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Role of socio-cultural and economic factors in cyprinid fish distribution networks and consumption in Lawa Lake region, Northeast Thailand: Novel perspectives on *Opisthorchis viverrini* transmission dynamics

Christina Sunyoung Kim[a], **John F Smith**[a], **Apiporn Suwannatrai**[b], **Pierre Echaubard**[a], **Bruce Wilcox**[c], **Sasithorn Kaewkes**[b], **Paiboon Sithithaworn**[b], and **Banchob Sripa**[a]

[a]WHO Collaborating Centre for Research and Control of Opisthorchiasis, Tropical Disease Research Center, Department of Experimental Pathology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand [b]Department of Parasitology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand [c]Faculty of Public Health, Mahidol University, Nakhon Pathom, Thailand

Opisthorchis viverrini

(*Ov*) is a fish-borne parasite endemic in parts of Lao PDR, Cambodia, southern Vietnam and Northeast Thailand (*Isaan*) where an estimated 10 million people are infected. Human *Ov* infection, associated with hepatobiliary complications, including cholangiocarcinoma (CCA), occurs when infected fish are consumed raw or undercooked, a longstanding cultural tradition in the region. This mixed-methods descriptive study was carried out in *Isaan* villages around Lawa Lake, Khon Kaen Province, known for their *Ov* endemicity. Focus group discussions (FGDs) and in depth interviews (IDIs) were used to explore socio-cultural determinants underlying raw fish consumption practices, and global positioning system (GPS) devices to map local fish distribution networks.

Qualitative data affirmed major socio-cultural and dietary lifestyle transitions occurring consequent on recent decades of modernization policies and practices, but also the persistence of *Isaan* traditional raw-fish eating practices and incorrect beliefs about infection risk avoidance. Fish traders/middlemen purchase most of the catch at the lakeshore and play the dominant role in district market fish distribution networks, at least for the larger and less likely infected, fish species. The lower economic value of the small potentially-infected cyprinid fish means local fishermen typically distribute them free, or sell cheaply, to family and friends, effectively concentrating infection risk in already highly *Ov* infected villages.

Corresponding author: Banchob Sripa, Tropical Disease Research Laboratory, Department of Pathology, Faculty of Medicine, Khon Kaen University, Khon Kaen 40002, Thailand. Tel: 66-43-202024, Fax: 66-43-204359, banchob@kku.ac.th.

Competing interests

The authors declare there were no conflicts of interests.

Our study confirmed the persistence of traditional *Isaan* raw-fish meal practices, despite major ongoing socio-cultural lifestyle transitions and decades of *Ov* infection health education programs. We contend that diffuse socio-cultural drivers underpin this practice, including its role as a valued cultural identity marker. A "fish economics" factor was also evident in the concentration of more likely infected fish back into local villages due to their low economic value at district market level. The complexity of factors supporting "risky" fish-eating traditions in *Isaan* underscores the importance of integrated liver fluke infection control strategies to draw on transdisciplinary knowledge beyond biomedicine and also embrace participatory protocols for engaging communities in developing, implementing and evaluating interventions.

Keywords

Opisthorchis viverrini; Cyprinid fish; socio-economic; modernization; food culture; GPS tracking; GIS

1. Introduction

Opisthorchis viverrini (*Ov*) is a fish-borne trematode endemic in Thailand, Lao PDR, Cambodia and southern parts of Vietnam with at least 10 million people in this region estimated to be at risk of *Ov* infection (Sithithaworn et al., 2012; Sripa, Kaewkes, Intapan, Maleewong, & Brindley, 2010; World Health Organization, 2010). While most infections are asymptomatic, heavy chronic infections are associated with clinical hepatobiliary complications such as cholangitis, advanced periductal fibrosis, hepatomegaly and in some cases cholangiocarcinoma (CCA), a bile duct cancer associated with very poor prognosis (Bouvard et al., 2009; Sripa et al., 2011). Northeast Thailand (*Isaan*) and Laos have the highest human *Ov* infection rates within Southeast Asia (SEA), with hot spots of endemicity near water bodies within the Lower Mekong River Basin (LMRB). The persistence of high infection rates in the region, despite decades of public health interventions (Sripa et al., 2014) is likely due to its cultural and ecological particularities where rice cultivation and a strongly embedded raw-fish consumption culture (Grundy-Warr et al., 2012) create ideal conditions for sustained transmission (Sripa et al., 2011; Sripa et al., 2007).

The human *Ov* transmission cycle involves two intermediate hosts, *Bithynia* freshwater snails and cyprinid fish, and humans as well as cats and dogs as the definitive piscivorous mammalian host (Kaewkes, 2003; Wykoff, Harinasuta, Juttijudata, & Winn, 1965). Past public health interventions have targeted two transmission interfaces where parasitic stages and hosts encounter each other. First, in rural endemic areas the sustenance of parasite eggs input into the environment, by mostly human-infected hosts, is fostered by labor-related defecation practices where rice farmers and fishermen, spending most of their day time out in the fields, cannot reasonably afford the time to go back home or find latrines to defecate (Phongluxa et al., 2013). Interventions targeting defecation practices have used education, improved sanitation and hygiene to reduce infection (Jongsuksuntigul & Imsomboon, 2003). However, the complexity of the problem, and its only partially addressed underlying behavioral nature, has prevented sustainable transmission interuption at this interface. Defecation by domestic cats and dogs adds to this complexity, after being fed fish waste or

scavenging household food waste. Intervention would need to incorporate education to reduce feeding of discarded fish to animals along with improved household waste management systems overall. Secondly, the human-fish interface is even more complex due to the dietary significance of fish in local diets; livelihood connection with the ecosystem; relatively high localized dependence on fisheries; and cultural food practices based on a variety of raw and fermented fish dishes (Grundy-Warr et al., 2012). *Isaan* people have long-established traditions of consuming raw fish dishes made from small cyprinids that can harbor *Ov* metacercariae, such as *koi-pla* (raw minced fish with Thai herbs); *pla-som* (raw fermented fish); and *pla-ra* (raw fermented fish paste) (Prasongwatana, Laummaunwai, Boonmars, & Pinlaor, 2013). Cyprinids are a dominant fish family in the LMRB area and more generally in SEA (Winfield & Nelson, 1991) and contribute greatly (economically and nutritionally) to the local communities through: income generation from the sale of fish (Shoemaker, Baird, & Baird, 2001); and as a source of cheap protein (Hortle, 2007). However, there is little data, on the diversity, abundance, economic and consumption yield of small cyprinids outside of the major water bodies. This is an important issue because smaller wetlands and reservoirs serve as major sources of occupational fishing for many rural people in LMRB, particularly in *Isaan*, where *Ov* infection rates are still high and transmission is still occurring (Hortle, 2007; Jongsuksuntigul & Imsomboon, 2003; Sripa et al., 2014; World Wildlife Fund, 2013).

Multiple complex socio-cultural and ecological factors associated with the “wetland livelihoods” of the local communities (Friend, 2007) underline the apparent preference for raw cyprinid fish consumption in *Isaan* and Laos; inadvertently contributing to sustaining high *Ov* infection rates in the region and to the complex geographic mosaic of *Ov* infection distribution (Grundy-Warr et al., 2012). For example, in Khon Kaen Province, infection levels range from 2% to 71% (Sripa et al., 2014). This complexity and lack of appreciation of this complexity have resulted in relatively limited successes in altering traditional dietary habits as a mean to interrupt transmission. This situation is further complicated by ongoing and possibly accelerating socio-economic development and a transition from subsistence to cash economy with risk pattern changes (Smith & Ezzati, 2005) and their associated health problems (Akrasanee, Dapice, & Flatters, 1991; World Bank, 2012). *Isaan*, still the poorest region in Thailand (Baker & Pongphaichit, 2014), is still in transition with the most rural villages characterized as peri-urban environments. And is now facing both traditional parasitic infectious diseases of rural communities and increasing rates of “modern” chronic diseases of urban dwellers (Smith & Ezzati, 2005). Raw fish consumption behavior is a remnant of traditional *Isaan* practices (Grundy-Warr et al., 2012) and a disappearing landmark possibly associated with a disrupted sense of cultural coherence/identity (Antonovsky, 1979). Although a risky behavior (i.e. from a biomedical perspective), raw fish consumption is associated with cultural identity and social capital (Bourdieu, 1986) contributing to communities’ cohesiveness as well as individual resilience and psycho-social health (Engel, 1977) for example, *Isaan* communities have long-standing beliefs that eating raw fish demonstrates manhood and strength (Sri-Aroon et al., 2005).

The above complex social-cultural factors are subtle and relatively diffuse and much less quantifiable than infection prevalence and associated physiological risks. Thailand’s national public health education campaigns have largely sought to eliminate foodborne parasitic

infection through demonizing the parasite and raw-fish-eating practices, due to their association with opisthorchiasis and CCA (Boonjaraspinyo et al., 2013; Jongsuksuntigul & Imsomboon, 2003; Sriamporn et al., 2004). The relative neglect of complex socio-cultural factors as drivers for raw-fish-eating practices, and simplistic uni-linear focus on raw-fish-eating in risk prevention programs, may be a significant contributor to the limited success of previous public health interventions. More integrated and participatory (i.e. transdisciplinary) research on macro and micro level social-ecological systems; and geographical variations in *Ov* prevalence and infection in humans is thus needed to better inform public health interventions and foster a more sustainable reduction of *Ov* infection risk in humans without negatively impacting the health and well-being of marginalized populations (Ziegler et al., 2016). Accordingly, the objectives of this study were to 1) further our understanding of the socio-cultural determinants underlying raw fish consumption from the perspective of the affected community members in rural *Isaan*, and 2) to characterize local fish distribution networks as a mean to refine our understanding of *Ov* infection's geographic distribution and transmission potential.

2. Material and methods

2.1. Study setting

This study focused on the Lawa Lake region in Khon Kaen Province, a semi-manmade reservoir and wetland ecosystem, whose products and services (food, water and traditional medicines) are central to local livelihood practices (Takaya, 1975). Lawa Lake also serves as a habitat to *Bithynia* snails and cyprinid fish (*Ov* first and second intermediate hosts) and is known to be a highly endemic area for human *Ov* infection and CCA incidence (Aunpromma et al., 2012; Sithithaworn & Haswell-Elkins, 2003; Sriamporn et al., 2004; Sripa et al., 2011). Seasonal flooding and climatic changes influence both ecosystem functioning and daily human activities like fishing and farming. We selected 7 villages directly bordering Lawa Lake, all previously identified as *Ov* infection hotspots (Sripa et al., 2011; Sripa et al., 2014). The villages were, (1) Ban Chikokor, (2) Ban Donpordang, (3) Ban Padang, (4) Ban Tad, (5) Ban Nonlamon, (6) Ban Pao and (7) Ban Nongnangkwan ("Ban" is Thai for village) (see Fig. 1).

2.2. Research design and data collection

This cross-sectional, multi-method study used a combination of qualitative methods — focus group discussions (FGDs) and in-depth interviews (IDIs)— to investigate the sociocultural foundations of raw food consumption, and quantitative procedures to characterize the geographic characteristics of the fish distribution network in relation to *Ov* transmission risk spatial dynamics.

2.2.1. Qualitative data—An FGD, consisting of 3–5 individuals including an *Isaan* translator, was conducted at each village totaling 7 FGDs overall. In total, these FGDs involved 31 *Isaan* villagers who held positions of responsibility within their villages: e.g. *puyaiban* (head villager), *aorsormor* (health volunteer), *aorbortor* (government official), and/or *pu-chuoi* (village helper). The FGDs were conducted in public and private settings to suit participants' personal preferences (Kitzinger, 1995). Each FGD had 2 sections; the first

introduced the study background and collected village demographic data, specifically regarding those who held certain fish-related occupations; the second section prompted discussion about food and food preparation practices as well as social, cultural and economic changes that occurred around Lawa Lake in the past two decades. Verbatim transcripts were made and qualitative analysis carried out using thematic content analysis (Lincoln & Guba, 1985).

In-depth interviews were also completed with 46 fishing-related participants (i.e. fisherman, fish seller/buyer, middlemen and fishmongers) identified in the FGDs phase. The main purpose of the in-depth interviews was to learn about the fish distribution networks and movement of local fish from an *Ov* endemic lake. Some of the questions that were asked included: where participants got their cyprinid fish; where the fish came from; and where they would send the fish. This interview was conducted once a month for 12 months in local *Isaan* language.

2.2.2 Geo-tracking of fish distribution—The 46 individuals with fishing-related occupations, engaged in the local and regional fish distribution networks, were all provided with Global Positioning System (GPS) loggers (Holux, M-241) to wear for one full working day to record their movements and infer fish distribution. The loggers automatically recorded position (longitude and latitude), altitude, and speed at 10 minute intervals. The completed data sets were downloaded onto a portable laptop, displayed using the Holux software and read directly through Google Earth to display waypoints and tracks. The tracks were layered over a satellite image of Lawa Lake using ArcGIS® software by Esri.

2.3. Ethical Review

This study was reviewed and approved by Khon Kaen University's Human Ethics Research Committee (HE 581117).

3. Results

The FGD and IDI data provided rich insights into many aspects of *Isaan* lifestyle, food traditions, culture, socio-economic changes and previously undocumented social and business interactions of local fishermen, middlemen, shopkeepers, and raw-fish dishes makers. This section first presents the major themes that emerged from the qualitative data. The second part describes the logistics and economics of fish distribution, including an illustrative network of fish distribution routes in the Lawa Lake region.

3.1. Qualitative data

Participants affirmed major social changes had occurred around Lawa Lake in the past 10–20 years. Emergent data categories revealed many of these changes and were eventually collapsed into 2 overarching themes: (1) modernization and globalization; and (2) *Ov* infection risk and raw-fish-eating practice. Complementarily a third 3) theme dealing with the social and economic value of fish was identified.

3.1.1. Theme 1: Transitions: Modernization and globalization—Inglehart and Baker (2000) define "modernization" as the becoming of an industrial society (with

presumed socio-economic development benefits), concurrent with comprehensive cultural shifts away from traditional value systems and practices. Similarly, the World Health Organization (2015) defines modern (neo-liberal) globalization as the opening (de-regulation) of borders to increase the flow of goods, services, finance, people and ideas across international borders in pursuit of a globally integrated market place (and profit maximization) (World Health Organization, 2015).

Baker and Pongpaichit (2014) and Gebhardt (2004) have previously outlined many social, economic, and cultural impacts of these two processes on rural Thailand, particularly the *Isaan* region. Participants' discussions reinforced this with recurring mention of concepts such as; new roads, better farm machinery, delivery services, bigger markets, improved household technology e.g., running water supplies; better water storage and latrine availability; improved food production and food security; increased household incomes from regional factory jobs; and income "in-flows" from villagers drawn away to work in Bangkok and other cities.

More specifically, participants described a transition from a traditional *Isaan* diet culture to a more western food culture occurring over the past 10–15 years with frequent use of terms such as: cheaper, faster, easier, fast food, convenience foods, coffee, bread, and hotdog. The ready accessibility of western (processed and pre-packaged) food due to improved transport routes, improved incomes and village-based convenience shops has had a major impact on food consumption patterns compared to past years, when there was always a shortage of food (and finances) and people were dependent on whatever foods could be sourced from local natural environments. Illustrative examples include;

> "We (now) have access to coffee, instant noodles, and different kinds of meats more than we had in the past. We used to eat a lot of food from the natural environment, but now kids usually buy snacks from local store. Kids like to buy chips and cookies more than eating from trees" (49-year-old female village shop keeper),
>
> "It is easier to get food now because we have food delivery services" (55-year-old female motorcycle mobile food-seller), and,
>
> "I (now) drink coffee before I work. All of us used to eat rice, vegetables and pork, but now people eat fast and easy food like energy drinks and instant noodles. The way people eat has changed a lot. Instead of eating food at home, we can go to a shop and order rice noodle soup or fried eggs. Our children (now) prefer this kind of food more than rice" (55-year-old male fisherman).

3.1.2. Theme 2: Ov infection risk and raw-fish-eating practices—Although massive Thai government-funded public health campaigns have reduced food-borne parasitic infection rates in recent decades, high rate areas still remain, particularly in *Isaan* (Grundy-Warr et al., 2012; Hortle, 2007; Sripa et al., 2014). In the FGDs, very good awareness of *Ov* infection risk from eating raw fish was evident, however, there were consistent contradictory admissions about current raw fish eating practices, and erroneous information about *Ov* transmission and *Ov* related disease prevention strategies.

i. Raw fish eating practices: In FGDs and formal interviews villagers were all initially adamant that they didn't eat raw fish any more, readily reproducing the major directives from earlier public health education programs;

> "We do not eat raw fish anymore because we 've learned that it is bad for our health and causes cancer in the liver," (66-year-old male villager), and
>
> "I don't eat it anymore but we 've eaten it for a long time. It is easy to make and tastes delicious" (44-year-old male fisherman).

Following these declarations, however, participants typically segued into passionate descriptions of the long-standing *Isaan* cultural tradition of raw fish preparation and consumption and later, informally, or, in further interviews, reversed their earlier position and admitted raw fish consumption was still common and had not disappeared from the village, or culture, after all. For example,

> "although we know what could happen if we eat raw fish, we still eat raw fish dishes on special occasions such as festivals, funerals or weddings" (63-year-old male head villager),
>
> "*I still eat raw fish occasionally"* (44-year-old male fisherman contradicts his earlier statement, above), and,
>
> "I eat raw fish dishes like somtam and plasom when I am spending time with people. We eat together it tastes good when you eat it together" (65-year-old female villager).

ii. Knowledge about Ov infection: Even after extensive health education campaigns, erroneous beliefs were still commonly reported about ways to avoid *Ov* infection from raw fish. For example,

> "putting lime over the fish cooks the dish and you won't get infected." (55-year-old male villager).
>
> "We eat raw fish because it is delicious. You don't have to worry about getting infected because putting lime over raw food makes raw food safe to eat. Drinking beer with the food will also keep you from getting sick. Look at me, I've been eating it all my life and I am very strong and healthy. " (61-year-old male villager) and,
>
> "You shouldn't eat raw fish when you're young because of cancer, but you can eat it after you are 40 years old because you will die naturally before you ever get liver cancer, " (57-year-old male fisherman).

iii. Practical or economic necessity: Practical daily necessity also surfaced as justification for continuing raw fish consumption. For example,

> "I don't think it tastes good, but I eat it because my husband likes to eat it. Sometimes we don't have any choice. It's all we have. We cannot be picky. Fish are everywhere. They are easy to catch while we are working and the traditional dishes

are easy to prepare with just a couple of simple ingredients." (47-year-old female shopkeeper), and

"Sometimes we don't carry money with us so we eat the food we see and can catch around us" (57-year-old male fisherman).

3.1.3. Theme 3: Social and economic value of local freshwater fish and raw fish dishes—In depth-interviews with fishermen and fish distributors indicated one major theme: Local relationships and local foods. Common words and concepts related to community kinship and locality included: family, community, neighbor, sharing, Lawa Lake, convenient, village middleman, village fisherman reflecting the significance of locality in dictating lifestyle choices that include, diet, occupation, relationships and daily whereabouts. Words and concepts related to the human/environment relationships also featured strongly, such as, lakes, rivers, rice paddies, seasons, weather, drought, climate, and flooding indicating the important role the environment plays in shaping *Isaan* choices and lifestyle.

i. Fish types caught in Lawa Lake: The three main fish types reported caught in Lawa Lake were from the family Cyprinidae, mainly: *Cyclocheilichthys apogon, Cyclocheilichthys repasson* and *Hampala dispar*. They were the most abundant fish in the lake and were popularly consumed by *Isaan* villagers. While fishermen preferred to catch bigger, more economic fish, they were considered harder to catch. Cyprinid fish were easier to catch and were either distributed free to family and neighbors, or sold within the village for a very low price, as small-size cyprinids were not the target of fish middlemen. Larger fish such as, *Notopterus notopterus* (featherbacks), *Oxyeleotris marmorata* (goby fish), and *Channa striata* (snakehead fish) (Fig. 2) were much more favored by both fulltime *Isaan* fishermen and middlemen, as they sold for higher price per kilogram (kg) in the fresh fish markets (Fig. 3).

ii. Social network and logistics of fish distribution: Distribution routes for potentially parasitized Lawa Lake fish had not been previously recorded. Our data suggest a key distribution role for middlemen who wait for returning fishermen at fishing piers around the lake. Other occupations involved in fish distribution include local vendors and *"Plasom"* makers (Fig. 4).

"I fish and sell to a middleman," 63-year-old male fisherman (Holux GPS logger orange line).

"I buy fish directly from the fishermen from Lawa Lake. Then I drive to Ban Phai District Market (8.15 kilometers away) to sell the fish." 61-year-old female middleman (Holux GPS logger red line)

"I buy fish directly from the fish middleman who waits for the fishermen at the lake fishing pier early in the morning located in my village. I do this because it is fresher than fish from fish farms and buying fish from my village fishing pier is more convenient than going to the market," A 66-year-old female villager.

3.2. Geo tracking of fish distribution

Although 46 loggers were initially distributed, only 17 usable data sets were obtained as some participants had difficulty operating the loggers. Fig. 6 displays the 17 GPS logger track data sets illustrating the movements and distance covered by fishermen and middlemen during routine working days. Fishermen in Lawa Lake spend an average of 5 hours each day setting up nets around water plants/vegetation in the lake. They return before sunrise the next morning to collect fish caught during the night and then spend four hours on average collecting the fish to sell to fish sellers or middlemen waiting at the fishing piers. Middlemen sell some fish to local villagers but mainly transport the fish 8.15 km away to Ban Phai, the nearest district town market, or, to other nearby district markets (Table 1).

4. Discussion

This multi-methods study investigated socio-cultural determinants of raw-fish consumption behavior among *Isaan* people in Lawa Lake region, an endemic *Ov* infection locality. It also used GPS tracking of fish sourced in the lake to refine our understanding of the potentially infected fish distribution networks and likely *Ov* transmission paths.

4.1. Transition from traditional to modern lifestyles

Focus group and interview findings clearly affirmed major socio-cultural and economic transitions occurring due to decades of central government modernization policies and more latterly neo-liberal economic globalizing forces. Participants gave insightful accounts of a wide range of factors impacting on their traditional socio-cultural practices and lifestyle; for example, improved transportation infrastructure, changes in food production and food security, work patterns, increased household incomes from local factory work opportunities and wage inflows from city based workers, greater accessibility of modern convenience foods and so on. Lawa Lake region has become a peri-urban community with a diminishing mix of traditional *Isaan* cultural practices nestled amongst the fast-growing social, economic, and ecological changes of modernizing Thailand (Rigg, 2006; Sripa et al., 2014).

The relative rapidity of this transition (Akrasanee et al., 1991: Ekachai, 1991) makes it unsurprising that long-established cultural practices persist within the newly emerging lifestyle. However, indications of the younger generation’s preference for modern western food also suggest more complete transition to a “modern” food culture as older generations pass and an anticipated *de facto* reduction of *Ov* transmission as raw fish consumption becomes obsolete. In addition, although there have been recent improvements in socio-economic status, long-standing relative socio-economic disparities still continue between *Isaan* and the rest of Thailand (see Komin, 1990:240 for an historical account) (Komin, 1990) (Phongpaichat & Baker, 2015). Thus, the *Isaan* region is still relatively marginalized in terms of social, economic opportunities, with attendant political power differentials expressed in locals’ lack of engagement with central decision makers on large projects that impact on their lifestyles and environment.

4.2. Ongoing raw fish consumption and health education

The transition from traditional *Isaan* foods and eating practices to more westernized food consumption patterns was evident in both discussions and observations of the ready availability of "new" foods in village markets/shops etc. However, despite embracing more western foods and decades of health education programs, traditional "risky" raw-fish eating continues, at least amongst older persons, as a strongly valued cultural practice and marker of *Isaan* identity. Indeed, fishermen and middlemen also reported the importance to their work of relationships based on eating and sharing traditional and familiar foods on a daily basis with others close to their home and work places. Furthermore, incorrect beliefs that *Ov* infection risk was mitigated by adding lime and/or drinking alcohol with raw fish consumption were common, and seriously problematic, given lime has no effect on *Ov* metacercariae in infected fish and alcohol is actually a major co-risk factor for *Ov* infection (Yeoh, Promthet, Sithithaworn, Kamsa-Ard, & Parkin, 2015).

Current *Isaan* iconic raw fish dishes are the expressions of traditional knowledge and adapted practices selected through centuries (Boontawee, 2005). Until relatively recently (50 years ago) *Isaan* people had to rely largely on sourcing foods in their local environment for survival (Boontawee, 2005). Isaan's dry climate is characterized by high variability in both rainfall amounts and intensities, and also prolonged periods of drought. This harsh environment imposed serious challenges for food security. Fish, mostly cyprinids in this region, are the most easily accessible protein food source representing up to 70% of the people's diet (MRC Fisheries Unit, 1998). During periods of abundance (rainy season) certain fish would be consumed upon capture while others, mostly the smallest ones (cyprinids) were prepared for long-term storage in anticipation of periods of limited food supply. The most adapted storage procedures are fermentation or salt-preservation which do not cook the fish but prevent them from wasting. Thus, a complex range of factors have contributed to developing and maintaining *Isaan* people's well-entrenched and well-adapted raw-fish meal practices today, and no doubt, bolster their resistance to alteration.

Past large scale "top-down" public health campaigns appear to have been epidemiologically-driven with health education based on simple proximal linear risk-factor models to change eating practices (Jongsuksuntigul & Imsomboon, 2003). However, neglecting to engage with the complexity of the factors likely behind such eating practices may well underpin the dogged persistence of risky raw-fish eating practices. Using "bottom-up" community engagement strategies to gain shared understandings of these issues and collaborative action in program design, implementation and evaluation should lead to improved problem analyses, greater community commitment to change, and more sustainable health gain outcomes.

4.3 Fish distribution patterns and "fish economics"

Interview and GPS logger data show middlemen having the major role in fish distribution after purchasing fish directly from returning fisherman at Lawa lakeside piers. Middlemen sell some fish to locals at the piers but mainly distribute the fish to the market in Ban Phai, the nearest district town, or other nearby districts within Khon Kaen Province. However, this pattern changes depending on the type of fish. The major summary point is that, larger, more

economically attractive (non-infected) fish are mostly transported away from local village communities to district town markets. Smaller and less economic, potentially infected *pla khao noi* (Thai for small cyprinid fish) typically stay in the local villages for cheap sale, or free distribution, to family and friends of the fishermen. Thus, "fish economics" becomes a further variable for concentrating *Ov*-infection endemicity in these villages.

Fish abundance and species diversity, hence the type of fish that become available on the market and consumed, were reported to have changed due to landscape and usage changes altering water flows and water quality, as well as over fishing (Dudgeon, 2000). Recent evidence confirms these reports and suggests that the intensification of agricultural practices in the area may have contributed to a reduction of water quality with higher salinity and nitrogen concentration resulting in higher relative abundance of cyprinid fish and greater abundance of the snails responsible for *Ov* transmission (Kim et al. submitted).

4.4 Methodological issue: Social desirability and compliance in Thailand

All participants in interviews and group discussions engaged enthusiastically about their sense of *Isaan* cultural identity, particularly their traditional fish dishes. A notable feature was consistent contradictions between eating practices' reports from formal group discussions and informal conversations/interviews later. In line with previous health education program directives, participants typically initially affirmed that they no longer ate raw fish, only to casually rescind this later in informal, more confidential, interactions. Raw-fish-eating appeared ongoing and widespread amongst older people, corroborated by local *Ov* infection rates data. In western research settings this would be described as *social desirability* bias—giving answers to please the questioner. However, it would be simplistic to merely describe it as social desirability within the Thai cultural context and particularly in the *Isaan* region. A fuller elaboration is required to present the depth of nuanced cultural influences likely to bear upon such responses.

Thailand is a hierarchical culture characterized by compliance with, and respect for, authority/older persons (Mee-Udon, 2014; Nilvarangkul, 2002). Thus, although our participants may have simply given responses based on their relatively lower socio-economic status and desire to please their questioners, more likely the Thai concept of *graeng-jai* played a part in their responding. *Graeng-jai* translates literally as "*fear heart or awe heart*," (Nilvarangkul, 2002; Sangkrit, 2013) and relates to refraining from doing/saying things out of concern for the welfare, feelings and/or situation of another. Due to previous public health campaigns in the Lawa Lake region, an amount of social stigma is also associated with admitting to raw fish consumption. Initial responses may have been biased out of avoiding sense of stigma, or, not wanting to publically embarrass or offend (cause *graeng-jai*) to the health researchers, by implication associated with previous health education officials. A further Buddhist concept, *por-jai* "being satisfied with what one has" (Gray, Kramanon, & Thapsuwan, 2008) may also be implicated here. Rural *Isaan* communities have often been considered so thankful for any goods and services intended to improve their lives that they were consequently unlikely to criticize the providers; government and/or other authorities. For instance, (Mee-Udon, 2014) found this was an

issue in attempting a rural community evaluation of the implementation of the Thai Universal Health Care (UHC) initiative in the early 2000s.

Thus a complex set of social-cultural factors, in this case a sense of stigmatization, Thai notions of *por-jai* and *graeng-jai* may combine to influence interactions with researchers and others in roles of perceived authority. This issue needs serious consideration, within and across cultures, in community engagement for the development and implementation of community research and health education campaigns. It has major implications for levels of community understanding and commitment with research and health behavioral change processes.

5. Conclusion

"Behavior change" and "health education" are often mentioned in connection with *Ov* infection control, but critical reflective studies on complexities likely inherent for such interventions are still largely missing (Thomas Fürst pers. comm.). Accordingly, the major strength of our study is that it integrates qualitative and quantitative measures of human *Ov* related activities to provide fuller understanding of the importance and complexity of the socio-cultural underpinnings of raw-fish-eating behaviors for liver fluke infection control strategies. Having community members' own perspectives on these practices should give us wealthy insights for more effective future program development.

Our findings confirmed the overarching importance of "modernization" and "globalization" as processes synergistically driving changes in exposure and susceptibility to liver flukes and directly impacting rural communities' livelihoods, including dietary habits and traditional practices. The changes in regional and local socio-economic and environmental settings in the region, largely consistent with the risk transitions and de-agrarianization characterizing rural SEA (Smith & Ezzati, 2005; Rigg, 2006), are elements of a much needed integrated health framework to better contextualize current control initiatives for health development, equity and sustainability.

These considerations also emphasize that infectious disease control, must go beyond biomedicine and also incorporate social sciences, anthropology and other humanities' knowledge as well as embracing fully participatory protocols to foster authentic stakeholder engagement in developing, implementing and evaluating interventions.

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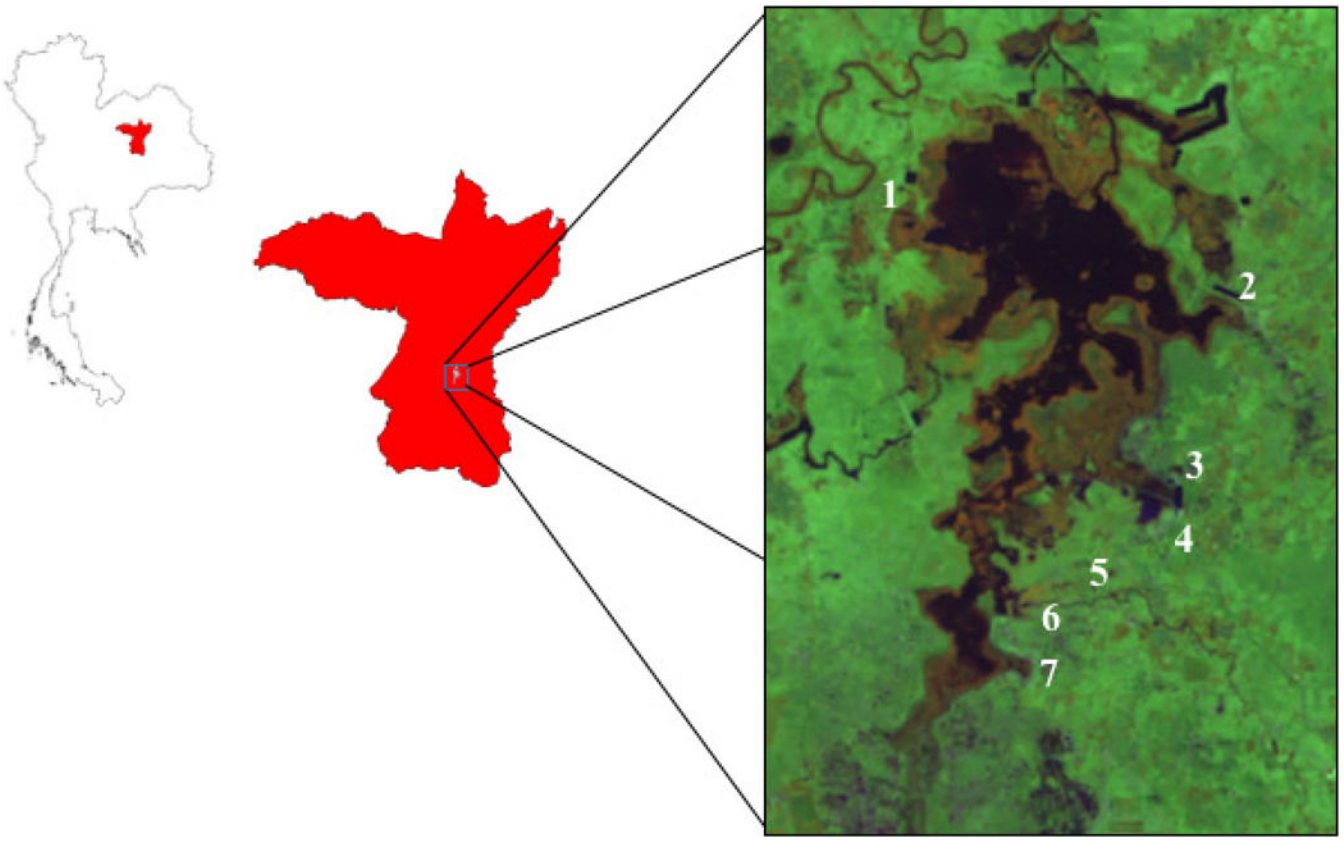

Fig. 1.

Map of *Isaan* Thailand and Lawa Lake in Khon Kaen Province, showing the 7 study villages: (1) Ban Chikokor, (2) Ban Donpordang, (3) Ban Padang, (4) Ban Tad, (5) Ban Nonlamon, (6) Ban Pao and (7) Ban Nongnangkwan.

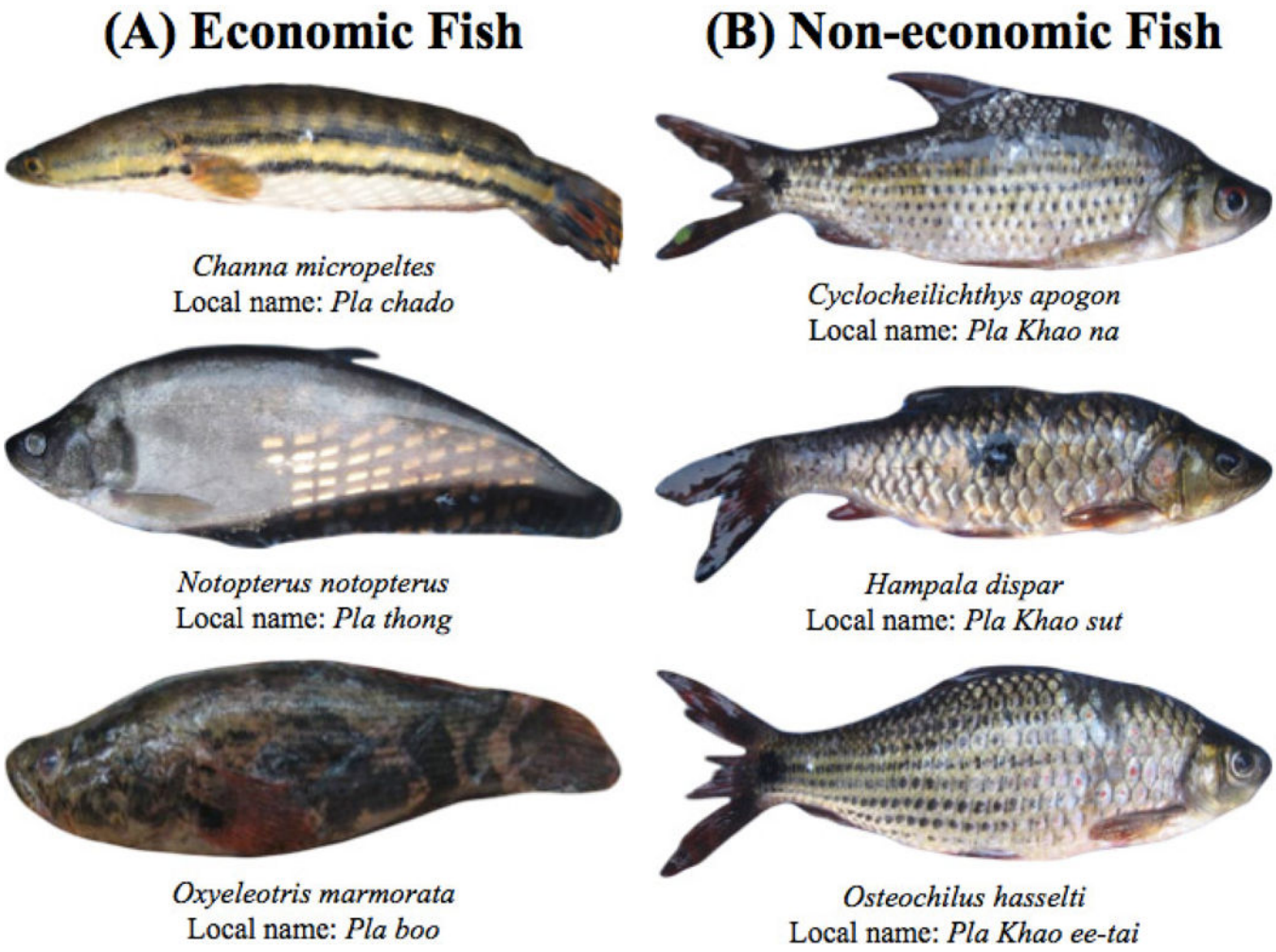

Fig. 2.

(A) Economic fish: Channa micropeltes, Notopterus notopterus, and Oxyeleotris marmorata and (B) Un-economic cyprinid fish: *Cyclocheilichthys apogon*, Hampala dispar, and Osteochilus hasselti of Lawa Lake.

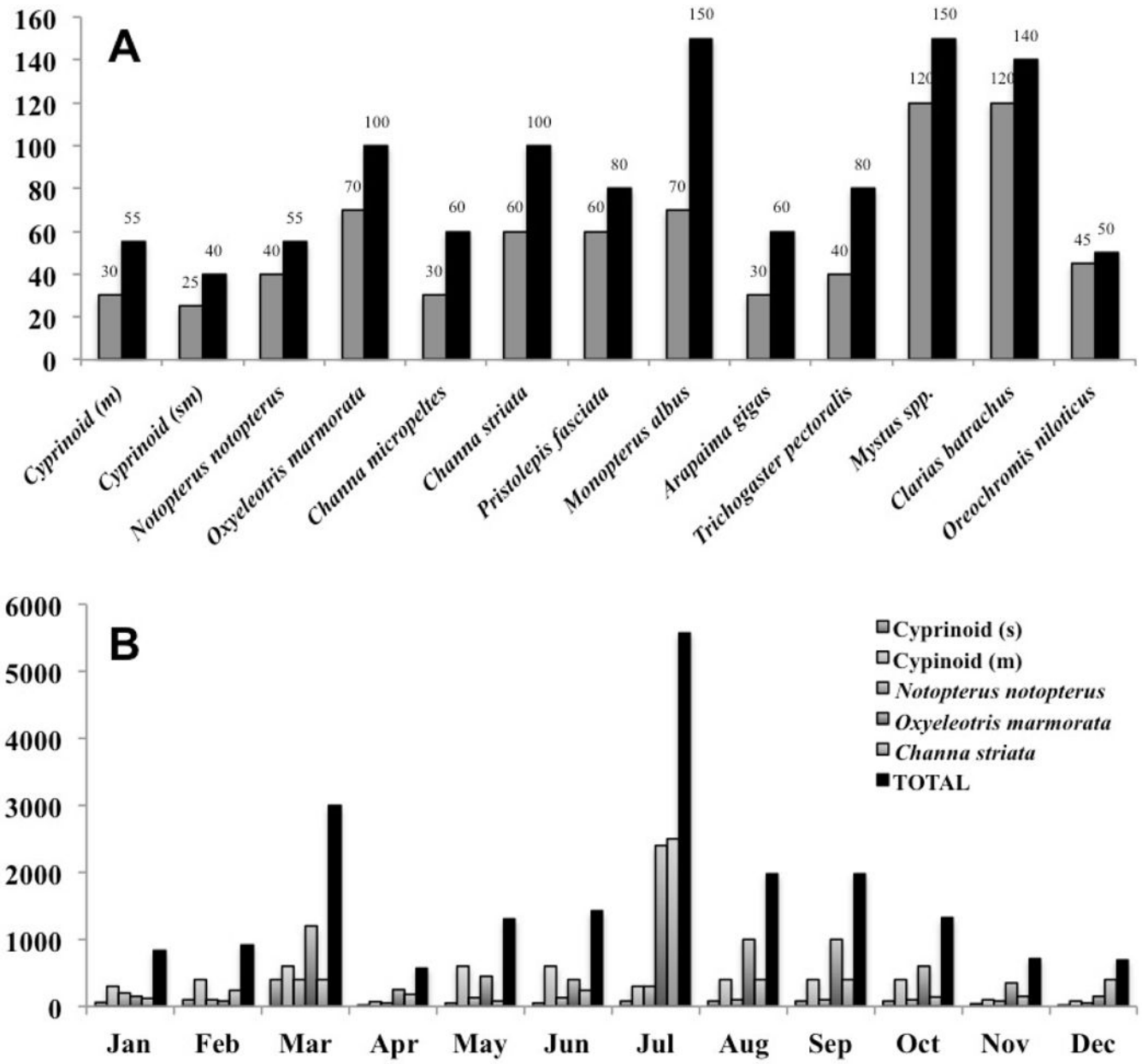

Fig. 3.

(A) Middlemen fish purchase and on-sell price per kg. Gray bars indicate purchase price from fishermen; black bars indicate on-selling price to fresh fish market customers. (B) Middlemen daily income per year by certain selected species of Lawa fish (Thai Baht;1 USD ≈ 30 THB).

Fig. 4.

Lawa Lake fish distribution network participants: (A) fisherman; (B) middleman or fish buyer/seller; (C) Ban Phai market fishmonger; and (D) *plasom* maker.

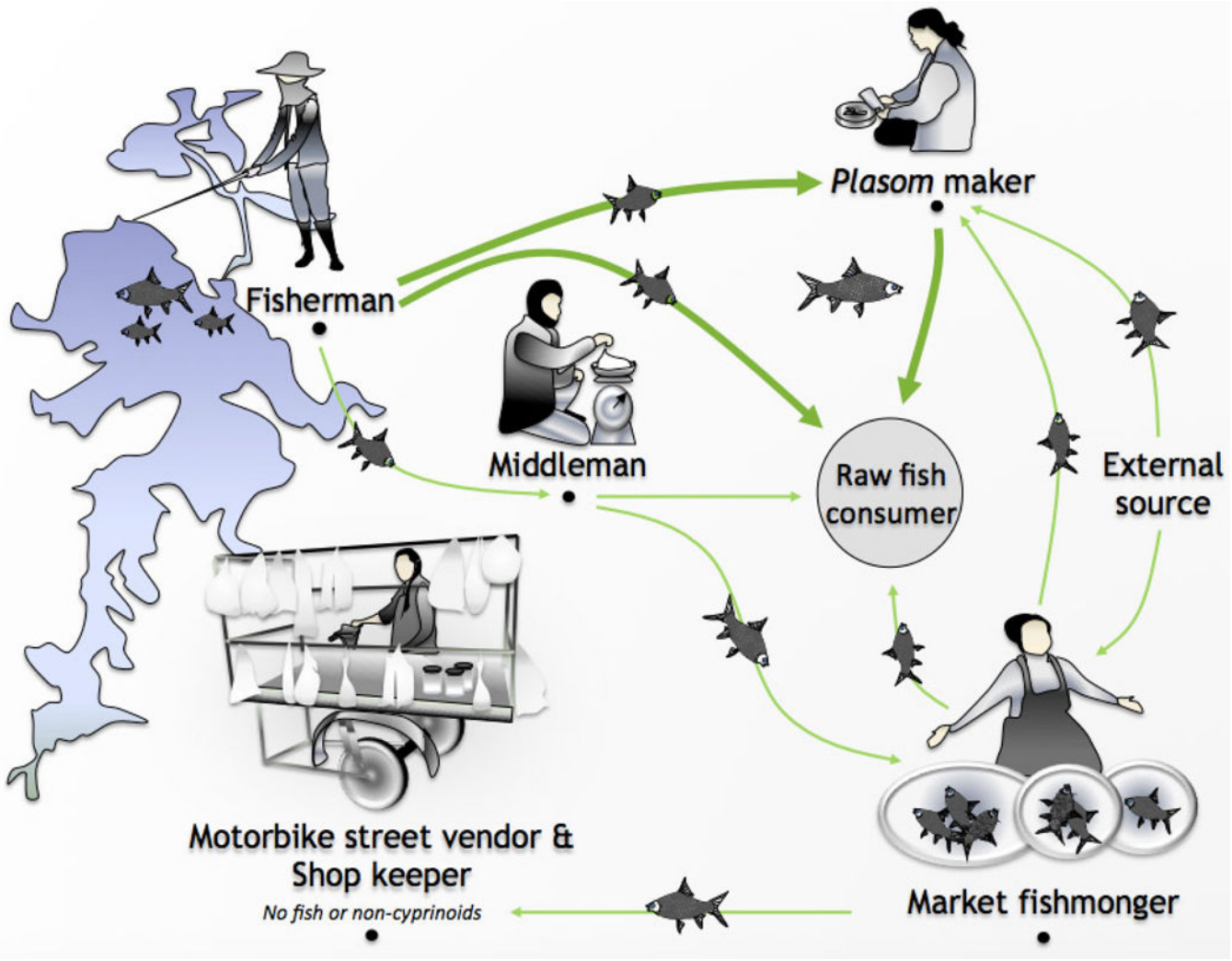

Fig. 5.
The social network and logistics of fish distribution.

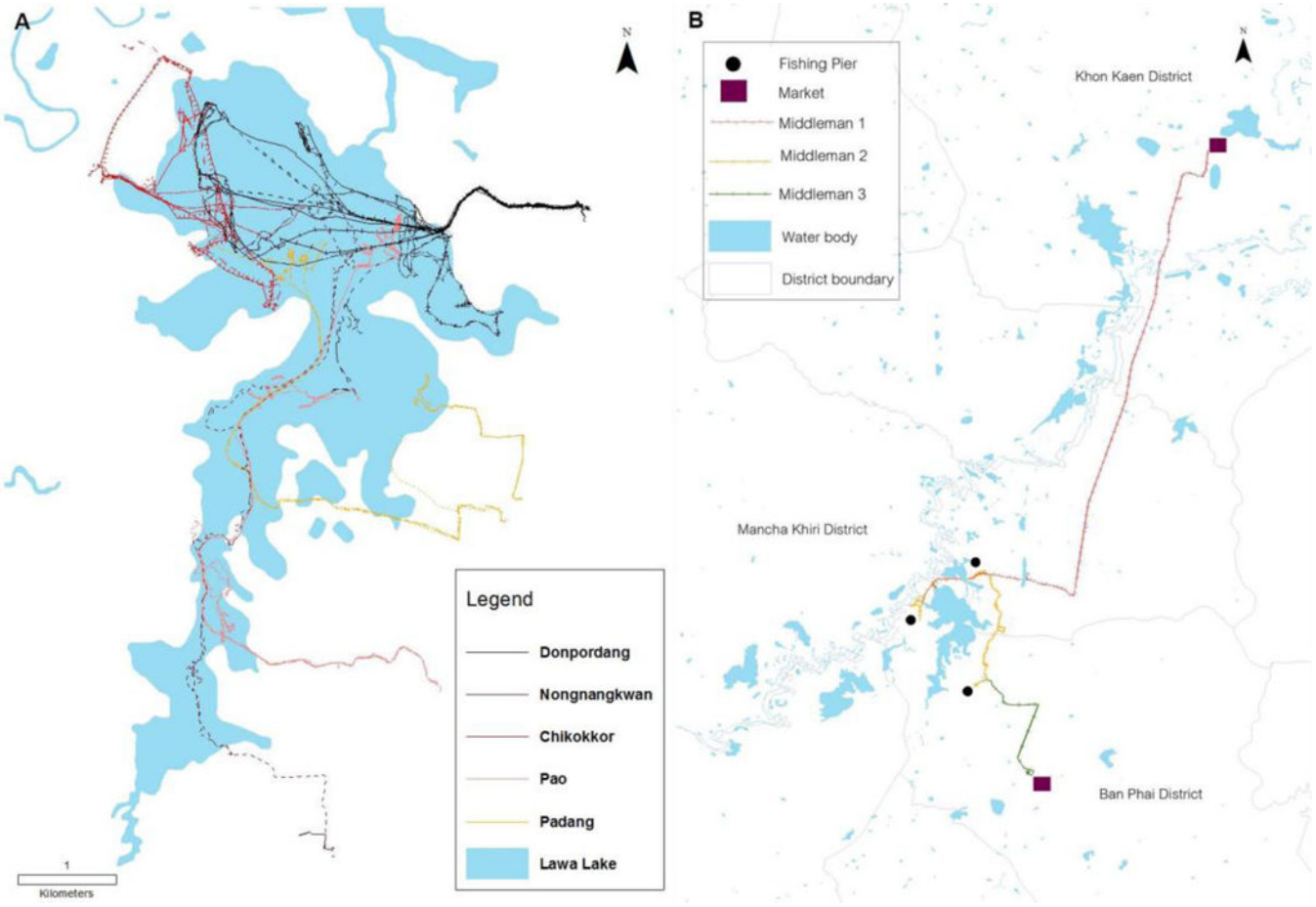

Fig. 6.

(A) GPS tracks of Lawa Lake fishermen; (B) GPS tracks from Lawa Lake middlemen.

Table 1

Details all GPS Holux logger variables

No.	Village (Ban)	Trip time (h)	Trip distance (km)	Moving time (h)	Stopped time (h)	Max speed (km/h)	Moving speed (km/h)	Total ascent (m)	Total descent (m)
1	**CKK**	1.56	3.2	0.39	1.17	19.34	4.89	195	192
2		4.33	3.6	0.28	4.5	16.6	7.5	154	144
3		2.47	8.6	1.47	1.38	46.4	7.54	299	281
4		2.58	9	1.8	1.49	21.47	7.9	522	484
5	**DPD**	6.15	12.1	1.34	4.41	14.99	7.65	772	793
6		4.49	10.8	1.31	3.17	15.05	7.09	508	503
7		6.23	8.6	1.11	5.12	23.82	7.16	668	688
8		5.23	10.3	1.2	4.2	15.66	7.67	362	366
9		6.32	11.6	1.42	4.49	15.25	6.77	1093	1092
10		1.00	4.7	0.42	0.17	13.77	6.65	134	132
11	**PAD**	9.35	15.4	1.4	7.55	15.66	9.21	708	709
12		6.12	9.7	1.18	4.53	17.49	7.36	618	641
13	**PAO**	9.22	13.5	2.5	6.32	15.23	4.76	886	874
14		1.13	2.3	0.17	0.56	11.22	7.72	92	113
15		10.13	11.6	4.11	6.2	15.23	2.77	669	670
16		6.03	4.7	1.25	4.38	4.45	3.32	375	353
17	**NNK**	2.34	0.756	5	2.29	17.74	8.93	49	45
Summary of means (SD)		4.98 (2.88)	8.26 (4.28)	1.55 (1.28)	3.64 (2.16)	17.61 (8.49)	6.76 (1.80)	476.71 (303.27)	475.29 (305.70)

*Ban: Thai word meaning “village”; h: hour; km: kilometer; m: meter; SD: standard deviation