing • Distance of households from fields and forest areas (access to animals) • Infrastructure (water, electricity, waste disposal) availability, location relative to housing • Market location and structure
Governance & politics (Local-National)	• Policy, regulations and enforcement (e.g., regarding hunting, transport and sale of domestic and wild animals and animal products, structure and hygiene of markets), number and location of roads & railways, dams, logging and mining concessions, large-scale agriculture, internal migration • Availability of vaccination and curative health services
Governance & politics (International)	• Policies, regulations and enforcement of trade in animals and animal products, global travel, multinational agriculture and extractive industries, migration

ethnic norms, livelihood systems, settlement patterns. The study is designed to facilitate such comparisons, for example, of different population groups (e.g., two ethnicities) living in the same location, thus having similar access to animals, or the same group in locations where access to animals is likely to differ (e.g., one ethnic group living in different settings). In addition, the design includes separate samples of men and women to assess the effect of gender on exposure and provides for subsamples of children likely to have different frequencies or types of exposure than adults. The instruments are designed to gather information on other social contrasts including, for example, religion, occupation, and education.

The study uses a mixed-methods approach carried out in two phases: qualitative formative research and a quantitative survey. A mixed-methods approach is especially suitable for this research because it accommodates the need to standardize while recognizing the importance of context for the information gathering process. A generic protocol and instruments are adapted for each site.

The first phase, formative research, involves collecting qualitative data that can provide an in-depth understanding of the human–animal interface, including the "how," "when," "where" and "why" of exposure. This information is also used to guide adaptation of the survey instrument to local conditions.

The formative research draws on a variety of qualitative approaches:

- Participatory rural appraisal (PRA) methods (Chambers, 1994) are employed to answer research questions where local knowledge is especially critical (e.g., seasonality of activities and animals, organization of physical space).
- Projective techniques (Wiehagen et al., 2007) are tools for uncovering and exploring underlying motivations or feelings that respondents might be unaware they have or might be unwilling to discuss openly (e.g., hunting protected wild animals). They use ambiguous images or descriptions of situations, on which participants may "project" their attitudes, feelings and opinions safely without divulging personal information.
- Structured anthropologic methods (Bernard, 2011) allow for systematic collection of data related to the cultural knowledge (e.g., taxonomies) held by the respondents (e.g., how a community categorizes animals into groups).

The second phase of the human-animal exposure study is a random survey of individuals to quantify their exposure to animals as completely and as accurately as possible. It uses a generic protocol and instruments that are adapted for each site. The sample size for the survey should be calculated to allow for estimation of exposure parameters within desired confidence limits for each gender group; we routinely use ±10%.

The generic survey instrument is structured in modules related to the most common ways (activities and locations) people are exposed to animals. These correspond to three categories of proximate determinants: norms, livelihood and settlement patterns. Finalizing locale-specific instruments is based on results of the formative research regarding the types, categorization, roles and uses of different animals in specific communities. (See below for discussion of the key factors considered in adapting the questionnaire for a specific site). If the formative research identifies activities or locations associated with human-animal contact that are not included in generic modules, the survey questionnaire is amended; in some cases entire modules may be developed and added. For instance, during the formative research phase in one setting we learned about use of animals and animal products for medicinal purposes and encounters with animals when gathering wood and non-timber products in the forest; questions about these potential contacts were included in the subsequent survey. Currently available modules are listed in Table 2.

Not all encounters between humans and animals are direct – or memorable. They can easily be overlooked or forgotten. To increase recall of events that may not be considered important, survey questions are supported with extensive, systematic probes.

To ensure that survey data are as valid and reliable as possible, we carry out cognitive interviewing (Willis, 2005) using the site-adapted survey instruments. This approach involves pretesting sections of the questionnaire to assess how people understand questions and process information in order to respond to them. Cognitive interviewing helps to identify potential misunderstandings and questions that are especially hard for respondents to answer and determine if response categories make

Table 2
Currently available modules for the human-animal exposure survey.

Topic	Modules
Consumption	• Animals that are eaten • Animals that are slaughtered, butchered, cut up • Animals encountered in markets • Animals used as medicine
Livelihood	• Animals that are raised (including pets) • Fertilizer • Animals that are hunted or captured • Animals associated with gardens and crops or near areas frequented by domestic animals • Animals associated with places people gather products (e.g., non-timber forest products, guano in caves)
Individual characteristics	• Respondent and household background characteristics
SES, House construction, available infrastructure	• Household information
Norms	• Beliefs and attitudes • Animals in and around the house & methods used to control them • Dead animals

sense; this information is used to finalize the questionnaire before deployment.

3.2. Key decisions related to the scope of the study

Two key decisions in developing a study design were the range of animals and the parameters of exposure that the study should cover.

Types of animals The survey collects some information about exposure to all kinds of domestic and wild animals and more detailed information to quantify human exposure to wild animals particularly likely to carry zoonotic viruses – bats, rodents and nonhuman primates – as well as to poultry.

This decision was based on current information about transmission of viral infections. Non-human primates, bats, and rodents (including rats, mice, squirrels and porcupines) are mammals of particular interest. All are reservoirs or suspected reservoirs of infections that have caused important outbreaks of human disease: nonhuman primates for HIV (Keele et al., 2006); bats for SARS, Nipah, Hendra and as suspected reservoirs for Ebola and Marburg viruses (A. P. Dobson, 2005; Kuzmin et al., 2011); rodents for Lassa fever virus and hantavirus (both confirmed) and as suspected reservoirs or important intermediate hosts for monkeypox (Meerburg et al., 2009). In addition to these reservoir species, it is important to obtain some information about possible intermediate hosts – animals that may be infected and in turn infect humans. A wide range of wild animals can be intermediate hosts; for example, both nonhuman primates and antelopes can be infected with Ebola and transmit the infection to hunters who find the carcasses (Lahm et al., 2007). Domestic animals, including pets, and other animals that come in frequent contact with humans also have to be considered, as they have been shown to be intermediate hosts or carry viruses such as avian influenza (Van Kerkhove et al., 2011), rabies (Chomel et al., 2007) or Rift Valley fever (Woods et al., 2002).

Our study therefore accounts for human interactions with a wide variety of mammals, both wild and domestic. It also includes human interactions with domestic poultry and pigs, because of the contribution of influenza viruses from both birds and swine to influenza H1N1 and the importance of H5N1 (and recently H7N9) as poultry diseases that can infect humans (D. J. Alexander and Brown, 2000).

Parameters of exposure The survey assesses frequency and duration of exposure to animals and to a certain extent, proxies of "intensity" of exposure (e.g., contact involving oral fluid from an infected animal on intact human skin is probably less risky than being deeply bitten by an infected animal). It was not designed to directly measure risk because for many diseases too little is currently known for accurate quantification of risk (even, for example, about the amount of viruses present in viscera vs. muscle vs. blood vs. nasal excretions vs. feces vs. oral fluid, or about the persistence of virus in various organs after an animal's death or on different surfaces under different conditions). Therefore, for the analysis, information about intensity is translated into weighted scales based on expert opinion.

3.3. Factors considered in local adaptation of the human-animal survey

Because language and cultural frameworks affect the validity of information gathered through surveys, the formative research is designed to elicit the information needed for local adaptation of the survey instrument. Particular attention is paid to local names of animals and how people speak about encounters, time and locations.

Identification of animals One of the main goals of the formative phase of the research is to generate local animal dictionaries for use during the survey. We have found that there are usually no comprehensive lists of local animal names and that even those lists that are available do not include regional or local variations.

Ethnic groups vary in the specificity with which they recognize animals. Recognition can sometimes serve as a proxy for exposure, as people tend to be more familiar with the animals they encounter most frequently. For instance, in Thailand people were able to identify rats (a food source as well as a pest) with a great deal of specificity and were able to name several types of rats. In contrast, they did not use different names for different species of bats.

During the formative research a concerted effort is made to identify local names and any areas of possible confusion by using an extensive array of animal photos and discussions about animals found in the community. One exercise uses probes focused around senses (e.g., What about animals you smelled? Or animals you heard?) to improve recall. In Thailand, when first asked to recall animals in the community (a question unlinked to senses), most people first mention animals they see. On being prompted for animals they "touch," new animals are recalled – mostly those that are cooked or cared for (such as fish, crab, cows, cats and dogs). Another prompt, for animals people have observed "evidence of being around," has elicited reports of wild boar and bear (stool, foot print), pangolin and mongoose (holes), squirrels (bitten fruits and food), fox (howling), snake (skin and smell), cockroach (stools), and civet (stool and foot print).

In Thailand, the formative research generated a dictionary of about 20 animal names just in the rodent, bat and primate animal orders and in Lao PDR, dictionaries included 45 names in those animal categories for Hmong and 30 for Lao-Tai. In addition to the dictionaries, naming conventions for animals are ascertained, enabling the identification of additional animals during the survey. For instance, *pua* is the generic name for bat in Hmong; names for different types of bats modify this generic name (e.g., *Pua-lor* and *Pua-sam-wa*). Whenever available, this kind of information allows researchers to determine the category of animal if they encounter a new animal during the fielding of the study.

The questionnaire is structured such that if respondents do not spontaneously mention specific animals of interest (bats, nonhuman primates, or rodents), interviewers probe for them by

local name (spontaneous and probed responses are coded differently). Information obtained during the formative research phase is analyzed to determine how specific these probes should be.

How people describe actions People vary in the way they talk about encounters. Use of the wrong term may lead to miscommunication and collection of incomplete or inaccurate data. Different terms may be used in slightly different situations; for example, among the Lao-Tai, people "hunt" [*larr suud*] for larger animals but "go looking for" [*pai ha kni*, *pai xook suud*] smaller animals. Thus "rice field rat" is not a response obtained when "What do you hunt?" is asked. The formative phase of the study explores use of language to describe animal encounters. Glossaries of key clusters of words are built, along with notes about the context of their use. For example, one such cluster is "slaughtering," "butchering," "cutting up," "preparing" – terms that can have implications for intensity of exposure since they are associated with how recently an animal has died and thus the amount and viability of pathogens that might be transferred.

Temporal variation To ensure that information about rare, as well as routine, encounters with animals is obtained and to account for seasonality, the survey documents human-animal contacts over the previous year. The single exception is information about hunting and eating animals. Recall about eating is especially problematic because the activity is so routine. Thus respondents are first asked about what animals have been hunted or eaten in the past four weeks, and then asked about the previous 12 months.

One portion of the formative research focuses on the rhythms of life in the community across the year to identify seasonal patterns of activities and encounters with certain animals. For example, formative research in Lao PDR identified two seasons (rainy and dry) significant to the community. For activities identified as seasonal (e.g., application of fertilizer, hunting) probes for these seasons are used during the survey to aid recall of encounters with animals. Such information is not only critical for understanding temporal patterns of risk of transmission; it may also be critical in the design of any strategies for the mitigation of such risk.

Spatial variation Location is a key factor that determines the number and variety of animals to which humans are exposed. Different groups identify key spaces differently. For example, space just outside a house may be considered "living space," equivalent to space inside the house, or may be considered part of "public space". One section of the formative study explores how people understand and talk about the spaces around them; the cognitive interviews include tests of questions involving specific locations.

4. Some findings illustrating the effect of social factors

Comparing two ethnic groups living in the same area is a good way to understand how socially-determined gender and age roles and norms affect different kinds of exposure to animals and thus potential risk. This section presents illustrative examples from Lao PDR, where Lao-Tai and Hmong ethnic groups living in the same location, with similar access to animals, were interviewed. The Hmong are an ethnic minority in Lao PDR and tend to be of lower socio-economic status compared to their dominant ethnic counterparts – the Lao-Tai. The Hmong and Lao-Tai are culturally and linguistically distinct groups; for instance almost all Hmong in our study practiced animist religion while a majority of the Lao-Tai were Buddhists. The survey included 292 men, 292 women, 191 boys and 188 girls across both ethnic groups, with roughly half of each age–gender category drawn from each ethnic group. Note that all difference between groups discussed in this paper were significant at $p < 0.05$ or below.

4.1. Consumption

A comparison of the consumption patterns of Lao-Tai and Hmong highlights the importance of social factors in key exposures. We examined the steps involved, from hunting or purchasing through preparation and eating. Practices associated with hunting offer opportunities for transmission: for example, hunters may be bitten or scratched by an infected animal, they may handle the carcasses and viscera of infected animals (whether killed or found dead) and get infected blood into wounds, or may have contact with animal feces. Slaughtering and preparing (butchering and cutting up) wild animals, whether done by hunters, their family members or people who buy animals, can place people at risk of transmission through direct exposure to blood and internal organs as well as feces. Finally, eating is an important source of potentially risky exposure, as ingestion of meat or blood from infected animals, especially raw or uncooked, or intake of other foods or liquids contaminated with viruses can cause disease.

Hunting is a common activity among both Lao-Tai and Hmong, but is clearly a domain of men and boys; very few girls and women hunt animals other than rats/mice and other rodents (Fig. 2). Although the two ethnic groups live in the same area, there is a difference in the types of animals they report hunting – a proxy of their familiarity with these animals (see Table 3). While respondents from the two groups both report hunting six types of bats, the Hmong report more types of nonhuman primates and squirrels while the Lao-Tai report more types of rats/mice.

The animals hunted most often by both ethnic groups are rats/mice and other rodents (squirrels and porcupines). Rats/mice are eaten by nearly three quarters of Hmong and Lao-Tai men, women, and children and more than half of adults and children also participate in preparing them. However, boys, especially Hmong boys, are the group most likely to hunt, slaughter, prepare and eat them; more than three quarters of Lao-Tai and more than 90% of Hmong boys reported hunting rats/mice in the last year. Boys are also more likely than any other group to report being scratched and bitten by rats/mice. About 25% of Hmong and about 10% of Lao-Tai boys reported being scratched or bitten by rats/mice in the four weeks. However, it is worth noting that women and girls also hunt rats/mice. Among the Hmong, about 20% of girls reported hunting them.

Women and girls are more involved in slaughtering and preparing rats/mice than in hunting, and their involvement differs by ethnicity. Among Lao-Tai, girls and women are the groups least likely to slaughter and girls are the least likely to prepare rats/mice; however even among girls, nearly 40% report preparing rats/mice in the last year. On the other hand, Hmong girls slaughter animals at rates equal to men (and higher than women) and prepare them at higher rates than men.

Bats are another animal to which Hmong and Lao-Tai boys are more exposed than others; more than 10% of boys from both groups reporting hunting bats compared to less than 7% of all other subgroups. Bat-eating by adults is delineated along ethnic lines; both Lao-Tai men and women were more likely to eat bats in the last year than their Hmong counterparts. Reasons for this pattern are suggested by results of the formative study: the Hmong noted that bats are primarily eaten only when there is less choice of alternative meats, as many people consider them to be dirty and smelly.

There is a striking difference between ethnic groups in consumption of nonhuman primates. Hmong were more likely to eat nonhuman primates, with more than 20% of Hmong, but almost no Lao-Tai (<3%), eating them in the last year. Hmong men were also most likely to report hunting, slaughtering and preparing nonhuman primates.

Finally, consumption of raw meats varies by gender. Both Lao-Tai and Hmong participants in the qualitative research reported that eating raw meat and internal organs, and drinking blood from

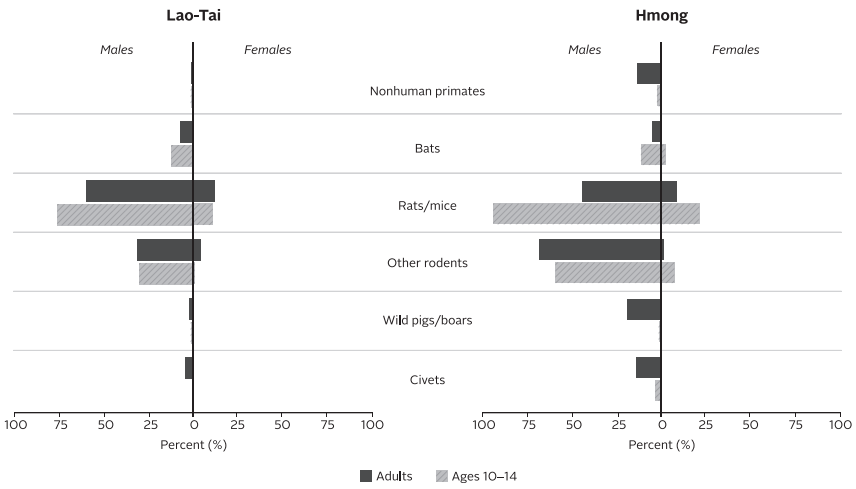

Fig. 2. Hunting among Lao-Tai and Hmong in Lao PDR. The bars represent the percent of each gender/age group who reported hunting different animals. Upper bars represent adults and lower bars, 10–14 year old children.

certain animals, including cows, pigs and squirrels, is considered a male activity. Participants also stated that eating raw meat is not appropriate for those who are "weaker," including women and children. The survey confirmed this finding; men (both Lao-Tai and Hmong) were three times as likely as women to consume raw animal products. The survey also showed some ethnic differences in patterns of raw meat consumption: Hmong men and boys were more likely than their Lao-Tai counterparts to consume raw meats.

As can be seen from these differentials, social factors clearly influence the possible risk of transmission associated with consumption. Both Lao-Tai and Hmong hunt, but different subgroups have different risks as a result of hunting: males in both ethnic groups are at higher risk from hunting any animal (compared to females); boys in both ethnic groups (compared to any other groups assessed) are at higher risk from hunting bats and rats; and Hmong men are at higher risk from hunting nonhuman primates. Women and girls, on the other hand are exposed to rats by being involved in preparing them. Finally, social factors also determine who is at risk from eating different meats: eating rats is an equal source of exposure for adults and children in both ethnic groups; the Hmong are more exposed to nonhuman primates and the Lao-Tai to bats as a result of eating; and men are more intensely exposed as they are more likely to eat raw meat compared to women.

4.2. Animal husbandry and agriculture

Raising animals is another area where the influence of social factors on exposure, and therefore the risk of transmission, is evident. Domestic animals are raised by nearly everyone in the study area: about 90% of both Hmong and Lao-Tai reported raising poultry in the last year, and more than half of both Hmong and Lao-Tai reported raising pigs, cows, cats and dogs.

Risk of transmission from raising animals can come from a number of sources, including sharing living quarters with the animals. More than 90% of respondents in both ethnic groups reported that poultry come into the house. There is a difference between the two groups in pigs in and around the house: nearly 20% of Lao-Tai reported pigs in or around the house, while fewer than 2% Hmong did so. The formative research also shows that the Lao-Tai build their houses on stilts and keep pigs and other domestic animals under the houses.

Table 3
Number of animal names mentioned as hunted by Lao-Tai and Hmong.

	Lao-Tai	Hmong
Bats	6	6
Nonhuman primates	2	9
Squirrels	6	7
Rats/Mice	21	8

Note: These names do not necessarily correspond to unique species of animals; different names might refer to the same animal.

The study draws attention to a specific risk for children in both communities. Among the Hmong, more children than adults, especially boys, reported being bitten or scratched by domestic animals in the past year; e.g., nearly one third of Hmong boys reported being scratched by poultry compared to <10% of Hmong men. While this may stem from inexperience when caring for domestic animals, the qualitative portion of the study identified other activities that might place children at particular risk, including playing with chickens and organizing cockfights. Children were also reported to keep squirrels and small monkeys as pets and to capture and use bats as playthings.

Another area with clear differences along ethnic lines is the use of animal feces for agriculture. Both groups, but more Lao-Tai than Hmong, use feces from poultry, cows and pigs as fertilizer. In contrast, more Hmong than Lao-Tai use bat guano as fertilizer. The formative study showed a difference in the division of labor among men and women and children in the acquisition and use of guano: men are responsible for collecting bat guano from caves once or twice a year, and women or children are responsible for applying the guano to fields and gardens once or twice a month.

While the study highlighted nearly universal exposure to domestic animals in these communities, it also shows a specific risk for Hmong boys during care of or playing with poultry (they reported being scratched and bitten more) and a possibly elevated risk for Lao-Tai households whose pigs may come indoors. Finally, exposure to feces used as fertilizer has been shown to vary by ethnic, gender and age groups; this may translate into different kinds of risks for different groups in contact with the same source of virus (feces) but from different animals (poultry and pigs vs. bats) and in different activities/locations (obtaining from around households vs. obtaining in caves vs. applying on fields).

5. Conclusion

Insight about the large-scale drivers of zoonotic disease emergence – land use patterns, increasing human population and global movement of people and goods – is useful for informing national

and global policies with regards to human development activities. Given current realities, a more in-depth understanding of the specific ("micro") aspects of the human-animal interface that can result in spillover events would complement current efforts for planning prevention or mitigation strategies. The expanded One Health model asserts that different people living in the same location, affected by the same large-scale drivers, may be at different risk of spillover because of the social factors that influence the types of activities they engage in. Who is at risk and how they are at risk of spillover are determined by social factors, such as those affecting communities within societies and families and individuals within communities (e.g., gender, age, family structures, SES, occupation, community resources), norms with regards to different animals (e.g., food taboos or preferences), settlement patterns that can limit or increase contact with certain animals (e.g. how homes are constructed) and livelihood systems that may involve direct or indirect contact with animals (e.g., whether or not people rely on subsistence or commercial hunting). Information about these factors can be used to develop targeted interventions to reduce risk.

As illustrated by the development of the human-animal exposure study, the expanded model can guide a more in-depth exploration of the human-animal interface. Information generated from such studies can be critical for identifying specific groups that are at high risk of spillover and assessing possible routes of transmission. For instance, in Lao PDR, where a human-animal exposure study informed by the expanded model was implemented with different groups living in the same general location, the unexpected finding that children were more exposed than adults to some animals suggests that children might warrant a special look if there is a concern about transmission of viruses from bats and rats. On the other hand, if the concern is about viruses from nonhuman primates, a focus on Hmong men might be very important.

In-depth study of the human-animal interface at the local level not only provides information about specific groups at risk of transmission, but also highlights the activities that put them at risk. For instance, in the communities described in this paper, hunting and ingestion of key animals previously implicated in outbreaks (rodents, bats and nonhuman primates) is common: men and boys hunt, and different sub-groups of the communities eat these animals, albeit at different rates. In addition, raising animals such as chickens and pigs, which are known to be intermediary hosts, is a universal activity. Depending on the specific animal, virus or route of transmission, interventions might be able to target specific groups involved in different activities. For example, since men and boys are the groups most involved in hunting, they could be the specific focus of general programs to promote safer hunting practices, but if exposure to rats/mice were a particular concern, the intervention would need to include women and girls as well. General interventions addressing butchering and preparation of animals should involve all age/gender groups.

The proposed expanded One Health model aims to focus attention on the local level factors that determine probability of disease emergence in conjunction with large-scale drivers. By understanding the complex interactions of these factors, the added value of the expanded model is that community or individual level behavior change interventions can be designed to complement policy-level strategies.

The human-animal exposure study described in this paper does not attempt to explore the entirety of the complex social dynamics that can determine the location, time and intensity of exposure. As a first step, we focused on demonstrating that the most basic socially determined factors affect exposure, and did not consider how community and family dynamics or governance and politics at the national and international levels play a role. Different types of studies would be needed to address and/or incorporate those factors.

We hope that the current study provides a solid start to the conversation about the need to embed social science approaches in explorations of human and animal health and opens the door to further in-depth studies exploring how social dynamics affect risk of spillover. Other groups are encouraged to use the model as a basis for developing studies to explore the complex interaction of various social and environmental factors that result in disease emergence. Some of the questions to be explored might include: how does urbanization and exposure to "international" norms affect attitudes and patterns of consumption of different types of wildlife meat? What effects do various approaches to community-based natural resource management in different types of communities have on the frequency and type of interaction with domestic and wild animals? How do national policies regarding universal primary education and their implementation at the local level affect community and family expectations, their socialization of children and different family members' relation with domestic and wild animals?

Answering these questions will involve different types of methods. A cross-sectional survey of a large group of individuals such as reported here is appropriate for capturing an overall snapshot of the human-animal interface, including all the animal species people could come interact with as well as all the major activities and locations associated with interactions. Other approaches would be optimal for more focused studies targeting a specific group of animals (e.g. primates) or specific activities (e.g. hunting). For instance, exposure could be documented by intense observation of individuals over long periods of time or by asking people to keep diaries of specific activities such as hunting or eating. More in-depth qualitative or ethnographic studies can help tease out the social and cultural influences shaping specific types of interactions with animals. It is important, however, to remember that all these methods bring their own set of methodological and ethical challenges that would need to be carefully considered, similar to the process described in this paper for the cross-sectional study.

Finally, it is important to note that the expanded One Health model does not address the factors that determine whether or not a spillover evolves into a full-scale outbreak – a critical topic worthy of immediate attention.

Acknowledgment

We thank Zo Rambeloson and Kanokwan Suwannarong who implemented the research; they and Sidney Schuler, Lonna Shafritz, Renata Seidel, David Sisanath, Mario Chen and Tim Mastro provided helpful comments. We also express sincere appreciation the Social Science and Medicine anonymous reviewers for their thoughtful suggestions. Support for this study was provided by FHI360 with funds from USAID Cooperative Agreement GHN-A-00-09-00002-00; this study was made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of the authors and do not necessarily reflect the views of FHI 360, USAID or the United States Government. The funder had no involvement in study design, collection, analysis, interpretation of data, writing or in the decision to submit it for publication.

References

Alexander, D.J., Brown, I.H., 2000. Recent zoonoses caused by influenza A viruses. Rev. Sci. Tech. 19 (1), 197–225.

Alexander, K.A., McNutt, J.W., 2010. Human behavior influences infectious disease emergence at the human–animal interface. Front. Ecol. Environ. 8 (10), 522–526. http://dx.doi.org/10.1890/090057.
Bernard, H.R., 2011. Research Methods in Anthropology. AltaMira Press.
Bonner, P.C., Schmidt, W.P., Belmain, S.R., Oshin, B., Baglole, D., Borchert, M., 2007. Poor housing quality increases risk of rodent infestation and Lassa fever in refugee camps of Sierra Leone. Am. J. Trop. Med. Hyg. 77 (1), 169–175.
Bradley, C.A., Altizer, S., 2007. Urbanization and the ecology of wildlife diseases. Trends Ecol. Evol. 22 (2), 95–102. http://dx.doi.org/10.1016/j.tree.2006.11.001.
Brashares, J.S., Golden, C.D., Weinbaum, K.Z., Barrett, C.B., Okello, G.V., 2011. Economic and geographic drivers of wildlife consumption in rural Africa. Proc. Natl. Acad. Sci. 108 (34), 13931–13936. http://dx.doi.org/10.1073/pnas.1011526108.
CDC, 2014. MMWR Morb Mortal Wkly Rep (2014/10/03 ed.. Ebola Virus Disease Outbreak – West Africa, September 2014, vol. 63, pp. 865–866.
Chambers, R., 1994. The origins and practice of participatory rural appraisal. World Dev. 22 (7), 953–969. http://dx.doi.org/10.1016/0305-750X(94)90141-4.
Chomel, B.B., Belotto, A., Meslin, F.X., 2007. Wildlife, exotic pets, and emerging zoonoses. Emerg. Infect. Dis. 13 (1), 6–11. http://dx.doi.org/10.3201/eid1301.060480.
Chua, K.B., 2003. Nipah virus outbreak in Malaysia. J. Clin. Virol. 26 (3), 265–275.
Chua, K.B., Chua, B.H., Wang, C.W., 2002. Anthropogenic deforestation, El Nino and the emergence of Nipah virus in Malaysia. Malays J. Pathol. 24 (1), 15–21.
Cunha, C.B., Opal, S.M., 2014. Middle East respiratory syndrome (MERS): a new zoonotic viral pneumonia. Virulence 5 (6), 650–654. http://dx.doi.org/10.4161/viru.32077.
Daszak, P., Cunningham, A.A., Hyatt, A.D., 2000. Emerging infectious diseases of wildlife–threats to biodiversity and human health. Science 287 (5452), 443–449.
de Merode, E., Smith, K.H., Homewood, K., Pettifor, R., Rowcliffe, M., Cowlishaw, G., 2007. The impact of armed conflict on protected-area efficacy in Central Africa. Biol. Lett. 3 (3), 299–301. http://dx.doi.org/10.1098/rsbl.2007.0010.
Dobson, A.P., 2005. Virology. What links bats to emerging infectious diseases? Science 310 (5748), 628–629. http://dx.doi.org/10.1126/science.1120872.
Dobson, A., Foufopoulos, J., 2001. Emerging infectious pathogens of wildlife. Philos. Trans. R. Soc. Lond B Biol. Sci. 356 (1411), 1001–1012. http://dx.doi.org/10.1098/rstb.2001.0900.
FAO, APHCA, 2002. Manual on the Diagnosis of Nipah Virus Infection in Animals.
FAO, UNICEF, UNSIC, WB, WHO, OIE, 2008. Contributing to One World, One Health: Strategic Framework for Reducing Risks of Infectious Diseases at the Animal-human-ecosystems Interface (Sharm el-Sheikh, Egypt).
Fauna, Flora, 2013. Batwa cultural values in Bwindi Impenetrable and Mgahinga Gorilla national Parks. Uganda 51.
Frank, D., 2008. One world, one health, one medicine. Can. Vet. J. 49 (11), 1063–1065.
Gurven, M., von Rueden, C., 2006. Hunting, social status and biological fitness. Soc. Biol. 53 (1–2), 81–99.
Hubalek, Z., Halouzka, J., 1999. West Nile fever–a reemerging mosquito-borne viral disease in Europe. Emerg. Infect. Dis. 5 (5), 643–650. http://dx.doi.org/10.3201/eid0505.990505.
Karesh, W.B., Dobson, A., Lloyd-Smith, J.O., Lubroth, J., Dixon, M.A., Bennett, M., Heymann, D.L., 2012. Ecology of zoonoses: natural and unnatural histories. Lancet 380 (9857), 1936–1945. http://dx.doi.org/10.1016/s0140-6736(12)61678-x.
Keele, B.F., Van Heuverswyn, F., Li, Y., Bailes, E., Takehisa, J., Santiago, M.L., Hahn, B.H., 2006. Chimpanzee reservoirs of pandemic and nonpandemic HIV-1. Science 313 (5786), 523–526. http://dx.doi.org/10.1126/science.1126531.
Keesing, F., Belden, L.K., Daszak, P., Dobson, A., Harvell, C.D., Holt, R.D., Ostfeld, R.S., 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. Nature 468 (7324), 647–652. http://dx.doi.org/10.1038/nature09575.
Kerkhove, Van, Mumford, M.D.E., Mounts, A.W., Bresee, J., Ly, S., Bridges, C.B., Otte, J., 2011. Highly pathogenic avian influenza (H5N1): pathways of exposure at the animal-human interface, a systematic review. PLoS One 6 (1), e14582. http://dx.doi.org/10.1371/journal.pone.0014582.
Kuzmin, I.V., Turmelle, A.S., Agwanda, B., Markotter, W., Niezgoda, M., Breiman, R.F., Rupprecht, C.E., 2011. Commerson's leaf-nosed bat (Hipposideros commersoni) is the likely reservoir of Shimoni bat virus. Vector Borne Zoonotic Dis. 11 (11), 1465–1470. http://dx.doi.org/10.1089/vbz.2011.0663.
Lahm, S.A., Kombila, M., Swanepoel, R., Barnes, R.F., 2007. Morbidity and mortality of wild animals in relation to outbreaks of Ebola haemorrhagic fever in Gabon, 1994–2003. Trans. R. Soc. Trop. Med. Hyg. 101 (1), 64–78. http://dx.doi.org/10.1016/j.trstmh.2006.07.002.
Masi, E., Pino, F., Santos, M., Genehr, L., Albuquerque, J., Bancher, A., Alves, J., 2010. Socioeconomic and environmental risk factors for urban rodent infestation in Sao Paulo, Brazil. J. Pest Sci. 83 (3), 231–241. http://dx.doi.org/10.1007/s10340-010-0290-9.
Meerburg, B.G., Singleton, G.R., Kijlstra, A., 2009. Rodent-borne diseases and their risks for public health. Crit. Rev. Microbiol. 35 (3), 221–270. http://dx.doi.org/10.1080/10408410902989837.
Meyer-Rochow, V.B., 2009. Food taboos: their origins and purposes. J. Ethnobiol. Ethnomedicine 5 (18).
Morse, S.S., Mazet, J.A., Woolhouse, M., Parrish, C.R., Carroll, D., Karesh, W.B., Daszak, P., 2012. Prediction and prevention of the next pandemic zoonosis. Lancet 380 (9857), 1956–1965. http://dx.doi.org/10.1016/s0140-6736(12)61684-5.
Mounts, A.W., Kwong, H., Izurieta, H.S., Ho, Y., Au, T., Lee, M., Fukuda, K., 1999. Case-control study of risk factors for avian influenza A (H5N1) disease, Hong Kong, 1997. J. Infect. Dis. 180 (2), 505–508. http://dx.doi.org/10.1086/314903.
Patz, J.A., Daszak, P., Tabor, G.M., Aguirre, A.A., Pearl, M., Epstein, J., Bradley, D.J., 2004. Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence. Environ. Health Perspect. 112 (10), 1092–1098.
PHAC, 2009. One World One Health: From Ideas to Action. Report of the Expert Consultation. Manitoba, Canda, Winnipeg.
Promkerd, P., Khoprasert, Y., Virathavone, P., Thoummabouth, M., Sirisak, O., Jakel, T., 2008. Factors explaining the abundance of rodents in the city of Luang Prabang, Lao PDR, as revealed by field and household surveys. Integr. Zool. 3 (1), 11–20. http://dx.doi.org/10.1111/j.1749-4877.2008.00069.x.
Riekert, K.A., Ockene, J.K., Shumaker, S.A., 2008. In: The Handbook of Health Behavior Change, third ed. Springer Publishing Company.
Slingenbergh, J.I., Gilbert, M., de Balogh, Wint, K.I.W., 2004. Ecological sources of zoonotic diseases. Rev. Sci. Tech. 23 (2), 467–484.
Smolinski, M.S., Hamburg, M.A., Lederberg, J., Century, C.E.M.T.H., 2003. Microbial Threats to Health: Emergence, Detection, and Response. National Academies Press.
Taylor, L.H., Latham, S.M., Woolhouse, M.E., 2001. Risk factors for human disease emergence. Philos. Trans. R. Soc. Lond B Biol. Sci. 356 (1411), 983–989. http://dx.doi.org/10.1098/rstb.2001.0888.
WCS. One World, One Health™. Retrieved from October 05, 2013 http://www.wcs.org/conservation-challenges/wildlife-health/wildlife-humans-and-livestock/one-world-one-health.aspx.
Whitehead, H., 2000. Food Rules: Hunting, Sharing, and Tabooing Game in Papua New Guinea. University of Michigan Press.
WHO, 2012. H5N1 Avian Influenza: Timeline of Major Events. Retrieved from October 5, 2013. http://www.who.int/influenza/H5N1_avian_influenza_update_20121217b.pdf.
Wiehagen, T., Caito, N.M., Thompson, V.S., Casey, C.M., Weaver, N.L., Jupka, K., Kreuter, M.W., 2007. Applying projective techniques to formative research in health communication development. Health Promot Pract. 8 (2), 164–172. http://dx.doi.org/10.1177/1524839906289818.
Willis, G.B., 2005. Cognitive Interviewing: A Tool for Improving Questionnaire Design. SAGE Publications.
Woods, C.W., Karpati, A.M., Grein, T., McCarthy, N., Gaturuku, P., Muchiri, E., Peters, C.J., 2002. An outbreak of rift valley fever in Northeastern Kenya, 1997–98. Emerg. Infect. Dis. 8 (2), 138–144. http://dx.doi.org/10.3201/eid0802.010023.