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CHAPTER FOUR

Social Influence in Liver Fluke Transmission: Application of Social Network Analysis of Food Sharing in Thai Isaan Culture

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Abstract

In northeastern Thai (Isaan) culture traditional raw fish dishes and raw fish-eating habits are common. Eating and sharing meals together among the community's members, especially relatives and neighbours, are a common practice in both daily life and social gathering events. Fish are a significant protein source and are associated with variety of traditional recipes. Cyprinid fish are one of the most preferred fish by Isaan villagers for daily consumption because they are accessible and affordable. Consumption of these fish probably causes the persistence of high endemicity of human liver fluke infection, particularly with *Opisthorchis viverrini*, in northeast Thailand. Because the consumption of raw cyprinid fish is a well-documented risk factor for liver fluke infection, sharing of risky raw fish dishes may influence disease transmission through a community. Social network analysis was used to investigate fish and fish-based meal sharing among household members in Isaan villages in liver fluke endemic areas. The findings from three studies confirmed the persistence of traditional Isaan raw fish consumption and food-sharing practice. Social connections via food sharing among villagers played an important role in liver fluke infection and transmission dynamics as a risk factor. Thus these sociocultural factors should be taken into account in designing strategies for control of opisthorchiasis and other food-borne illnesses at the community level.

1. INTRODUCTION

Human liver flukes are food-borne trematodes that remain a significant public health problem in various parts of Southeast Asia, especially in the Lower Mekong Basin (Sripa et al., 2010; Sithithaworn et al., 2012). Liver fluke infection is acquired by eating raw fish, a behaviour related to traditional fish recipes. In northeast Thailand (Isaan) where *Opisthorchis viverrini* is endemic, intensive and continuous liver fluke control programs have been carried out as public health service activities. These strategies have coincided with lifestyle transitions that changes the communities from traditional agricultural life to modern urban industrial life, which potentially resulted in a decrease of liver fluke prevalence (Jongsuksuntigul and Imsomboon, 2003). However, prevalence data still indicate high *O. viverrini* infection rates of up to 50% in certain Isaan provinces, where infection has tended to persist in highly endemic areas (Sithithaworn et al., 2012).

This may be caused by failure to inspire communities to long-term change, or it may be due to the fact that control strategies did not take into account the various effects of social and ecological factors on OV transmission dynamics. Effective and sustainable *O. viverrini* control needs integrative, multisectoral and multidisciplinary approaches to overcome these obstacles (Sripa et al., 2015). Focussing on social determinants, including local culture, beliefs and behaviour, the *Lawa model* indicated that local culture can determine behaviours associated with fishing, food preparation and the consumption of undercooked fish. All these practices are deeply rooted as part of the native rice-fish culture in the region (Sripa et al., 2015). Social network analysis (SNA) is an approach based on the relationships between *nodes* and *ties* which describe interactions between individuals within a group, improving our understanding of the behaviour of a group (Martínez-López et al., 2009). Networks diagrams are regularly represented as nodes and links between these nodes. This technique can be used for mapping the distribution of freshwater fish within a community and characterizing the pattern of food sharing, particularly of traditional fish dishes, among villagers in an endemic area of human opisthorchiasis.

2. SOCIOCULTURAL FACTORS RELATED TO HEALTH

Perception of the world by particular people is deeply influenced by sociocultural factors, including the beliefs, customs and practices within cultures and societies that affect the thoughts, feelings and behaviours of its citizens (http://psychology.wikia.com/wiki/Sociocultural_factors). These sociocultural aspects include religious beliefs, culture, attitudes, role of the family, societal status and perception on various issues. Our understanding of these factors can be applied in different fields, such as psychology, design, marketing, business and the health professions.

Health is influenced by various factors, including genetics, human behaviour, the external environment, sociocultural factors and healthcare access. Sociocultural variables affect health at critical stages throughout the course of life, and there are multiple levels of exposure. These include socioeconomic status (SES), ethnicity, gender, poverty, social network, social support, the psychosocial work and social environments (Hernandez and Blazer, 2006).

2.1 Effect of Socioeconomic Status on Health

The association between health and SES is extensive in all societies which results in diverse health outcomes (Case et al., 2002). Educational attainment, income and occupational status have been used as SES indicators,

separately or combined. Education has been linked with health outcomes through disease morbidity, mortality, health behaviour and functional limitations, which does not necessarily imply causation (Hernandez and Blazer, 2006). Knowledge and skills acquisition have been hypothesized as causal pathways for better health outcomes, including health promotion, health literacy improvement, higher social status and prestige and employment prospects (Cutler and Lleras-Muney, 2006). The effect of income on health is complicated and difficult to measure because of its dynamic and mutual relationship. The causal pathway of income and health linkage suggests that health is strongly associated with level of household income, with lower income relating to worse health status (Case et al., 2002). On the other hand, there is evidence that health status is improved in higher income groups (Costello et al., 2003). Income certainly allows individuals to pay for necessary goods and services, allowing them to maintain their health status, and provides a psychological sense of control and mastery over their environment. Thus higher income is also related with healthier behaviour (Case and Paxson, 2002). Occupational status is the standard component of SES, which includes different levels of prestige, authority, power and resources. Illness is a crucial cause of downward occupational mobility. This means an association between occupational status and health can partly reflect reverse causation (Hernandez and Blazer, 2006). Education, income and occupation can mutually influence and interplay with each other throughout the life course of individuals, determining health outcomes at multiple levels of social organization (Hernandez and Blazer, 2006).

2.2 Social Network, Social Support and Health

Social determinants of health are important in terms of the scope, power and quality of social connections. Steady linkages are necessary for both material resources, such as food and warmth, and nonmaterial resources, including love and security, that are significant for human development (Berkman et al., 2000). Social relationships are characterized by two particular variables: social network and social support. A social network is defined as a person-centred social ties Web that assesses social linkage structure including size, density, boundedness and homogeneity (Berkman et al., 2000). Social support refers to different types of assistance that people receive from social networks and can be identified as instrumental, emotional and informational support (Berkman et al., 2000). Social network or social support is bidirectional. These are associated with health that can have a positive or negative

influence concurrently. However, temperament and personality may be confounders that affect these relationships. The effects of social network and social support on health can be extended to the community level. The resources and other social contexts that are available for community members have been defined as social capital according to the community-level mechanisms such as informal social control, collective efficacy, collective socialization and social contagion (Kawachi et al., 2004). Therefore social capital and social cohesion are significant characteristics of the sociocultural environment that affects health outcomes in different ways from disease onset to progression and survival.

3. SOCIOCULTURAL INFLUENCES ON FOOD AND EATING BEHAVIOUR

3.1 Food as Social Function, Food Production and Distribution

Food is a crucial society element and plays important roles not only as a source of nutrition but also in daily life, beliefs and socioeconomics. Interpersonal relationships between community members and their sociocultural environments can be expressed and established by food (Ma, 2015). Various messages can be transmitted through different kinds of foods, indicating the relationship proximity among people (Fieldhouse, 1995). SES can be indicated by the consumption of rare and expensive food, as well as group characteristics indicated by families, races, religions, regions or countries (Ma, 2015). People celebrate important events or festivals by eating special food. However, different societies and cultures potentially influence particular food traditions (Fieldhouse, 1995).

Food cultivation, harvesting, production, serving, consumption and eating habits are culturally defined. Women in most societies play an important role in food production, selection, purchase and processing (Ma, 2015). Women usually act as cooks and food providers for their families, so engagement in food market trade and decision-making relating to the type, quantity and quality of available food are often their responsibility. Women are also responsible for food distribution within the family according to two modes: demand and contribution. The demand mode has been defined by food distribution based on the distinct physical demand for nutritional intake among family members. The contribution mode is indicated by the level of contribution to the family by each family member. Priority in food selection and having the largest amount and best part of food are reserved for the

members who earn more money. Gender and age also play different roles in food distribution and have an effect on the health of family members (Ma, 2015).

3.2 Food and Culture

Eating and sharing meals among the community's members are basic elements of a society, and no culture has been established without food sharing. Daily routine and ritual structure at both the formal and informal life stages is associated with food transfer. Food also creates a common vision for culinary culture sharing. The fundamental rule in food culture is identifying which food is edible. Biological and geographical conditions, as well as cultural norms, define the eating behaviour within a particular community. However, ideas and traditions regarding edible foodstuff differ between nations or social classes (Nordström et al., 2013). Food leads to mutual obligations among relatives and the community. Relationships are usually started by an offer of food sharing, with refusal of meal sharing resulting in the rejection of a social connection. Food presentation is relevant to the level of power of the sharer and is also associated with the conflicts between social classes, ethnic groups and nations (Nordström et al., 2013). Food can be used to show respect to an individual's social rank. It is a crucial part of the links between genders because, traditionally, females act as family food providers. Women may be excluded from public power but nevertheless imprint power, values and morals because of their role of cooking for their family.

3.3 Eating Behaviour and Social Influences

Sharing a meal with the family, friends and colleagues is a common activity. Through various means, other social group members affect particular persons through their food intake and selection (Oh et al., 2014; Xayaseng et al., 2013). Social context potentially influences eating behaviour because different people eat differently when they are with other people compared with when they are alone. In such situations food selection has the tendency to harmonize with close social connections in society because of behavioural adaptation and rewarding. Thus other people's behaviour, cultural expectations, sharing and environment set up suitable eating norms. Eating norms are certain codes of conduct or guidance for appropriate eating, including both food choice and the amount of food intake (Higgs, 2015). Based on social comparison, people who are perceived to be relevant to particular social group are more likely to follow an eating norm. During the process of eating, action synchronization, consumption monitoring and modified

food preferences are involved with norm matching (Higgs and Thomas, 2016). Different groups of people can be characterized by their eating patterns. These are embedded in their social relations and reflected in the fundamental political, economic and meaning system of their places (Delormier et al., 2009).

4. FOODS AND FOOD-CONSUMING BEHAVIOUR IN THAI ISAAN CULTURE

The Mekong River passes through six countries: China, Myanmar, the Lao PDR, Thailand, Cambodia and Vietnam. Thirty-seven percent of the land area of Thailand lies within the Lower Mekong Basin. The major subbasins in northeast Thailand are the Kok River Basin, the Chi River Basin, the Mun River Basin and the Ang Sakon Nakhon Basin (Na Mahasarakarm, 2007). Despite extensive dam building for water storage and irrigation purpose, much of this region is flooded annually, either from rainfall or floodwaters. Dams, water reservoirs and seasonal wetlands, especially rice fields, are created in vast areas which are the basis of much fishery production. Fisheries are important particularly to the rural people who live in the basin and rely on fish as a crucial part of their daily diet (Na Mahasarakarm, 2007).

Isaan is located on the Khorat Plateau, bordered by the Mekong River to the north and east and by Cambodia to the south. To the west it is separated from Northern and Central Thailand by the Phetchabun mountain range. In Isaan rice paddy fields comprise 95% of the land classified as 'wetlands'. The other significant wetland habitats are lakes and ponds (natural or artificial) and swamps (including backswamps, grasslands and marshes) (Na Mahasarakarm, 2007). Swamps are known for their high fish productivity. Fish species composition varies between water bodies, but the major species belong to the carp family, Cyprinidae, and include *Cirrhinus jullieni*, *Barbodes gonionotus*, *Puntioplites proctozysron*, *Micronema* sp., *Channa striata*, *Hemibagrus nemurus*, *Oxyeleotris marmorata* and *Clupeichthys aesarnensis* (Sayasone et al., 2007; Vonghachack et al., 2017). Besides the various fish species, other aquatic animals such as frogs, small shrimps, crabs, tadpoles, clams and snails also make an important contribution to the wild-caught freshwater diet of the Isaan population (Na Mahasarakarm, 2007). This is consistent with the Lawa Lake study in the Chi River Basin which showed that three species of Cyprinidae are the most abundant fish caught and consumed (Kim et al., 2017). Cyprinid fishes are mostly preferred by

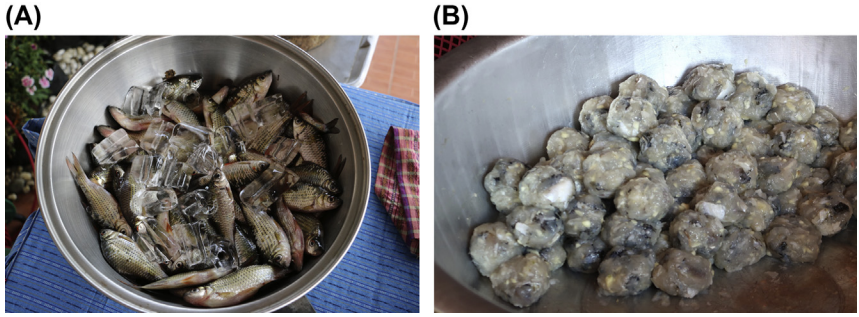

Figure 1 Cyprinid fish (A) and *Pla-som* (B) from Lawa Lake area, Khon Kaen Province.

Isaan villagers for daily consumption because they are easy to catch or locally sold at an affordable price. If caught, they can then be distributed for free to family and neighbours (Kim et al., 2017).

Fish and fermented fish products (Fig. 1) are crucial for Southeast Asian diets as the major protein source in most meals (Mutsuyama, 2003). Many rural Southeast Asians raise fish in ponds near their homes and rice fields. Since ancient times, rice and fish have been the staple diet for the people in this region. Fishing is commonly practiced in most rural communities, particularly those located near water bodies. Fishing skills are traditionally handed down from parents to children, generation after generation, so that this local knowledge and expertise remain alive. Fishing was formerly restricted to providing food for fishermen and their family members. Any excess amount was turned into processed products such as dried or fermented fish for household consumption and sharing with relatives or friends. In addition, fish and fish products were sometimes used as commodities to barter for other goods (Mutsuyama, 2003).

Isaan foods and eating practices have shifted from traditional to more modern lifestyles. However, traditional consumption of raw fish continues despite the improvements in eating habits and health education programs (Grundy-Warr et al., 2012). In addition, there remains persistence of incorrect beliefs that adding lime and/or drinking alcohol when eating raw fish will reduce risk of food-borne parasitic infection (Kim et al., 2017; Xayaseng et al., 2013). Isaan iconic raw fish dishes are the expressions of their culture: *Koi-pla* is a spicy minced fish salad, eaten soon after preparation; *Pla-som* is moderately fermented and can be stored for a few days to weeks and *Pla-ra* is an extensively fermented, highly salted fish dish that can be stored for at least 2–3 months (Kaewpitoon et al., 2008). Traditional Isaan dishes prepared from freshwater cyprinoid fish, such as *Koi-pla* and *Pla-som*, are the

usual sources of liver fluke infection in northeastern Thailand and Lao PDR (Sripa et al., 2011; Sithithaworn et al., 2012). One of the difficulties relating to disease prevention and control is to dissuade risk populations from eating raw or fermented fish and encourage them to properly cook this food to kill the parasites (Sithithaworn and Haswell-Elkins, 2003; Andrews et al., 2008; Sripa and Pairojkul, 2014; Shin et al., 2010; Sriraj et al., 2016). Today the consumption of raw fish dishes is discouraged as villagers and public health officials consider them unhealthy (Sithithaworn et al., 2012; Kim et al., 2017).

5. LIVER FLUKE INFECTION IS A FOOD-BORNE DISEASE

Liver flukes causing fish-borne zoonotic trematodiasis cause major public health problems worldwide. The number of people currently infected with liver flukes (family Opisthorchiidae) exceeds 18 million (Chai et al., 2009), but it is estimated that more than half a billion are at risk of infection (Lima dos Santos and Howgate, 2011). Humans contract liver fluke infection by the consumption of raw or undercooked infected fish (World Health Organization, 1995). Lima dos Santos and Howgate (2011) indicated that these food-borne parasitic zoonoses have increased significantly for various reasons: (1) the development of new and improved diagnosis, (2) increased raw fish consumption in traditional dishes, (3) increased consumption of regional fish dishes such as sushi, sashimi, ceviche and carpaccio based on raw or minimally processed fish, (4) the growth of international trade in fish and fish products and (5) the striking development of aquaculture, particularly in Asia (SEAFDEC, 2017).

O. viverrini is endemic in Thailand, Lao PDR, Cambodia and the southern parts of Vietnam, with an estimated 10 million plus people in this region being at risk of infection (World Health Organization, 1995; Sripa et al., 2010; Sithithaworn et al., 2012). *O. viverrini*, which is of great medical importance, is highly endemic in Thailand. Infection with this liver fluke is particularly widespread in the north and northeastern regions of this country (Sripa et al., 2003; Kaewpitoon et al., 2008), where an estimated six million people are infected (Jongsuksuntigul and Imsomboon, 2003; Sripa et al., 2003). One reason for the persistent high infection rates in this region is likely its cultural and ecological identity, where rice cultivation and a strongly embedded raw fish consumption culture are present (Grundy-Warr et al., 2012) and create ideal conditions for sustained

transmission (Sripa et al., 2007; Sripa et al., 2011, 2015). The transmission of liver fluke is associated with behavioural patterns that are determined by sociocultural and economic conditions. Raw fish consumption usually occurs among inhabitants living around lakes, streams and ponds (Hung et al., 2013). Food safety education may be the most appropriate strategy to control the spread of the disease due to its inherent link to human behaviour (Ziegler et al., 2011). However, changing eating habits is challenging because these are deeply rooted in cultures.

6. SOCIAL NETWORK ANALYSIS

6.1 History of Social Network Analysis

Social network was mentioned in 1932 to describe an epidemic of runaways at the Hudson School for Girls (Moreno, 1934). The reason for the increasing number of runaways was more dependent on the social position of the individuals affected in their social network than on their individual personalities and motivations. Sociometric techniques were used to elicit and graphically present the individual's feelings such as 'like' or 'dislike' of the other individuals. In the 1940s and 1950s the concept of social networks was developed in two ways. First, matrix algebra and graph theory were used for discovering emergent groups in network data to formalize basic social–psychological concepts. Second, laboratory experimentation of networks programs was developed (Borgatti et al., 2009). The effects of different communication network structures on the speed and accuracy of problem-solving were studied by researchers from Massachusetts Institute of Technology (MIT) (Borgatti et al., 2009). They found that a more centralized network structure outperformed decentralized structures (Leavitt, 1951). In human networks, information tends to be conveyed from peripheral members to the most central nodes, so those systems with the shortest distance between all nodes from the distinct integrator nodes performed fastest (Borgatti et al., 2009). In 1978 Pool and Kochen published the 'small world' concept that determined the chance that randomly selected pairs of people will know each other. Based on mathematical models half of the total number of pairs among USA population could be linked with not more than two mediators (Pool and Kochen, 1978). Concordance with this finding, the famous concept called *six degrees of separation* was developed by Milgram (1967). Network analysis was also used by sociologists to study the concrete relations between people, as well as to represent community

structure (Borgatti et al., 2009). Community network structure analysis has become an increasingly significant research tool in social sciences (Wellman et al., 1996). Social network application has been successfully used in anthropology to study patterns or networks of relationships, kinship and for the network-based explanation of a wide range of outcomes (Borgatti et al., 2009). According to strong or weak ties theory close contacts between persons form cluster(s) of strong ties which subsequently leads to the redundancy of information sharing (Granovetter, 1973). Social capital theory was derived from this idea to determine whether these connections enable people to access resources leading them to a better situation. In the 1990s network analysis research increased in a number of fields, including physics and biology, and also to various applied fields such as management consulting, public health and crime/war fighting (Borgatti et al., 2009).

6.2 Social Network Terminology and Description

A network is a collection of units of interest which are generally called *nodes*, *vertices* and *actors* in physics, mathematics and social sciences, respectively. *Nodes* are members of the network representing distinct individuals or collective units. Attributes are the nodes' properties, qualities or characteristics that belong to them as an individual or group. Nodes are connected to each other through different types of relationship (Dubé et al., 2011). These links also called *ties*, *edges* or *arcs* and can be classified into four basics types of dyadic relations: similarities, social relation, interactions and flows (Borgatti et al., 2009). These ties can be informal or formal, and multiplexity occurs when actors have multiple ties with other nodes. *Edges* refer to reciprocal or undirected links, whereas *arcs* refer to the links that are unidirectional or directed (Wasserman and Faust, 1994). *Edges* and *arcs* describe the network representation as undirected or directed networks and are defined by binary or other values based on their relationships as characterized by the study considered. The total number of *nodes* determines the size of a network. SNA can be illustrated either in matrix format or as graphs. However, using the matrix format allows the execution and calculation of a range of measures that provide network descriptive statistics (Dubé et al., 2011).

Networks can be classified in four main types (Hawe et al., 2004) including the following:

6.2.1 *One-mode networks*: the connections among a single set of similar nodes, such as exchange of information among health volunteers in the village.

6.2.2 *Two-mode networks*: the connections among two different sets of nodes used to explore the relationship between nodes and a series of events. Ties exist distinctively only between nodes that are considered more responsible for tie creation than others such as the links between researchers and disciplines or specialities related to their field of research.

6.2.3 *Sociocentric or complete networks* are composed of the connected ties among single, bounded community members such as a network of medical doctors in a hospital.

6.2.4 *Egocentric or personal networks* are mentioned based on the focal node's perspective only. The ties directly connect the focal node (ego) with others (ego's alters) and also ego's views on the ties, if any, among the alters. For example, in the ego network of health-related information sharing among village members, the ego would be the health volunteers who are asked if the information is directly shared with other villagers. These alters are subsequently asked to identify the next nodes with whom the information is shared.

6.3 Measure of Centrality and Cohesiveness

Individual-level network data are collected, but these data can also be analyzed at the structural level. In general, network data are typically entered into a database by node similarity or distance matrix. Existence of ties is defined by '1', whereas no tie is defined by '0'. The ties can be labelled as valued data if ties' intensity is examined. The strong and weak ties represent the large number of connected nodes in a similarity matrix and the larger number of distances between nodes in a distance matrix, respectively. These data can be illustrated in graphs visualized and analyzed using a variety of special network analysis software packages (Hawe et al., 2004) , such as UCINET 6 (Analytic Technologies, Harvard), Pajek (http://vlado.fmf.uni-lj.si/pub/networks/pajek/default.htm) and StOCNET (version 1.4, ProGAMMA/ICS, Groningen).

6.3.1 Measure of Node-Level Centrality

To conduct SNA, one of the main objectives is to identify the important nodes or central nodes in the network. The nodes are then characterized using three measures: degree, betweenness and farness (Wasserman and Faust, 1994). The node degree shows the number of contacts per node, as well as the number of linked nodes in an undirected network. The degree value can be categorized into out-degree, which is the number of ties

that originate from each node, and in-degree, which is the number of ties that each node receives in a directed network (Wasserman and Faust, 1994). The node betweenness reveals the frequency of the shortest 'path' between pairs of nodes in the network, indicating their important role for linking a large number of pairs and fragmentation of the network. The node farness demonstrates topologically the distance from particular nodes to all other nodes in the network; it is the inverse of node closeness (Dubé et al., 2011).

6.3.2 Measure of Network-Level Cohesiveness

Network-level cohesiveness estimates the coherence level of the whole network. The measured parameters consist of network density, fragmentation, average path length and clustering coefficient (CC) (Dubé et al., 2011). The network density refers to the proportion of actual links out of all possible links, and the value can range from 0 to 1. Network fragmentation demonstrates the proportion of unreachable pairs or the pairs that the path does not link (ranges from 0 to 1). The network average path length represents the average shortest distance or number of steps among reachable pairs in the network. Social scientists apply this measure to explain the connected world leading to the *six degrees of separation* concept (Milgram, 1967). The network CC is a principal measure because of its application to network characterization such as small world. The CC is defined as the proportion of one's neighbours in the network who are also neighbours of one another (Watts and Strogatz, 1998). Characteristics of small-world networks include high CCs and short average path length with few numbers of topologically long-distant cluster links in the network (Dubé et al., 2011).

6.4 Social Network Analysis Reflects Disease Transmission Patterns

Social networks have been used as a map of direct contact that facilitates infectious disease transmission. Focussing on the person-to-person transmission perspective, individual-level risk is associated with relationships between society members (Newman, 2002). Social cohesion and organization resided in the networks influence on community-level risk of infection with infectious diseases (Pahl-Wostl et al., 2008). Social connectedness has long been considered as contact in disease transmission models (Klovdahl et al., 2001; Meyers et al., 2003; Bansal et al., 2010) and as a protective factor for chronic disease (House et al., 1988; Berkman and Glass, 2000; Cohen et al., 2007). The mechanisms of social organization and action for enhancement or inhibition of pathogen transmission via the

environment are necessary for understanding the role of the social network in infection risk (Zelner et al., 2012).

The crucial role of a complex network of transmission routes has been revealed in a variety of infectious disease outbreaks. Epidemiologists have studied the roles of social networks in disease spread over the last two decades (Riolo et al., 2001; Hawe et al., 2004; Trostle et al., 2008). SNA was applied for a number of epidemiological studies focused on risk potential networks and their social relationship to sexually transmitted infections (Doherthy et al., 2005) or for the transmission of human immunodeficiency virus (HIV) through a range of contacts in a network, including sexual contact and intravenous drug use infection (Klovdahl et al., 2001; Friedman et al., 2000; Rothenberg et al., 2001; Riolo et al., 2001). The contact network for the severe acute respiratory syndrome (SARS) outbreak has been mentioned because of the long distance travel that caused its local and later worldwide spread (Peiris et al., 2003). The foot-and-mouth disease outbreak in the UK, similar to SARS outbreak, was influenced by long-range movements, in this case of cattle, both nation-wide and then locally (Kao, 2002; Mansley et al., 2003). SNA can be used to conceptualize and demonstrate complex networks for these infections (Christley et al., 2005). Centrality measures have been used to determine the importance of each individual within a population according to the network criteria. These criteria include the number of contacts made by each individual, the number of steps from each individual to all others and the frequency that an individual presents a pathway among others (Wasserman and Faust, 1994). Centrality measures have already been applied to study HIV and syphilis infection in humans (Bell et al., 1999; Rothenberg et al., 2001) and *Mycobacterium bovis* infection in captive possums (Corner et al., 2003) to indicate the individuals who could be associated to the disease transmission. There are many network parameters associated with infectious disease risk. Network parameter specification will help identifying intervention targets, such as control measures and surveillance, and in developing mathematical models and simulations to predict disease transmission through the networks (Bell et al., 1999; Lloyd and May, 2001; Liljeros et al., 2001). Networks involving person-to-person contact could also demonstrate the enhanced transmission of several diseases, including influenza (Sattenspiel et al., 2000), and *Staphylococcus aureus* infection (Lowy and Miller, 2002). Moreover, SNA has also been used in the study of the distribution of obesity (Christakis and Fowler, 2007) and diarrhoeal disease transmission via food sharing (Bates et al., 2007; Trostle et al., 2008; Zelner et al., 2012).

7. APPLICATION OF SNA TO FOOD-SHARING BEHAVIOUR ASSOCIATED WITH LIVER FLUKE INFECTION IN THAI ISAAN CULTURE

Three community-based studies were conducted in Isaan region at the centre of Lower Mekong Basin to elucidate the association of raw fish meal practice and food-sharing habit with risk of *O. viverrini* infection and transmission. Stakeholder analysis was considered to confirm the key informants for community engagement and information gathering including the local authority officers, village headmen, health volunteers, fishermen, fishmongers and villagers. Multimethod approach that combined both qualitative and quantitative methods was used to collect all relevant information. Qualitative methods such as focus group discussion, in-depth interview and participatory epidemiology were used to investigate sociocultural basis on fish recipes, raw fish consumption and food-sharing behaviour of Isaan villagers. Quantitative methods including questionnaire survey, geographic information system (GIS) and SNA were used to characterize network that shares fish-based dishes as well as geographical distribution of freshwater fish and estimate risk of liver fluke infection associated with raw fish meals sharing among household members under village level.

7.1 Food-Consuming Behaviour in Endemic Area

Food-eating and food-sharing behaviours were determined among villagers living in an *O. viverrini* endemic area around Lawa Lake, Khon Kaen Province (Kim et al., 2017; Phimpraphai et al., 2017) and in Maha Sarakham Province (Saenna et al., 2017) where many kinds of cyprinoid fish are abundant. Fish, especially cyprinids, were the most important protein source and contributed significantly to the daily diet because of their palatability, availability and affordability. Most of the local villagers prepared food by themselves, and the favourite fish dishes for all household members were prepared by deep-frying, boiling and using fish-based chili sauces. The three most popular traditional raw fish dishes of Isaan cuisine are *Koi-pla*, *Pla-som* and *Pla-ra*. Gender is one of the important factors for *O. viverrini* infection, and the prevalence in males is higher than in females (Sriamporn et al., 2004). But, the effect of gender on raw fish consumption was masked by using the household as a unit of interest. The information from participatory epidemiology revealed that males had more opportunities for eating raw fish with drinking alcohol during social gatherings, but both genders ate raw fish dishes such as *Pla-som* on a daily basis, which is similar to the finding

of Grundy-Warr et al. (2012). Because many public health activities and campaigns to prevent consumption of raw fish have been introduced aimed at preventing *O. viverrini* infection, the villagers are likely to be aware of the risk of eating raw or undercooked fish dishes such as *Pla-som* and *Koi-pla*. Nevertheless, eating raw fish still remains common in particular groups of people because of the long-standing tradition of preparing raw fish dishes and the consumption culture in Isaan. In addition, spicy papaya salad (*Som-tam*) prepared with *Pla-ra* is still consumed regularly among people in the endemic areas.

Additional information was described by the participants from Lawa Lake study about the transition of traditional Isaan diet to be of more western style which had happened since last 10–15 years. Fast food or ready-to-eat meals such as instant noodles, bread, coffee and hotdog have easy access because of the better transportation, incomes and village-based convenience shops (Kim et al., 2017). These will have an impact on food consumption practices in Isaan region that is becoming modernized compared with the past year.

7.2 SNA on Fish and Food Sharing and Liver Fluke Infection in Lawa Lake, Khon Kaen and in Maha Sarakham

Wetland livelihoods of the local communities are associated with multiple and complex sociocultural and ecological factors related to liver fluke transmission and persistence (Friend, 2007). Wetland ecosystem produces and provides water, food and traditional medicines that are crucial for local livelihood practices. Various kinds of fish can be either caught naturally or cultivated in this rich ecosystem. Cyprinidae was the family of fishes found most abundantly which had been caught naturally. The preference for raw cyprinid fish consumption in Isaan and Lao PDR is underlined by these factors (Grundy-Warr et al., 2012; Xayaseng et al., 2013). In Khon Kaen Province *O. viverrini* prevalence levels range from 2% to 71% (Sripa et al., 2015).

Food sharing, especially of cyprinid fish and raw fish dishes, happens regularly during daily life, as well as at social events, among family members, relatives and neighbours. Grundy-Warr et al.(2012). Focussing on the application of SNA to our understanding of both fish distribution and fish-based meal sharing (Fig. 2) with respect to liver fluke infection in Thailand, two studies were carried out at the Lawa Lake region in Khon Kaen Province (Kim et al., 2017; Phimpraphai et al., 2017). Lawa Lake is a semiartificial reservoir and wetland ecosystem. It serves as an ideal habitat for *Bithynia*

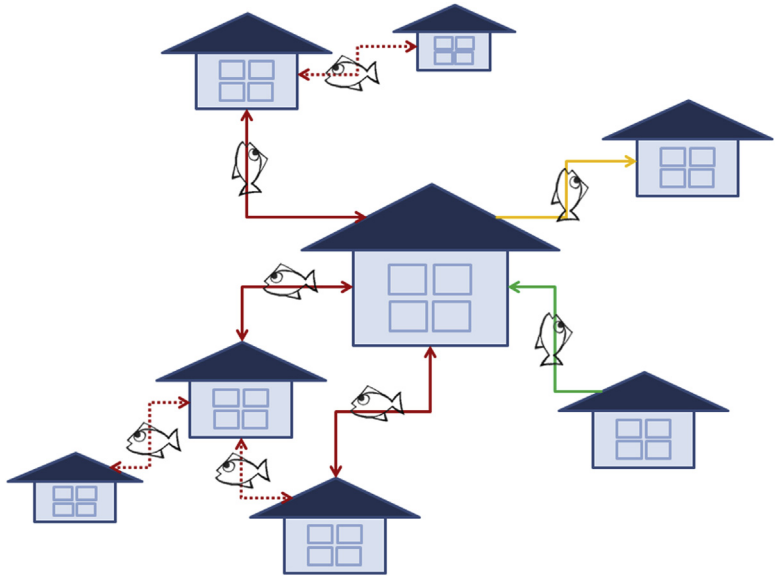

Figure 2 Social networks of freshwater fish sharing and fish-based dishes sharing among village households. Direction of food sharing indicated by *arrow* and *colours*, red: both sharing-in and sharing-out; yellow: sharing-out only; green: sharing-in only.

snails and cyprinid fish, the first and second intermediate hosts of *O. viverrini*, respectively. The area is known to be a highly endemic area for opisthorchiasis in humans (Sithithaworn and Haswell-Elkins, 2003; Sripa et al., 2011). Another study was carried out in Maha Sarakham Province located at the centre of the Lower Mekong Basin where the gathering, preparing and sharing practices of fish dishes are deeply rooted in the local culture (Saenna et al., 2017).

A multimethod study was carried out by Kim et al. in 2017 to explore the sociocultural determinants of raw fish consumption behaviour among Isaan people at Lawa Lake region. Distribution routes for potentially parasitized fish were studied using partial network analysis. In-depth interviews using SNA questionnaires, which highlighted in direction of catching and selling fish, were conducted with 46 fishing-related participants including fishermen, fish sellers/buyers, middlemen, *Pla-som* makers and fishmongers to define the fish distribution networks and movement of local fish from this *O. viverrini* endemic lake to every actor among market chains. The results revealed the fish distribution and logistics network and elucidated the key roles of middlemen, *Pla-som* makers and local vendors in terms of the important links for fish distribution between fishermen and consumers. According

to fishermen's opinion, larger fish are more economically attractive than smaller fish, so these kinds of fish are mostly transported away from local communities to town markets. Smaller fish, particularly cyprinid fish, remain in the local village for sharing and selling at a low price to fishermen's families and friends, which maintains the continuity of *O. viverrini* infection in these villages (Kim et al., 2017).

A second study was carried out in 2017 by Saenna et al. in Maha Sarakham Province, which is located 35 km southeast to Khon Kaen municipality. The area is a typical lowland floodplain along the Chi River. Ego network analysis was used to determine raw fish sharing in 2 of 12 rural villages. The selection criteria for these two villages are they have high *O. viverrini* prevalence (34.6% and 48%) and distinct spatial layout of the households. One village has a closely clustered pattern of households, but the other has a linearly pattern such that households disperse along the road. The researchers expected that different spatial arrangement of each particular village might result in dissimilar social interaction and food-sharing patterns. Questionnaires consisted of two phases; the first phase was designed for *O. viverrini* community-level intervention, and the second phase had a supplementary SNA questionnaire that exclusively focused on questions about fish dish sharing. Partial network analysis was carried out using nodes defined as households and ties defined as food-sharing relationships based on four types of raw fish dishes *Koi-pla*, *Pla-som*, *Pla-ra* and *Pla-jom*. Household locations were determined by a handheld global positioning system receiver (Garmin Ltd.; Olathe, KS, USA), and household maps were created using Quantum GIS, version 1.8.0 (http://www.qgis.org/en/site/). This information was then used to visually characterize the spatial pattern of households in each village. Statistical analysis of raw fish sharing and *O. viverrini* infection risk associated with exposure to raw fish dishes were performed using R statistical package, version 3.0.3 (R Core Team, 2013). Raw fish-sharing networks were constructed, and the degree of food sharing (DFS), which is defined as the number of the household members who share food together regardless of providing or receiving food, was measured using the igraph R package. These networks were complex and showed an apparent association between household food sharing and *O. viverrini* infection prevalence. Information from the network analysis demonstrated that a household's members who were positive for *O. viverrini* infection also tended to consume a greater variety of raw fish dishes. The direction of the ties showed that providers were household members who fished and prepared fish dishes, whereas the recipients were household members

who did not fish, mainly elderly or disabled individuals. A statistically significant association was showed between DFS and *O. viverrini* infection and other risk factors such as raw fish consumption and types of raw fish dishes. However, the result revealed the different networks that share raw fish dishes which illustrate more complexity or greater number of sharing in a clustered pattern village than in a linear pattern village. In addition, social determinants of raw fish dish sharing were observed. Three factors associated with these behaviours were expressed: enjoyment of raw fish dishes among relatives and friends, alcohol drinking and access to the fish used in raw fish dishes (Saenna et al., 2017).

A third study was conducted as a part of the Lawa Model established by the Tropical Disease Research Center of Khon Kaen University (Phimpraphai et al., 2017). The model is an integrated liver fluke control program using a transdisciplinary approach to address interventions for *O. viverrini* infection in the Lawa wetland (Sripa et al., 2015). Participatory epidemiology was used to explore food sources and food-eating habits among key informants, consisting of village leaders, fishermen, health volunteers and villagers. Related information, including livelihood, agricultural patterns, protein sources and fish recipes, on daily consumption and social gatherings was also collected (Fig. 3). Two villages with the lowest and highest *O. viverrini* infection (29.17% and 88.17%, respectively) at the household level were recruited to investigate food sharing among households. Ego network was applied in these two selected villages when food sharing occurred directly between the focal households (ego) and other households (alter) as well as the ego's perspective on food sharing among alters and other nodes. The ego nodes were defined as the households randomly selected from 10% of total households in each village including equal number of either positive or negative *O. viverrini* infection households. Alter nodes were all possible households who share food with egos and also with others. The links between egos and alters were indicated by their food-sharing or trading activities. The link direction was considered by the direction of sharing-in (in-degree) and sharing-out (out-degree). Questionnaire surveys including social network and attributes data, such as *O. viverrini* infection, fish sharing, food sharing, freshwater fish recipes and raw fish-eating behaviour, were conducted with all egos and their alters. The data included food-sharing events in the previous year, but data on raw fish-eating behaviour were from the previous 10 years as well as the previous year. The DFS and trading among households in each village's network was assessed. UCINET, version 6.530 (Borgatti et al., 2002)

Figure 3 Ranking of favourite traditional Isaan fish dishes for daily consumption. According to daily fish-based meals, *Pla-ra* is the most favourite fish dish, whereas the second to fifth ranks are given to cooked fish dishes including sundried and deep-fried fish, steamed fish, Isaan style fish soup and grilled fish, respectively. Traditional raw fish dish such as *Koi-pla*, *Pla-som* and *Pla-jom* were still preferred in small number of villagers.

was used to generate network diagrams and calculate network parameters. Different degree numbers between networks were also adjusted by normalized data.

In each village the results revealed that most of the inhabitants were rice farmers and freelance workers. Lawa Lake, where cyprinoid fish are abundant throughout the year, was their main food source, particularly during rainy season (September to November). Fish and eggs were the most important protein sources of the villagers because of their palatability, availability and affordability. Raw fish dishes such as *Pla-som* and *Koi-pla* were avoided, but spicy papaya salad with *Pla-ra* was still regularly consumed. Food sharing usually happened during particular social events and more regularly among peers and relatives (Phimpraphai et al., 2017).

Ego network analysis was conducted to explain all possible links of food sharing among the households between these two villages with different infection rates. To formulate an ego network, 179 out of 353 households were enrolled from these two villages. A graphical illustration of ego networks of food sharing between the two villages is shown in Fig. 4. A sparse pattern of small group sharing is found in the high infection village, whereas a larger and more connective pattern was present in the low infection village. Between these two villages, food sharing was similar in numbers

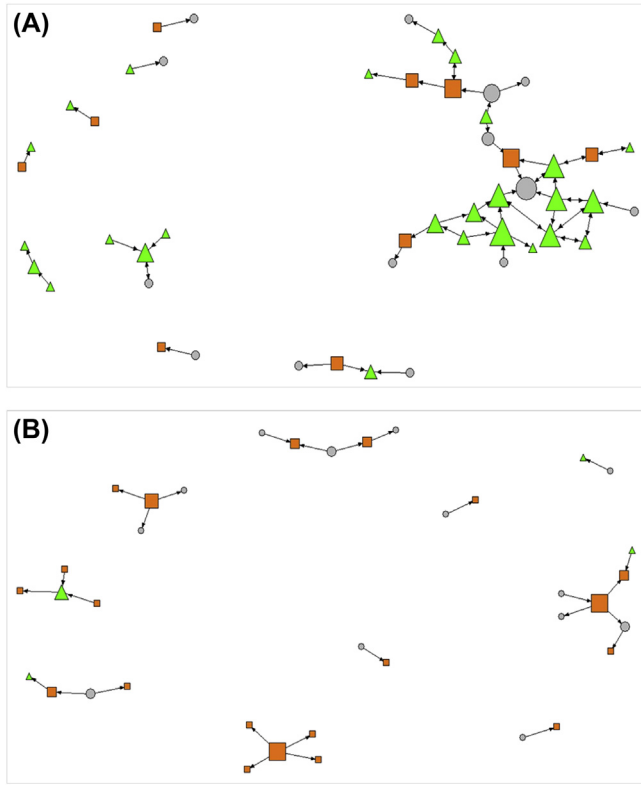

Figure 4 Ego network of food sharing among households of villages A (low OV infection, 4A) and B (high OV infection, 4B), nodes indicate by shapes "Square": Positive households "Triangle": negative households "Circle": households with no fecal examination results, and "Arrow": food sharing links between households.

of sharing-in but significantly different in the number of sharing-out. So, the numbers for giving or selling foods to other households in low infection village were higher than in the village with high infection. Attributing data, such as *O. viverrini* infection and eating raw fish experiences, were taken into account. The prevalence of eating raw fish was declined from last 10 years in both villages, and when simulated the network of food sharing with the history of raw fish eating, the pattern of sharing food was assumed stable. This study demonstrated the different range of relationships for sharing food between low and high *O. viverrini* infection villages which illustrated the influences of sociocultural relationships among people in particular communities for disease transmission (Phimpraphai et al., 2017).

8. PERSPECTIVES

Building effective *O. viverrini* prevention and control programs and integrated approach between multidiscipline and multisectors has to be considered. The 'bottom-up' policies that engage community collaboration and ownership are crucial for program sustainability. These three community-based studies revealed the effectiveness of local stakeholder's participation which is similar to the study by Sripa et al. (2015) which revealed that community public health volunteers are one of the best intermediaries for local information gathering and intervention actions. So, using participatory approach, key informants should be identified and initially participate in the process of questionnaire development to ensure the solid understanding of the study objectives and relevant implementations (Saenna et al., 2017).

The studies also confirmed how deep eating raw fish and sharing food had been embedded in Thai Isaan culture in which rice-fish culture and social connections remain in the villages. The transition from traditional Isaan food-eating practices to more westernized food consumption pattern was found to be according to the availability of modern convenient foods in the village markets or shops (Kim et al., 2017). Lawa Lake region has also become a peri-urban community with the mix of decreasing traditional Isaan cultural practices concurrently happened with the rapidly growing social, economic and ecological changes of modernizing Thailand (Sripa et al., 2015). The trends of eating raw fish had declined among villages located around Lawa Lake area because of the preference of the younger generations for modern western food and the successful of massive liver fluke control campaigns (Kim et al., 2017; Phimpraphai et al., 2017). However, raw fish consumption was still common and had not disappeared in particular groups of people, either men who preferred eating *Koi-pla* with drinking alcohol during social gathering events or elderly people who ate *Pla-som* on a daily meal (Kim et al., 2017). So, health education using community engagement strategies to gain shared issue understanding and collaborative action in intervention program design, implementation and evaluation should be valued for improved local problem analyses, change of community and sustainable health outcomes (Kim et al., 2017).

SNA was used to illustrate the network of fish distribution based on different definitions of nodes and links. Partial network analysis had been carried out among the fishermen, middlemen, fishmongers and *Pla-som* makers to explain the connection of each important actor along the local

freshwater fish market chain (Kim et al., 2017). To demonstrate the networks of eating raw fish and fish-based meal sharing among households, the partial networks were calculated by using GIS to compare two high *O. viverrini* prevalence villages with distinct landscape patterns (Saenna et al., 2017). Ego network was also used to explain the different number of food sharing and change of eating raw fish experience between two villages with high and low *O. viverrini* infection (Phimpraphai et al., 2017). So, network parameters, particularly degree (including in-degree and out-degree) that refers to number and direction of sharing, could be used to define the key actors of risky fish distribution and the raw fish dish sharing network and *O. viverrini* transmission pattern among households in Isaan villages. Study of food-sharing links is particularly valuable in households in the rural areas of Thailand where food sharing is related to several public health problems. SNA reflected food-sharing behaviour and demonstrated different food-sharing patterns. Greater connectivity of food sharing among household was associated with increasing number of types of raw fish consumed as well as the frequency of raw fish consumption (Saenna et al., 2017). However, the outcomes from SNA sometimes did not support the hypothesis that food sharing is the main sociocultural factor affecting the transmission of *O. viverrini* among households. So, the others factors such as duration of village settlement, family background, occupation and lifestyles which can affect the social network pattern have been considered. In addition, mapping of the network did provide evidence to support an effective and targeting control strategy. Target households or actors were emphasized by the number of connections between themselves and others, as well as their roles in raw fish-eating practices. These targets should be recruited as a part of community-based intervention that involves promoting properly cooked food or more thoroughly fermenting fish (Saenna et al., 2017). Identification of individuals with high vulnerability to infection could greatly enhance targeted surveillance and prevention programs. Individuals in strongly connected, socially cohesive communities are more likely to perceive economic and social interests as shared. Consequently they may be more motivated and better organized to pursue collective goals such as building and maintaining effective public health interventions. Social network approaches offer a way to apply analytical insights and computerized techniques to move the focus one step above the individual. These particular techniques can be used to demonstrate the flow of social support, social influence and infectious diseases through populations, as well as

among organizations. These considerations also emphasize that infectious disease prevention and control must go beyond biomedical sciences and also incorporate the social sciences, as well as associated disciplines. Integrative and participatory approaches have also been considered to encourage authentic stakeholder engagement in developing, implementing and evaluating interventions on liver fluke and other food-borne illness control in the Isaan region.

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