Livelihoods in the changing Tonle Sap : past, present and future

Ratha Seng

Université de Toulouse

THÈSE

En vue de l'obtention du

DOCTORAT DE L'UNIVERSITÉ DE TOULOUSE

Délivré par :
Université Toulouse 3 Paul Sabatier (UT3 Paul Sabatier)

Cotutelle internationale avec :

Présentée et soutenue par :
Ratha SENG
Le mardi 11 juillet 2017

Titre :

Livelihoods in the changing Tonle Sap: past, present and future

---

École doctorale et discipline ou spécialité :
ED SEVAB : Écologie, biodiversité et évolution

Unité de recherche :
Évolution et Diversité Biologique

Directeur(s) de Thèse :

Sovan LEK (Professor, Unversité Paul Sabatier, Toulouse, France)
Robert POMEROY (Professor, University of Connecticut, Avery Point, USA)

Rapporteurs :

Thomas VALLEE (Professor, Université de Nantes, Nantes, France)
Phillippe MERAL (Director of Research, Université Paul-Valery, Montpellier, France)

Autre(s) membre(s) du jury :
Sovan LEK (Professor, Unversité Paul Sabatier, Toulouse, France)
Young-Seuk PARK (Professor, Kyung Hee University, Seoul, Republic of Korea)
Jean Michel CAPUIS (Associate Professor, Université Paris1 Panthéon Sorbonne, Paris, France)
Jocelyne NAPOLI (Associate Professor, Unversité Paul Sabatier, Toulouse, France)
Saveng ITH (Researcher, Royal University of Phnom Penh, Cambodia)

LIVELIHOODS IN THE CHANGING TONLE SAP:

PAST, PRESENT AND FUTURE

RATHA SENG

Director:
Prof. Sovan LEK
Laboratoire Evolution & Diversité Biologique, UMR 5174, Université Paul Sabatier – Toulouse III, 118 route de Narbonne, 31062 Toulouse, cédex 4-France

Co-director:
Prof. Robert POMEROY
Connecticut Sea Grant/Department of Agricultural and Resource Economics, University of Connecticut-Avery Point, 06340-6048 Groton, CT USA.

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the Université Paul Sabatier- Toulouse III

RESUME

L'objectif général de ce travail était d'évaluer les stratégies des moyens de subsistance dans le lac Tonle Sap en rapport avec divers facteurs de changement. Plus précisément, l'étude visait à étudier les variations et les déterminants des moyens de subsistance (spatial et temporal), ainsi que les impacts des futurs changements et des communautés de pêcherie (CFis) dans les plaines inondables de Tonle Sap. En utilisant les approches multivariées, j'ai pu mettre en évidence les résultats suivants :

- Les différentes caractéristiques écologiques déterminent les différentes stratégies des moyens de subsistance et les ressources environnementales sont indispensables pour la période post-conflit des pays comme le Cambodge ;
- Les divers facteurs humains, naturels et économiques, sociaux et physiques ont influencé le choix et le revenu des ménages ; parmi lesquels, la possession de terrain était le plus important;
- La perte de net revenu est attendue dans tous les futurs scenarios de changement, particulièrement avec ceux qui dépendent uniquement un moyen de subsistance, subi une perte en moyenne de 18% dans tous les scénarios, comparativement à 9% pour le groupe des multi-moyens de subsistance ;
- La taille idéale de la zone communautaire est de 2 310 hectares et l'impact positif des CFis peut être réalisé en améliorant la planification, le processus opérationnel et le mécanisme de résolution des conflits, également qu'en développant et renforçant des réseaux et la conformité des règles.

Les résultats suggèrent que les moyens de subsistance sont spécifiques au contexte et le choix des stratégies des ménages est associé à une gamme de facteurs socio-écologiques. Nous devons éviter une prescription unique pour aborder les problèmes des moyens de subsistance dans le Tonle Sap. Effectivement, les implications politiques pour améliorer la participation aux moyens de subsistance ainsi que pour maximiser les avantages économiques et sociaux à long terme pour les ménages devraient accorder une attention particulière aux ménages pauvres en ressources. Par conséquent, l'augmentation de la richesse et des biens du ménage, ainsi que l'établissement des programmes efficaces de conservation des ressources améliorent effectivement la capacité d'adaptation des ménages en réponse aux changements inattendus et également contribuent à renforcer et soutenir les organisations des CFis.

MOTS CLÉS : Moyens de subsistance, déterminants, impact, communauté de pêcherie, Tonlé Sap

ABSTRACT

The overall goal of this research was to assess the livelihood strategies in the Tonle Sap in the face of various drivers of change around the lake. Specifically, the study intended to investigate livelihood variations and determinants (both spatial and temporal), and the impact of future scenario changes and of the Community Fisheries (CFis) in the Tonle Sap's floodplain. By using multivariate approach, I am able to highlight the following findings:

- different ecological characteristics influencing livelihood strategies and the environmental resources are imperative in post-conflict Cambodia;
- various human, natural and economic, social, and physical capitals have influenced household's choice and income. Land was the most significant;
- net income loss is expected for under all future scenarios, with those engaged in single livelihoods experiencing an average loss of 18% across all scenarios compared to 9% for the multi-livelihood group;
- an ideal size of community area is 2,310 hectares and the positive impact of CFis can be achieved by improving planning, operational process and conflict resolution mechanism, developing networks and reinforcing rule compliance.

The findings suggest that livelihood is context specific and the choice of household's strategies is associated with a range of socio and ecological factors and we should avoid a one-size-fit prescription to tackle livelihood problems in the Tonle Sap. Policy implications to improve livelihood participation and maximize the long-term economic and social benefits for household should consider special attention to resource poor households, increase household's wealth and assets, design and implement effective resource conservation programs, improve households' adaptive capacity in response to unexpected changes and continue strengthening and supporting the CFi organizations.

KEY WORDS: Livelihoods, determinants, impact, community fisheries, Tonle Sap

ACKNOWLEDGMENT

First and foremost, I would like to thank my thesis directors: Prof. Sovan LEK, Université Paul Sabatier – Toulouse III, France, and Prof. Robert POMEROY, University of Connecticut. USA, for their guidance, support, patience during the period of my PhD. Prof. LEK and Prof. POMEROY have provided me exceptional scientific supports from the very beginning till the end of my PhD journey and are always ready to assist in whatever academic problems I am facing. Also, I have a great privilege to be recruited to involve in the Belmont Forum-funded Tonle Sap Climate Change Project by Prof. Sovan LEK, where I have opportunity to meet all amazing researchers, scientists and professors from the three continents (Asia, Europe and America), including my co-director Prof. Robert POMEROY. Furthermore, I would like to take this opportunity to thank H.E Dr. TOUCH Visalsok, Under Secretary of State, Ministry of Education, Youth and Sport, and former University of Battambang Rector, for introducing me to the Belmont Project team. My scientific support thank is extended to Prof. Evan FRASER and Dr. Krishna KC from Department of Geography, University of Guelph, Canada for hosting my mobility in Guelph and who are instrumental in my socioeconomic survey design and data collection as well as the livelihood analysis.

I am also grateful for my referees and jury members (Prof. Thomas VALLEE, Dr. Phillippe MERAL, Prof. Young-Seuk PARK, Assoc. Prof. Jean Michel CAPUIS, Assoc. Prof. Jocelyne NAPOLI and Dr. ITH Saveng) for accepting to review, evaluate and read my thesis as well as providing useful comments on my work and for continuing to inspire me to go on with the research career path.

This research would not have been possible without all the amazing team at the University of Battambang. Firstly, I am grateful for H.E Mdm. SIENG Em Totim, Rector, for her continued support on the research activities and make every means possible to ensure the research work a success. Special thanks also go to our colleagues, Dr. CHEA Ratha, Dr. SREAN Pao and our most helpful project administrator, Mr. CHREA Socheat for all kinds of support for my research work and PhD. I am forever grateful for my data collection team led by Mr. IV Channara and inspiring and dedicated students at the Faculty of Sociology and Community Development, including Mr. TEP Langdy, Ms. MOM Lita, Ms. MAO Sotheavy, Mr. REAN Sothea, Mr. SUN Kimseng, Ms. CHHON Sanda, Ms. SOEUM Sreynin and Mr. KIT Singheang. Finally, my appreciation is also to villagers and Community Fisheries leadership and members in Tonle Sap for allowing us to meet and learn about their situation, experience and struggle.

Special thanks also go to National Institute of Statistics, Cambodia, for sharing Cambodian Socio Economic Survey data and Mr. SOK Sotheavuth for being so helpful and patience in answering any questions or providing clarifications to the data.

Thank you to the Belmont Forum, Agence Nationale de la Recherche, Erasmus Mondus – Techno 1 Project and the Open Society Foundation for funding this research and my mobility in France, Canada and US. I would also like to extend my thanks to the staff at EDB Lab: Nicole HUMMET, Linda JALABERT, Dominique PANTALACCI for their administrative, academic and other support and for enabling the research work and stay in Toulouse pleasant and fruitful. Thank you also to my AQUAECO team: Loïc Tudesque, Mathieu Chevalier, Pengbun Ngor, Ratha Chea, Ratha Sor, Kong Heng, Bunyeth Chan, Chuanbo Guo, Mingli Lin, Tongtong Fang and others for sharing insights, discussion and support at different points of time during my research work in Toulouse.

My stay in Toulouse would be more difficult without the hospitality of Prof. Sovan LEK and Mrs. Sithan LEK. The care, kindness, food, love and so many other things I experienced leave very beautiful memories and will forever be in my heart.

Finally, the most important pillar always standing for me in every walk of life is my family: my parents, brothers, sisters in law, mother in law and of course my lovely wife and two sons. I began my PhD journey during both a very difficult and an exciting time when we started welcoming our second boy. My wife and our two boys continued to stay strong back in Cambodia and at the same time provided me strength in another continent. You are the strongest support at all time. I love you!

Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

1.1 Status and importance of inland small-scale fisheries

Fish stocks, both marine and inland, have either degraded or collapsed from their historical peaks (Allan et al., 2005; Pauly et al., 2002). The main threats to biodiversity associate with either overfishing or being fished at their biological limit, putting them at risk with increasing human and environmental pressures. Overfishing has been natural resource concerns in both industrialized and developing world. It is considered to precede all other human disturbances in contributing to the resource extinction (Jackson et al., 2001). In Southeast Asian countries, overfishing leads to several negative impacts, such as decreased employment opportunities and revenues, food security, poverty, social stability and conflicts (Salayo et al., 2008). From the governance perspective, it is being compromised by the failure of the centralized governance system of resource (Acheson, 2006; Pomeroy, 1995) which drove an increased recognition of community role in resource management.

The total capture production from inland waters, exclusive of aquaculture, is 11.9 million metric tons in 2014, of which Asia made up the largest share of the world total catch. China accounted for 19.3%, followed by Myanmar (11.6%), India (10.9%), Bangladesh (8.4%), Cambodia (4.2%), Uganda (3.9%), Indonesia (3.5%), and Nigeria (3%), making up almost 65% of the world total inland production. However, the actual catch size could be much greater than this figure or even higher than the marine catches (FAO, 2016). The inland fisheries are generally small-scale and subsistence in nature, making it difficult to properly value. The contributions of inland waters are usually underestimated.

Fishing and fishery products play important role for livelihoods and food security especially among low income families in developing countries where employment op-

tions are limited. Small-scale commercial and subsistence fishing are often the last resort choice of employment of households where lucrative labor opportunities cannot be found (Kura, Revenga, Hoshino, & Mock, 2004). Additionally, the fish contribution, in 2013, to total animal protein intake was 17% for global average and it constituted more than 50% in developing nations like some small-island states, Bangladesh, Cambodia, Ghana, Indonesia, Sierra Leone and Sri Lanka (FAO, 2016). Globally, the annual fish consumption per capita was 20 kg and the figure was projected to increase (FAO, 2016). In the Lower Mekong Basin, it was estimated up to 52 kg (Hortle, 2007). Overfishing, habitat loss and environmental degradation or the combination pose serious threats to freshwater fisheries, its biodiversity and those whose livelihoods primarily depend on the resources. Freshwater ecosystems and their associated biological resources are, on average, more threatened than those of the marine (Ricciardi & Rasmussen, 1999). The under-appreciation of the importance of freshwater fisheries put this sector (i.e. small-scale fisheries) even at higher risk.

1.2 The Tonle Sap's fisheries and livelihoods

According to Yu & Fan (2011), Cambodia is divided into four main agro-ecological zones, namely Plateau/Mountain, Plain, Coast, and Tonle Sap. The Plateau/Mountain zone includes the northeast Cambodia and Kampong Speu province in southwest bordering the coastal provinces is dense in forests and with low population density. The coastal zone consists of a very small portion of the country located in the Southwest. Crop cultivation, mostly rice, is mainly in the Northwest-Southeast corridor, known for a high population density. Thus, the northwest areas bordering Thailand around the Tonle Sap zone and southeast areas bordering Vietnam in the Plain zone are the main

producers of rice. Dry season rice is mostly grown in the Plain zone, accounting for 70% of total land area of the country.

The Tonle Sap Lake, the largest lake in Southeast Asia and one of the most productive freshwater fisheries in the world, covers about 5 to 8 percent of Cambodia's total land area (MRC, 2003). Connected to the Mekong River by the 120 km long Tonle Sap River, the Tonle Sap Lake's surface area annually fluctuates from 2,500km^2 to over 15,000km^2 driven by seasonal flood pulse from the Mekong River accounting for 53.5 percent of total water inflows into the lake system (M. Kummu et al., 2014).

The rice fields, rivers and forests have supported the livelihoods of Cambodian population for centuries. Local people depend on the traditional ways of living from rice farming, fishing and extracting forest resources, mainly for subsistence purposes. Households become more or less diversified (i.e. crops, fishery, forestry) depending on the degree of interactions of the adjoining ecosystems.

In Cambodia, fish and fishing activities have been primary sources of nutrition and income. Fish from the Tonle Sap provide an essential source of protein and micronutrients critical to the health of families in a country still plagued by high rates of childhood malnutrition, as well as livelihoods. Fish supplies up to 80% of all animal protein in the diet (Hortle, 2007), of which the majority are from the Tonle Sap Lake (Baran et al., 2014). The annual fish consumption per capita is as high as 71 kg around the Tonle Sap's floodplain in the high-yield fishing areas (Ahmed, Hap, Ly, & Tiongco, 1998). Moreover, income from capture fisheries and other aquaculture contributes about 10% of Cambodia's Gross Domestic Products (GDP) (Baran, Schwartz, & Kura, 2009).

The lake provides essential ecosystem services and supports livelihoods of at least 2 million people as well as a large number of small-scale fishers. Households in the vicinity of Tonle Sap Lake primarily engage in small-scale artisanal and subsistence

fishing, with supplemental income from agriculture, raising livestock, aquaculture, off-farm work, and remittances (Bond, 2015). Yet, many of the poorest household depend on one livelihood, which is generally fishing (Nuorteva, Keskinen, & Varis, 2010). In particular, floating villages on the Lake are heavily dependent on fisheries resources, and their limited access to land resources, education, and livelihood options make them especially vulnerable to ecological change (Nuorteva et al., 2010). Moreover, almost 70% of floating households on Tonle Sap Lake were classified as being low-wealth (Bond, 2015), where wealth was an index measuring household location, diet diversity, and livelihood strategy. In contrast, richer households were typically not as reliant on fishing as their main income source (Bond, 2015). While inhabitants around the Lake have adapted to seasonal changes of the lake, they have poor capacity to react to irregular environmental events (Nuorteva et al., 2010). Lower income Tonle Sap fishers, therefore, exemplify a vulnerable population.

1.3 Problems

1.3.1 Livelihoods, natural resources and post-conflict building

A livelihood comprises "the capabilities, assets and activities required for a means of living"; a sustainable livelihood is when it "can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, without undermining the natural resource base"(Scoones, 1998). In developing countries and those affected by conflicts, a significant percentage of population relies on land, water, forests and other natural resources. In conflict-affected countries, it is estimated that the dependency on agriculture and natural resources is around 60% to 80% (Bruch, Jensen, Nakayama, & Unruh, 2012). The armed conflicts usually destroy the livelihood systems and house-

holds are forced to adopt coping strategies which are sometimes environmentally unsustainable. Not only does the conflict damage the livelihood bases (i.e. household capabilities and assets, natural resources and infrastructure), but it also undermines the formal institutions especially the tenure systems governing access to resources which sometimes turn into conflicts or violence. The weakened formal institutions results in poor enforcement of rules, particularly when dealing with environmental resources (Clements et al., 2010; Travers, Clements, Keane, & Milner-Gulland, 2011).

Moreover, the potential sources of conflicts are associated with resource access and ownership (Andre & Platteau, 1998). In some cases, the conflict is driven by social groups who work together to take advantage of the weakened institutions and of peace by further devastating the economy and local livelihoods through unsustainable and illegal resource extractions (Oglethorpe, Ham, Shambaugh, & van der Linde, 2002).

On the pathway of reconstruction, war-torn countries may adopt economic policies that emphasize accelerating rapid economic growth, resource extraction and attracting foreign investments by neglecting long-term livelihood and ecological purposes of the natural resources. For instance, Cambodia's recovery policies have resulted in rapid structural transformation. Cambodia has been highly depending on subsistence agriculture, dominated by rice, and its allied activities such as forestry and fishery (Acharya, Kim, Chap, & Meach, 2003). However, the share of agriculture to GDP has been on the decline from over 50% to just about 30% over the past two decades and is offset by increasing role of services and industry which is principally dominated by tourism, garments and construction (World Bank, 2015a).

Meanwhile, arable land per capita in Cambodia has continued decreasing since 1990s (World Bank, 2016). Cambodia prioritizes the allocation of arable land to business tycoons and foreign investors in the form of Economic Land Concessions over the

landless and land-poor families under the Social Land Concessions program (Neef, Touch, & Chiengthong, 2013; Vrieze & Naren, 2012). The average farmland is one and a haft hectares; 48% of rural households own land of less than one hectare, and 20% of rural population has no land access (World Bank, 2006, 2015a). With an average household size of five, the majority of the rural population faces a high level of vulnerability.

While poverty rate has declined sharply from the early 1990s of more than 50 to 20 percent in 2011, one-fifth Cambodians are living close to the poverty line and are at risk of vulnerability due to simple shocks (World Bank, 2014). In Cambodia, the highest poverty incidence is centered in areas where households are more primarily dependent on agriculture and natural resources such as Tonle Sap, the plateau and mountain areas (Varis, 2008; World Bank, 2006, 2014). To ensure economic viability and to cope with change, households in developing countries and in Cambodia in particular pursue a variety of livelihood activities like crops, livestock, fishing, forestry, and nonfarm (Babulo et al., 2009; Ellis, 2000; Nielsen, Rayamajhi, Uberhuaga, Meilby, & Smith-Hall, 2013; Soltani, Angelsen, Eid, Naieni, & Shamekhi, 2012). Households decide to diversify their livelihood strategies depending on varying socio-economic factors (Eneyew & Bekele, 2012; Tesfaye, Roos, Campbell, & Bohlin, 2011).

The poorest households generally rely on a single strategy, for example fishing, and have limited access to land resources, education, and livelihood options, making them especially vulnerable to ecological change (Nuorteva et al., 2010). For instance, even though inhabitants around the Tonle Sap Lake have adapted their life and livelihoods to the annual fluctuations of the natural resources of the lake, they have poor capacity to react to irregular environmental events (Nuorteva et al., 2010). Lower income Tonle Sap fishers, therefore, exemplify a vulnerable population.

1.3.2 Livelihood vulnerability

Within the global change literature, livelihood vulnerability is seen as being dependent on peoples' exposure (likelihood of being impacted), sensitivity (dependence on natural resources), and capacity to adapt to likely impacts (Adger, 2006). These three dimensions collectively determine the extent to which peoples' livelihoods are vulnerable to climate and socio-economic change. Cambodia is classified as being highly vulnerable to the effects of climate change on fisheries (Allison et al., 2009). However, poverty, marginalisation, and lack of alternative livelihoods impede fishing communities' ability to cope with changes in fishery productivity (Baran et al., 2009).

Despite the relative abundance of the Tonle Sap's natural resources, the area remains one of the poorest in the country. The inhabitants of the Tonle Sap are also highly vulnerable especially related to the changes in the Mekong River and the lake itself. The upstream dam development of the Mekong River and its tributaries, notably the large hydropwer projects in Mekong countries, are threathening the ecosystem and the livelihoods of the Tonle Sap's flood plain as it causes the rise of dry-season water level (Keskinen, Tola, & Varis, 2007). The increase in dry-season water level leads to the destruction of flooded forests surrounding the lake and therefore causes significant loss of livelihoods of the people and negative impact on aquatic production in the lake. The effects likely put additional pressure on the remaining resources and thus potentially cause resource competition and fuel related conflicts in the area.

1.3.3 Agricultural expansion

Rice and fish are backborn of the Tonle Sap's flood plain. Cambodia considers rice as "white gold" and has an ambition to become one of the major milled-rice exporting countries in the global market. This has its effects on the Tonle Sap area as well. The

development of large-scale irrigation projects in the upper basin and the emergence of private irrigation structures in the flood plain influence the avaiability of resources to different user groups (Keskinen et al., 2007). The rapid agricultural development does not only associate with the built irrigation structure, the access to the floodplain has also been improved through the construction of rural roads. Literature shows that built structures have led to biodiversity loss as a result of flow modification, habitat alterations or loss and water pollution (WorldFish Center, 2007).

Associating the impact on local livelihoods, the destruction of flood plain not only change the traditional forms of livelihoods of different user groups, but the effects are more concerning with the subsistence and small-scale fishers who generally have lower capacity (i.e. household capital) to take advantage of opportunities provided by the development of either the infrastructure or irrigation scheme. For instance, households in southern edge of Steung Chinit irrigation project in Kampong Thom reported decreased fishing income and are forced to diversify into either farm or non-farm employment because of the declined inome (WorldFish Center, 2007).

1.3.4 Management change

The fisheries of the Tonle Sap were traditionally divided into three types: small-scale or subsistence fishing, middle-scale or licensed fishing and large-scale or fishing lots. Open-access areas are shared between small-scale and middle scale fisheries, which are outside the fishing lots and fish sactuaries. While small-scale or subsistence fisheries can fish for the whole year round, middle-scale fisheries can only operate with a fishing license restricting the number and kinds of gears used and the fishing period which is allowed only during the open season between October to May (for areas north of Phnom Penh). 63% of gears used for middle-scale fisheries are gillnets (Ahmed et al., 1998).

Large-scale fisheries or fishing lots refers to as industrial fisheries in which access and exploitation rights are acquired through public auction; and locations, boudaries, fishing actions, timing and other conditions are determined in the leasing contract. The fishing lots cover large areas and use large traping device. The lessee has his own force to control access and regulate fishing activities inside the lot and prevents any unlawful access or fishing activities within the defined boundaries.

In 2000, first fishery reform was carried out by converting 56% of total fishing lot areas for Community fisheries. In 2012, the government completely abolished the industrial-scale century-old private fishing lot system covering an area of 270,217 hectares, and re-arrange 35% of the areas for conservation and the remaining for open access (Sithirith, 2014). The transition from the private fishing lot areas to community-use areas poses questions to be investigated in terms of fishing income, functioning and impact of community-based fisheries management, fishery sustainability and the conditions for succesful co-management of resources.

1.4 Solutions

Small-scale fisheries has become scholarly and policy attention because of its social and economic dimensions, especially in some of the world's poorest countries. The sustainability of the resources is important as it can continue to maintain food security and income for those depending on them. Recent studies associate with factors to improve performance and promote sustainability of the fisheries (Di Franco et al., 2016; Kosamu, 2015). For instance, Di Franco et al. (2016) identified key attributes (i.e. high enforcement, presence of management plan, fisher participation in management and board and promotion of sustainability) essential to increase the performance of small-scale fisheries. In developing countries, sustainability of small-scale fisheries associates

with improving social capital and community engagement (Kosamu, 2015). Additionally, Pomeroy (2012) shows similar finding by highlighting people and community-focused solutions should be enhanced to manage overcapacity or overfishing in Southeast Asia. Other researchers emphasize wealth-based approach (Allison & Ellis, 2001; Schuhbauer & Sumaila, 2016) and the vulnerability of small-scale fisheries to management change (Tilley & Lopez-Angarita, 2016).

Within the recent literature, there is a common understanding on the importance of socioeconomic conditions, the vulnerability and adaptive responses of resource users as well as a shared concern over resource sustainability. Here, I propose the livelihood approach based on Sustainable Livelihood Framework and the co-management of fisheries resources as the solutions to address livelihoods of fishing communities in the Tonle Sap. The two approaches integrate the social and ecological perspectives by linking human livelihoods and natural resources, which is important to maintain ecosystem integrity and productivity.

1.4.1 Sustainable Livelihood Approach (SLA)

The SLA by Chambers & Conway (1991) initially built on three fundamental conceptual principles of capability, equity and sustainability. Within the generality of meaning used by Sen (1993), capability refers to an ability to perform basic functionings a person is capable of doing or being. The functionings represent various activities or states a person manages to do or to be in life. The livelihood capability mean an ability to cope with stress or shocks or being capable to find or make use of livelihood opportunities (Chambers & Conway, 1991). The capability means not just being reactive, but proactive and dynamically adaptable. This also focuses on household strengths or assets that enable them to make decision of livelihood choices or withstand crises. While livelihoods of some people are predetermined, for example as successors from

their parents, many other are influenced by socio, economic and ecological environments and it depends on their adaptive capabilities whether being able to exploit new opportunities or become vulnerable to the change.

The role of assets was also suggested by Swift (1989) to improve understanding of the famine vulnerability. It provides additional insights not just about the patterns of social or economic failure by different groups of asset holdings, but why? It continues to explain why war and conflicts are a crucial cause of vulnerability. It also helps to explain how households and the community make decision about their livelihood strategies and rebuild their life. Furthermore, the 5-asset pentagon (human, natural, financial, social and physical) (Figure 1) provides an appropriate way to picture the multidimensional nature of poverty and vulnerability being faced by fishing communities, such as poor living condition, inadequate services, lack of skills and assets, or high exposure to risks (Pittaluga, Corcoran, & Senahoun, 2004; Townsley, 1998).

Equity can be measured in terms of distribution of income, assets, capabilities or opportunities (Chambers & Conway, 1991). In fisheries, equity means fair allocation of access rights or enforcement of rules. It focuses on people and social justice where people not only gain access to assets or resources but are able to maintain adequate and decent living.

According to Chambers and Conway (1991), sustainability falls into two groups: environmental and social sustainability. Environmental sustainability concerns with resource productivity and its effects on livelihoods. It associates with the enhancement of one livelihood activity which may impact other livelihoods. From ecological literature, sustainability refers to “the ability of a system to maintain productivity in spite of major disturbance, such as is caused by intensive stress or a large perturbation” (Conway,

1985). On the other hand, social sustainability concerns with internal capacity to respond to pressure. This also links to resilience which is referred to " an ability of ecological or livelihood system to bound back from stress or shocks" (Allison & Ellis, 2001). To enhance the resilience in the Tonle Sap, it is necessary to understand how households cope with changes and the determinants in their livelihood choices.

The development of SLA leads to a broader view of sustainability to encompass other dimensions. The four key pillars of sustainability associates with social, economic, institutional and environmental factors (Carney et al. 1999), which are important in fishery management. For instance, the focus of institutional dimension is critical since the degraded or collapsed fishery resources (Allan et al., 2005; Pauly et al., 2002) is in part attributed to the governance system (Acheson, 2006; Pomeroy, 1995). The main challenges associate with addressing compliance, conflicts and resource depletion (Ayers & Kittinger, 2014; Butler et al., 2015; Evans, Cherrett, & Pemsl, 2011).

Figure 1 presents the sustainable livelihood analysis framework, illustrating the interactions between various elements such as livelihood capitals or assets, livelihood activities and outcomes, external vulnerability context, and policies and institutions. The role of assets is significant as earlier discussed and particularly in the context of Tonle Sap and war-torn Cambodia, in which the livelihood base was destroyed or weakened and households have limited adaptive capacity (Bond, 2015; Nuorteva et al., 2010). Access to assets or livelihood activities are also influenced by policies, institutions and processes. Postwar economy policies, fisheries reforms and the roles of community-based fisheries management enable access to livelihood assets and activities. Furthermore, livelihood assets or capitals permit households to make decision of livelihood choices or undertake the livelihood activities. The framework also emphasizes

on the significance of the external environment, known as vulnerability context, affecting livelihood sustainability. Trend, shock and seasonality influence households' success or failure. Understanding these external factors can help to design policies and interventions which assist people's existing coping and adaptive strategies (Allison & Horemans, 2006). For instance, various studies indicate that the livelihoods of households in the Tonle Sap are likely to be adversely impacted by future socio-economic, policy, ecological and climate change (Arias et al., 2014; Salmivaara, Kummu, Varis, & Keskinen, 2016), adding to existing poverty problems in this region which is higher than the national average (JICA, 2010).

The concept of SLA has been used to study different topics of livelihood in rural development, poverty, fisheries and natural resources management (Allison & Horemans, 2006; C. Barrett & Swallow, 2004; Ellis, 2000; Erenstein, Hellin, & Chandna, 2010; Solesbury, 2003). The approach has been popular to study resource management systems, identifying what existing systems are appropriate and why some have failed (Ferrol-Schulte, Wolff, Ferse, & Glaser, 2013). However, the main limitation is associated with the level of detail of information collected, which can be costly and labor intensive. Nevertheless, this does not undermine the value of this holistic, multidimensional approach if the livelihood intervention focuses on people-centered solution.

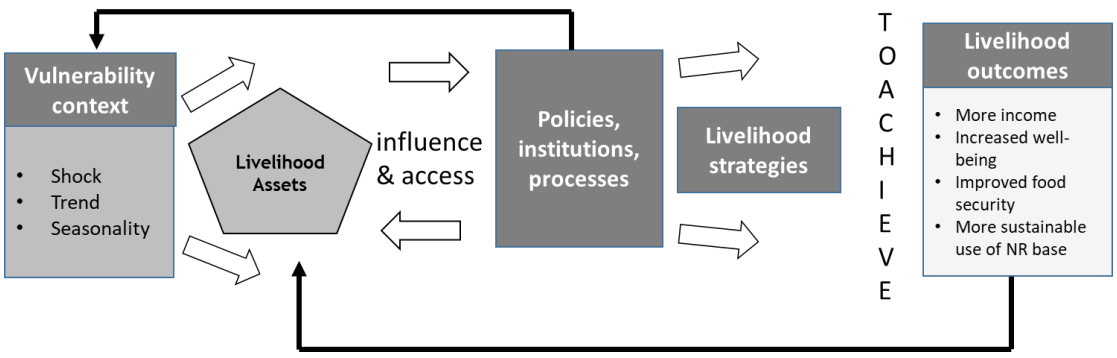

Figure 1. The Sustainable Livelihood Framework.(source: modified from UK Department for International Development)

1.4.2 Community-based fisheries management (co-management)

The failure of conventional fisheries management (Allan et al., 2005; Pauly et al., 2002) makes the co-management more appealing. The overarching issues are resource depletion and conflicts (Ayers & Kittinger, 2014; Butler et al., 2015). Co-management can be broadly defined as a shared responsibility and authority between the government and local resource users/community (Pomeroy and Williams 1994). Thus, resource users directly and formally involve in decision making and resource management process through the delegation of regulatory functions to fishers' organizations. The complexity of the socio-ecological systems requires the knowledge of more than a single agency and collaborative actions of multiple parties to effectively address the problems. This bottom-up approach is now widely recognized as a means to managing natural resources, which promote collaboration and learning, responsible resource use and rule compliance (Jentoft, 2000; J. R. Nielsen et al., 2004; Yandle, 2006). It is vital to address sustainability, efficiency and equity which exist in small-scale fisheries today (Pomeroy and Williams 1994).

Below as the summary of different aspects of co-management have been emerged to the frontline of the literature over the past decades.

- Co-management is power and responsibility arrangement between the government and local fishers/community (Pomeroy and Williams 1994). The recognition and legitimization of local fisher organizations help promote equity, even to some degrees, in the partnership arrangement and address imbalance of power and make collaboration less problematic (Berkes, 2009; Nadasdy, 2003).
- Co-management is an institutional building. The arrangement promotes closer collaboration between the community and government and other agencies,

providing opportunities for empowerment, capacity building and leadership development. Identifying appropriate local institutions and building on their strengths or establishing new ones, formulating favorable policy environment, supporting network building and feedback learning over time develop leadership and institutional capacity and economically and politically empower the impoverished majority through transfer of access of and control over resources from a few to a community at large (Pomeroy, Katon, and Harkes 2001).

- Co-management provides means of building trust and social capital. The success or survival of co-management depends on the established relationship of trust and mutual respect among partners (Pomeroy, Katon, and Harkes 2001) and social capital in general . Usually, local fisheries have low trust on the government and are rarely ready to work together (Jentoft and McCay 1995; Pomeroy, Katon, and Harkes 2001). Trust and working relationship grow through coordination, communication and consultation process which provides opportunities for clarification of needs, roles and responsibilities, concerns, and expectation of all partners.
- Co-management is a process. Co-management is not an end point, but an evolving and learning process (Armitage, Marschke, & Plummer, 2008; Pinkerton, 1992). It may take substantial time for the co-management to evolve in its development process (Pomeroy, Katon, and Harkes 2001).
- Co-management is a problem-solving and conflict resolution mechanism. Co-management enables learning among partners and increasingly addresses complex problems of the socio-ecological systems (Olsson, Folke, & Berkes, 2004; Plummer & Baird, 2013). It provides means to address conflicts among user

groups and reinforce rule compliance (Kearney 2002; Pomeroy, Katon, and Harkes 2001).

- Co-management is a governance approach in which resource users directly involve in managing and making decision about the resources which influence their livelihoods. It is considered the alternative to the centralized governance system to address ecosystem sustainability (Acheson, 2006; Pomeroy, 1995).

Co-management should not be considered as a single alternative strategy to address all problems of fisheries management, but as a set of alternative management strategies, appropriate for specific areas and situations (R S Pomeroy & Williams, 1994). While co-management is not a universal panacea, more experience and research are needed to understand the conditions leading to successful fisheries co-management. The International Centre for Living Aquatic Resource Management (ICLARM) and Institute of Fisheries Management and Coastal Community Development (IFM) developed a research framework for institutional analysis of co-management, adapted from theoretical and empirical work on the Institutional Analysis and Development (IAD) framework (ICLARM & IFM, 1998). The aim of the analytical framework is to enable the systematic and comparative analysis of co-management institutions, which allows generalizations to be made on the conditions of successful co-management. The research framework incorporates the concepts of common property resources, co-management, institutional analysis, and rights and rules.

A graphical representation of the institutional analysis framework is given in Figure 2, which has three major components:

- Institutional Arrangement Analysis: This component links contextual variables characterizing key attribute of the resources (biological, physical) and the resource users (technology, market, social, cultural, economic, political) with the

management institutional arrangements (rights and rules). The relationship between contextual variables and institutional arrangement influence the actions of resource users and authorities in coordinating and cooperating in fisheries resource governance, management and use. This associates with incentives and disincentives which shape the patterns of interactions and behaviors between co-management partners.

- Co-management Performance Analysis: The second component focuses on the outcomes. The outcomes, in turn, influence, the contextual variables and behaviors of co-management partners (i.e. resource users, authorities and other stakeholders). The performance analysis enables the evaluation of the co-management institutional arrangement associating with management efficiency, equity and sustainability of resource utilization.
- Characteristics of Successful Co-management Institutional Arrangements: The last component, the most important aspect, concerns with identification of conditions and processes which lead to successful long-enduring fisheries co-manent arrangements.

Across developing countries, the co-management is now considered as a mainstream approach to small-scale fisheries management (Evans et al., 2011). An assessment of the impact of fisheries co-management in developing countries by Evans et al., (2011) indicates a positive trend associating with both the outcome and process indicators. On the outcome measures, only resource access shows a negative trend while other four indicators, namely resource well-being, fishery yield, household well-being and income, indicates positive change. Associating with co-management process indicators, the top five measures as participation, influence, rule compliance, control over resources and conflict report a positive trend especially across Asian countries for both

marine and inland fisheries. Despite some reported challenges, the co-management approach shows more on the success than failure in small-scale fisheries particularly in the Asian context.

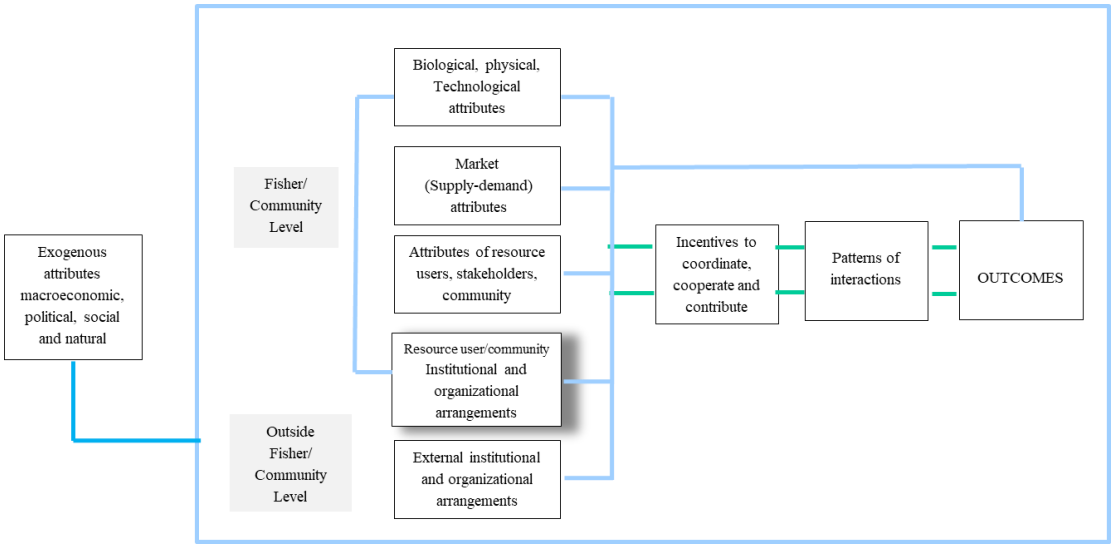

Figure 2. Research Framework for Institutional Analysis of Fisheries Co-Management. (source: modified from (ICLARM & IFM (1998))

Across developing countries, the co-management is now considered as a mainstream approach to small-scale fisheries management (Evans et al., 2011). An assessment of the impact of fisheries co-management in developing countries by Evans et al., (2011) indicates a positive trend associating with both the outcome and process indicators. On the outcome measures, only resource access shows a negative trend while other four indicators, namely resource well-being, fishery yield, household well-being and income, indicates positive change. Associating with co-management process indicators, the top five measures as participation, influence, rule compliance, control over resources and conflict report a positive trend especially across Asian countries for both marine and inland fisheries. Despite some reported challenges, the co-management approach shows more on the success than failure in small-scale fisheries particularly in the Asian context.

1.5 Specific objectives

The co-management can be conceptualized as an institution intervention in the SLA framework to achieve desired outcomes of fishing communities in the Tonle Sap. The livelihood of fishing households and their adaptive strategies depend on the vulnerability context, the interactions of livelihood assets and activities and the performance of co-management arrangement (community fisheries). Here, the overall goal of this research is to assess the livelihood strategies of fishing communities in the Tonle Sap in the face of various drivers of change around the lake, by integrating SLA and co-management perspectives in the analysis.

The specific objectives of the research are to:

1. assess spatial and temporal characteristics of livelihood strategies of post-conflict Cambodia from 1999 to 2013;
   1.1 identify livelihood cluster and characteristics in Cambodia, associating with crops, livestock, fishery, forestry and nonfarm.
   1.2 Assess spatial and temporal variations of livelihood strategies in Cambodia from 1999 to 2013, associating the five strategies.
2. analyze the current livelihood choices and the determinants of household total income;
   2.1 identify factors (associating with livelihood assets) affecting households' livelihood choices.
   2.2 identify factors (associating with livelihood assets) affecting households' total income.
3. measure the economic impact of adaptive responses to future scenario change in the Tonle Sap;

3.1 analyze the net income from current livelihood strategies of households in the Tonle Sap.

3.2 predict the economic impact under future scenarios in the Tonle Sap (i.e. a. fish decrease, b. more farm land, c. urbanization, and d. stagnation).

4. assess the impact of community fisheries and the determinants in the Tonle Sap.

4.1 assess the impact of community fisheries associating with different ecological zones and community size (area) in the Tonle Sap.

4.2 identify factors influence in the impact associating with ecological zone and community size in the Tonle Sap.

CHAPTER II: MATERIALS AND METHODS

2.1 Study area

2.1.1 Study area for livelihood dynamics and determinants

The study area for understanding livelihood dynamics and identifying the determinants of household's choices and income focuses on entire Cambodia, which includes Cambodia's all regions of Plateau/Mountain, Plain, Coast, and the Tonle Sap. Covering the entire country helps to better understand the variations of livelihood strategies and provides a broader picture of household's choices and responses to socioeconomic, policy, ecological and climate change. That broader context has its implications on the Tonle Sap, especially in terms of the linkages between livelihoods, natural resources and post-conflict development. For instance, how the macro change influences livelihood resources and strategies, institutional processes and household's economic performance.

Similarly, the analysis of the determinants of livelihood strategies and income from the national setting provides useful insights and comparative views how household's choices and economic performance in Tonle Sap may differ from the national benchmark.

2.1.2 Study area for economic impact to future scenario change

The location for the assessment of economic impact is in Pursat province which is situated in northwestern Cambodia. It is one the three provinces in the Tonle Sap (Pursat, Battambang and Kampong Thom) previously identified as important case studies by the Belmont Forum's Tonle Sap climate change project. This project is a consortium of 18 different institutions worldwide, including Cambodia, France, US and Canada, seeking to improve income and productivity of Tonle Sap fisheries in the face of climate change. Pursat has one of the largest coastlines along the Tonle Sap Lake and is con-

nected to an important tributary and fishing location. The study area focuses on 26 villages located in three districts of Pursat province (Krakor, Kandieng, and Bakan) (Figure 6).

2.1.3 Study area for impact of CFis

Battambang and Kampong Thom exhibit an important fishing-farming ecology in the Tonle Sap and therefore were selected to study the impact of CFis. While fishing is fundamental in both zones, Kampong Thom reflected a more significant role of farming in which large-scale private irrigation structures were built up to support the rice production systems. In contrast, households in Battambang still largely depend on fishing as their primary livelihood. A total of 26 CFis located in both provinces was used to assess the impact of CFis and comparative study (Figure 13).

2.2 Cambodian Socio-Economic Survey (CSES)

The Cambodia Socio-Economic Survey (CSES), a nationwide representative survey conducted by the National Institute of Statistics, Cambodia. The survey was first conducted in 1993/1994 aiming to collect statistical information about living conditions and the extent to poverty of the Cambodian population. It was used to monitor the Cambodian National Strategic Development Plan (NSDP) and to measure progress towards global development goals (i.e. Millennium Development Goals and Sustainable Development Goals). The survey was conducted intermittently between 1993/1994 to 2004 and it was until 2007 that it has been annual. The CSES has experienced a significant development in the first few surveys associating research design, sampling and questionnaire in order to better address the needs of different users and enable comparative studies.

The CSES 1999, 2003/2004, CSES 2008 and CSES 2013 were chosen to study the dynamics and determinants of livelihood strategies. For the study on livelihood dynamics, four years (1999, 2003/2004, 2008 and 2013) were selected as the research objective was to investigate the spatial and temporal variations of livelihood strategies. Another important reason is that variables in the selected years are appropriate for time-series analysis. The determinants of livelihood choices and income (objective 2) focuses on 2013 survey as the study was aimed what factors influence households' income and decision to participate in livelihood activities at present.

Consolidating data into a single data matrix ready for analysis took some efforts and sometimes was challenging. For instance, datafile for each year is not in a single file, but a separate main category which is sometimes inconsistent in structure and makes it difficult to be merged by household reference number. The value of some variables are not consistently coded, for example land size can be coded in square meter, acre, hectare, or other. In some cases, there are different in coding system across years. Care must be taken when trying to consolidate data across years. Even effort being taken to improve consistency of the survey, there are still some small variations and therefore coding system and operational manuals should always be referred carefully for each year from which the data is extracted.

For this study on livelihood dynamics, the total number of household observations is 28,388 across the four years. The analysis of livelihood determinants was based a total of 3,138 households.

2.3 Household and Community Fisheries surveys

Data collection is part of the project funding by the Belmont Forum's Tonle Sap climate change project. Additional funding was supported by Open Society Foundation which partly funded the fieldwork in Kampong Thom. Three provinces of the Tonle

Sap (Pursat, Battambang and Kampong Thom) were identified for household and CFi surveys. For the household survey, the goal is to gain understanding the characteristics, livelihoods, and opinions associating with the changing fishery resources. The goal of CFi survey was to assess the performance of CFi in managing fishery resources in Tonle Sap lake.

For the case study on economic impact to future scenario change, a total of 181 households in Pursat were randomly selected to complete the surveys. 26 CFis were selected for the study of the determinants of impact of CFis with a total of 437 respondents.

2.4 Overview of statistical analyses

2.4.1 Case study on livelihood dynamics

The main objective of the study on livelihood dynamics was to examine the livelihoods of Cambodian households from multiple resource dependence (crops, livestock, fishery, forestry and nonfarm self-employment) during the post-conflict recovery by looking at spatial and temporal variations of the livelihood strategies from 1999 to 2013.

Non-metric multidimensional scaling (NMDS) and cluster analysis were performed to analyze the livelihood strategies characteristics, and spatial and temporal variations. ArcMap was also used to display clustering results and spatial and temporal patterns of livelihood classifications.

2.4.2 Case study on livelihood determinants

The aim of the study was to use various socio-economic variables taking from the CSES 2013 to identify the determinants of livelihood choices and total income for households in Cambodia. In the first stage of analysis, household net income from each

livelihood strategy (crops, livestock, fishery, forestry and nonfarm self-employment) was calculated using standard income method earlier mentioned.

Multinomial logit regression (MNL regression) was used to identify the determinants in livelihood strategy choice because the choice is a polychotomous variable. In the MNL regression, crop strategy was set as reference strategy as majority of Cambodian rural labor force engaging in crop production strategy. Furthermore, in order to see the determinants in household's total income, ordinary least-squares regression (OLS regression) was carried out with the same set of explanatory variables.

2.4.3 Case study on economic impact of future scenarios

The objective of the study was to investigate the economic impact of households' adaptive responses to future socioeconomic, policy, ecological and climate change in the Tonle Sap. The four future scenarios conditions were set as below:

- Scenario A (Less fish) – A 50% reduction in fish production in Tonle Sap Lake.
- Scenario B (More farm land) – An increase in agricultural land due to changes in flood plain habitats.
- Scenario C (Urbanization) – The creation of more jobs due to urbanization and increased economic activities in urban centers, particularly in Phnom Penh.
- Scenario D (Stagnation) – The status quo is retained, i.e., same situation as today.

The analysis was based on household survey in Pursat province, one of the five provinces in the Tonle Sap, and involved two steps: (i) estimate net income from current activities, and (ii) estimate economic impact from future scenarios.

To estimate net income from current livelihood activities, benefits and costs data collected from the field survey were used for the calculations and livelihoods were divided into 3 groups:

- Group 1 = Fishing only
- Group 2 = Fishing + Farming and/or Off-farm work
- Group 3 = Non-fishing work

To estimate economic impact under future scenarios, four hypothetical conditions were proposed:

- Scenario A (Less fish) – A 50% reduction in fish production in Tonle Sap Lake.
- Scenario B (More farm land) – An increase in agricultural land due to changes in flood plain habitats.
- Scenario C (Urbanization) – The creation of more jobs due to urbanization and increased economic activities in urban centers, particularly in Phnom Penh.
- Scenario D (Stagnation) – The status quo is retained, i.e., same situation as today.

For each scenario A-D, each respondent provided: a) whether they would continue with their current livelihood strategy (i.e., allocate same amount of time or resources to each livelihood activity); and b) how they would reallocate their time to different livelihoods options. If in (a) the respondent indicated no change in current allocation, then current livelihood net income was assigned to that scenario.

The net income of each livelihood activity the respondent chose for each scenario was assigned based on the respondent's current livelihood net income. If an individual chose a new livelihood that he/she did not currently participate in (i.e., no current net income data was available for that activity), then an averaged net income for that livelihood activity was assigned. For detailed information on the methods and calculations, see section 5.2.

2.4.4 Case study on impact of CFis

This study aimed to assess the impact of CFis associated with different ecological zones of the Tonle Sap and the size of community managed area, seeking to understand the links between management arrangements and the ecological determinants.

The analysis involved two steps. First, the classification and regression trees (CART) analysis (Breiman et al., 1984) was carried out to identify the impact of CFi in association with ecological factors of the Tonle Sap and the size of the community area. Second, logistic regression was implemented to find the determinants of the impact of the CFi based on the CART model results by using a set of explanatory governance variables.

CHAPTER III: LIVELIHOOD DYNAMICS IN THE DEVELOPING WORLD: EXPERIENCE FROM POST-CONFLICT CAMBODIA

Ratha Seng[1,2,*], Robert S. Pomeroy[3], Sovan Lek[1,2]

1. Laboratoire Evolution & Diversité Biologique, Université Paul Sabatier – Toulouse III, 31062 Toulouse, France.

2. Research and Development Center, University of Battambang, 020302 Battambang City, Cambodia.

3. Connecticut Sea Grant/Department of Agricultural and Resource Economics, University of Connecticut-Avery Point, 06340-6048 Groton, CT USA.

* Corresponding author's email address: ratha.seng@gmail.com

Running head: LIVELIHOOD DYNAMICS IN CAMBODIA

3.1 Introduction

In developing countries and those affected by conflicts, a significant percentage of the population relies on land, water, forests and other natural resources. In conflict-affected countries, it is estimated that approximately 60 to 80 percent of household income are from agriculture and natural resources (Bruch et al., 2012). The armed conflicts usually destroy the livelihood systems and households are forced to adopt coping strategies which are sometimes environmentally unsustainable.

Revitalizing livelihoods is critical during the recovery as it can either promote development and peace or fuel violence or new forms of conflict. The potential sources of conflicts are associated with resource access and ownership (Andre & Platteau, 1998). In some cases, the conflict is driven by social groups who work together to take advantage of the weakened institutions and of peace by further devastating the economy and local livelihoods through unsustainable and illegal resource extractions (Oglethorpe et al., 2002). On the pathway of reconstruction, war-torn countries may adopt economic policies that emphasize accelerating rapid economic growth, resource extraction and attracting foreign investments by neglecting long-term livelihood and ecological purposes of the natural resources. This pattern was also observed in the damaged economy of post-war Japan where maximizing natural resource harvesting was initially prioritized to address immediate needs of the country (Jones & Scheiber, 2015; Makino & Matsuda, 2005; Yoshimura, Omura, Furumai, & Tockner, 2005).

This article examines the livelihoods of Cambodian households from multiple resource dependence during the post-conflict recovery by looking at spatial and temporal variations of the livelihood strategies from 1999 to 2013. Given multidimensional links of peacebuilding, economic growth and natural resources, Cambodia shares important

historical and current characteristics and draws interest for an investigation of the dynamics of livelihood change at the micro level.

The linkages between farm/resource-based and nonfarm strategies have been popular among scholars and development practitioners, particularly in a transitional and developing economy (Djurfeldt, 2012; Fritzsch, 2012; Hitayezu, Okello, & Obel-Gor, 2014; T. T. Nguyen, Do, Buhler, Hartje, & Grote, 2015). The study adds to existing literature on the livelihood diversification and, hence, provides a good understanding of the socio and ecological interactions and how households might cope with various drivers of change over time. Another specific contribution of this study is related to the role of nonfarm self-employment in rural economy in which the sector is recognized to play a vital role in addressing rural-urban migration and contributing to national income growth (Lanjouw & Lanjouw, 2001).

The research differs from previous studies in two important aspects. First, while some studies focus on a particular area, especially by Nguyen et al. (2015) and Rahut et al. (2012) in the context of Cambodia, here the analysis covers the entire country and thus contributes to the generalization of the findings of the livelihood strategy patterns. Second, the analysis during the 15-year period from 1999 to 2013 provides a more dynamic picture of the livelihood strategies moving from post-war and closed-economy period to an open and market-based system.

The combination of temporal and cross-sectoral analysis provides a useful basis for determining and understanding livelihood change and other driving force of variations over time. By doing so, this study offers policy makers useful information to feed into development initiatives, for improving the efficiency of policy interventions, and for sustaining peace.

Post-Conflict Cambodia and Livelihoods

Cambodia is a small and one of the least developed countries in Southeast Asia. Once a center of the glorious Khmer Empire, Cambodia has struggled for independence, peace, and stability over the past centuries. Cambodia's history has been uneasy periods of the French colonization (1863-1953); of the Indochina War until 1975; one of the world's most murderous regimes, the Khmer Rouge (1975-1979); and of civil war until the Paris Peace Accord in 1991. Despite returning to peace in 1991, Cambodia continued to experience some armed conflicts among political fractions and between the government and the Khmer Rouge forces. It wasn't until 1998, when the remaining force of the Khmer Rouge dropped off their weapons, that the Cambodian people were able to realize the long-awaited dream of full peace after decades of wars and bloody conflicts.

On one hand, Cambodia shares many similarities with other post-conflict or war-torn states including being at a low level of economic development, depleted physical and human capital, highly resource and aid dependent, and limited capacity to prevent economic failure and sustain peace. On another hand, Cambodia might be a distinct case. With one-third of the population killed during the Khmer Rouge regime between 1975 to 1979, the conflict prolonged for another two decades. Cambodia started from an extremely low starting point and the country was almost completely destroyed. Experience from Cambodia is not just about a post-conflict, but a 'post-post-conflict'. That is because peace was not being realized after one conflict was ended and it always returned to a new form of conflict until 1998.

Building a post-conflict Cambodia could be more challenging when one of every 236 Cambodians is an amputee (Human Rights Watch & Physicians for Human Rights, 1991) and the country is classified as one of the world's most contaminated with

landmines and explosive remnants of wars (ERW). Landmines remain problematic despite many years of demining efforts, which continue to threaten the life of the Cambodian people and constrain land accessibility by rural population, especially for livelihoods.

Since the restoration of peace, Cambodia has experienced a period of rapid growth. Between 1999 to 2013, Cambodia's economy has grown at an average rate exceeding 8 percent per annum. The period from 1999 to 2008 was particularly fast, achieving a two-digit economic growth rate, placing Cambodia among the world's top performers and as one of only 46 countries which have achieved an average 7 percent annual growth rate for 14 consecutive years (Guimbert, 2010). The Cambodian growth rate is one of the fastest among post-conflict and developing economy standards, and only below a few high performance countries such as China, Hong Kong and Singapore for some selective decades since the 1960s (Guimbert, 2010; Hill & Menon, 2014). Furthermore, Cambodia has tripled income per capita over the past two decades and recently graduated to lower-middle income economy. Meanwhile, the poverty rate has declined sharply from the early 1990s of more than 50 to 20 percent in 2011 (World Bank, 2014).

The growth rate has resulted in rapid structural change. During the early 1990s, Cambodia was primarily engaged in subsistence agriculture, dominated by rice, and its allied activities such as forestry and fishery. Almost 80 percent of total labor force is engaged in agriculture (Acharya et al., 2003). Although agriculture continues to grow, its share of GDP has been on the decline from over 50 percent to just about 30 percent over the past two decades (World Bank, 2015a) and the share is offset by increasing role of services and industry which is principally dominated by tourism, garments, and construction. Cambodia's economic recovery policies aim at promoting rapid growth

rather than improving resource governance and protecting property rights and tenure. In that sense, Cambodia prioritizes the allocation of arable land to business tycoons and foreign investors in the form of Economic Land Concessions over the landless and land-poor families under the Social Land Concessions program (Neef et al., 2013; Vrieze & Naren, 2012).

A number of policies are formulated to attract foreign investments and accelerate growth including the Open Sky Policy for the tourism sector, adoption of investment law and incentives, and the establishment of special economic zones (SEZs) in mid-2000s. This resulted in rapid urbanization in some areas of the country. At the same time, there is a rapid increase in the level of rural-urban migration. For instance, Phnom Penh's population has increased by 70 percent from about 1 million in 1998 to 1.7 million in 2013 (Asian Development Bank, 2014). A study in 2011 in 375 villages across Cambodia reveals that half of rural migration is to Phnom Penh and one-third is to other countries, mainly Thailand (MoP, 2012).

3.2 Materials and methods

3.2.1 Data source and study area

Data for this study was derived from the Cambodia Socio-Economic Survey (CSES), a nationwide representative survey conducted by the National Institute of Statistics, Cambodia. The survey was first conducted in 1993/1994 aiming to collect statistical information about living conditions and the extent to poverty of the Cambodian population. It was used to monitor the Cambodian National Strategic Development Plan (NSDP) and to measure progress towards global development goals (i.e. Millennium Development Goals and Sustainable Development Goals). The survey was conducted intermittently between 1993/1994 to 2004 and it was until 2007 that it has been annual. CSES 1999 (4^{th} survey) was selected as the first year in this study because it was the

year that Cambodia marked the real national unity after decades of conflicts. The CSES 2003/2004 (5th), CSES 2008 (7th) and CSES 2013 (13th) were chosen to understand the temporal change in household's livelihood strategies. Sampling procedures and field operations manual for all surveys were detailed in NIS (2016). This study focused on all provinces in Cambodia, featuring different ecological zones such as upland, plain and coastal areas.

For the four periods of time, the total number of household observations is 28,388. The individual household observations were pooled into district-level data using median values. In this study, the district was the unit of analysis, which was further elaborated below.

From the socio-economic survey data, five categories of households' livelihood portfolio were selected: (1) crops, (2) livestock, (3) fishery, (4) forestry and hunting, and (5) self-employed nonfarm activities. The selection of livelihood strategies was based on existing literature showing that households pursue a variety of livelihood activities as a survival strategy associating with agriculture, natural resources and nonfarm (Babulo et al., 2009; Ellis, 2000; Ø. J. Nielsen, Rayamajhi, Uberhuaga, Meilby, & Smith-Hall, 2013; Soltani, Angelsen, Eid, Naieni, & Shamekhi, 2012). Furthermore, the role of nonfarm livelihoods is fundamental after the recovery period and while the conflict-affected countries are en route to development. The empirical evidence from Africa and Asia confirms growing role of rural nonfarm income during the transformation process (Canagarajah, Newman, & Bhattamishra, 2001; Kung & Lee, 2001)

According to Yu & Fan (2011), Cambodia is divided into four main agro-ecological zones, namely Plateau/Mountain, Plain, Coast, and Tonle Sap. The Plateau/Mountain zone includes the Northeast Cambodia and Kampong Speu province in southwest bordering the coastal provinces is dense in forests and with low population density. The

coastal zone consists of a very small portion of the country located in the Southwest. Crop cultivation, mostly rice, is mainly in the Northwest-Southeast corridor, known for a high population density. Thus, the Northwest areas bordering Thailand around the Tonle Sap zone and Southeast areas bordering Vietnam in the Plain zone are the main producers of rice.

3.2.2 Data analysis

The analysis of livelihood strategies of households involved several steps. In the first stage, household net income from each livelihood strategy was calculated. As evidenced in recent literatures in which income share is used to measure standard of living, poverty and livelihood strategies, net income from each livelihood strategy was calculated to gain an understanding of livelihood dynamics and choices of household (Babulo et al., 2008; de Sherbinin et al., 2008; Soltani et al., 2012). The income share method has been long recognized as an important factor to measure economic performance, especially in the evaluation of household's livelihoods and to enable direct and straightforward comparison across several different years. In computing the net income from each livelihood strategy, a standard income method was followed as below:

$$\text{Net Income} = \text{Total Revenue} - \text{Total Cost}$$

The value of income or revenue is nominal. Net income in this study is equivalent to net profit accounting for both variable production and selected fixed costs, but not all. Data on some fixed expenses (depreciation) at household level were not available particularly associating with valuation of assets and their cost classification. Total revenue was calculated as Quantity of Production x Selling Price. Total cost was the sum of all cost items of each livelihood strategy.

Net income from crops: Revenues from crop cultivation were from all types of crops, fruits, and vegetables. The total cost of crop inputs comprised of expenditure in

seeds & seedlings, fertilizers, hired labor, transportation, technical support, and other payments.

Net income from livestock: It included revenues from both livestock and poultry production comprising livestock and poultry sales and by-products. The production expenditure items such as feed and feed supplements, hired labor, veterinary services and medicines, service payment for technical support and transportation cost were aggregated to obtain the total cost for livestock.

Net income from fishery: Total revenue from fishery was made of revenue from aquaculture and proceeds from captured fishery. Similar to livestock, the total cost for fishery consisted of breeding stock, feed, hired labor, fuel, repair and maintenance, payment for technical support, boat rent and transportation.

Net income from forestry and hunting: The total revenue from forestry and hunting were from resource extracting activities including timber (charcoal, firewood, timber and others) and non-timber (juices, root crops, honey, herbs, wild animals or birds and others) forest products. The total cost was made up of feed, fuel, transportation, hired labor, rents, tools and equipment expenses.

Net income from self-employed nonfarm activities: The nonfarm activities associate with enterprise and business activities in secondary and tertiary sectors. Nonfarm revenues were proceeds from economic activities associating with merchandising, manufacturing and services. Total cost includes cost of sales or goods sold, variable production costs, fixed expenses, overhead and other operating costs.

Then, household-level net income data from each livelihood activity was grouped into district-level data. The total 28,388 household observations were then summarized into 578 district observations using median values for the analysis.

All the statistical analysis of the data was performed using R 3.2.5 and mapping visualization of spatial patterns of livelihood strategies was carried out through ArcMap 10.2. To analyze the livelihood characteristics, non-metric multidimensional scaling (NMDS) was performed to measure the district dissimilarity by using the 'metaMDS' function in vegan package (Oksanen et al., 2016). The NMDS technique enabled the district points and livelihood strategies to be plotted in ordination space. In the two-dimensional NMDS diagram, the distance between each district point indicates the dissimilarity of the samples. Then, cluster analysis performing hierarchical clustering based on the ward agglomerative method on the results of the NMDS's solutions was undertaken to identify groupings of district points which have surface similarity (R Core Team, 2016). The results were placed into ArcMap to display clustering results and spatial patterns of net income classifications. Kruskal-Wallis test was performed to test for significant differences among clusters and of variations among years, followed by post-hoc tests using R's function kruskalmc in package *pgirmess* (Giraudoux, 2016).

3.3 Results

3.3.1 Household cluster and characteristics

With the five livelihood strategies (crops, livestock, fishery, forestry and nonfarm), the NMDS ordination with a stress value of 0.15 was found. The hierarchical clustering of 578 samples between 1999 to 2013 identified four distinct clusters (Figure 3a and Figure 3b). Cluster 1 (23% of all samples) was characterized as crops and livestock dependence. Cluster 2 (40%) and 3 (19%) were more diversified and natural resource-driven. Cluster 2 was dominated by crops and its allied activities such as forestry, fishery, and livestock whereas cluster 3 was principally contributed by natural resource income, including forestry and fishery. Finally, Cluster 4 (18%) was associated with nonfarm and livestock.

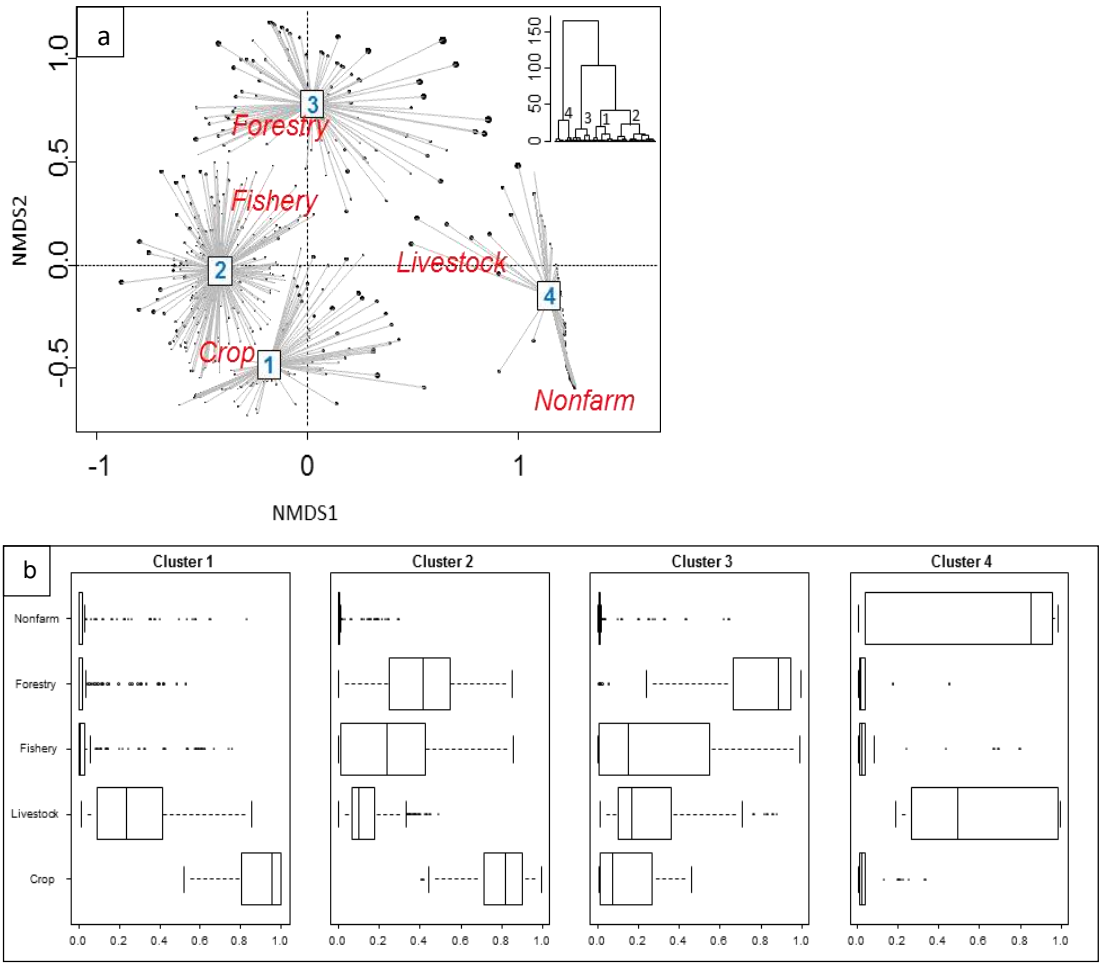

Figure 3. Non-metric multidimensional scaling (NMDS) ordination of the district data based on the five livelihood strategies; a, ordination map of dimensions 1 & 2 of NMDS showing samples clustered by hierarchical clustering into four clusters and the relating livelihood strategies; b, boxplots showing contribution of each livelihood strategy to each cluster on the NMDS map

The NMDS ordination map (Figure 3a) showed clearly along the first axis the opposition between livestock and nonfarm on the one hand and to the forestry, fishery and crops on the other hand. The non-parametric multiple comparison Kruskal-Wallis test revealed a significant difference between the four clusters (χ^2=356.49, df=3, p<0.001). The post-hoc pairwise comparison tests showed a significant difference between each cluster. Axis 2 showed the opposition between natural resources (forestry and fishery) to the land-based one (crops and nonfarm). The Kruskal-Wallis test revealed a significant difference between clusters (χ^2=375.74, df=3, p<0.001). The pairwise comparison indicated that cluster 1, 2 and 3 are significantly different. No significant difference was observed between the cluster 2 and 4.

3.3.2 Temporal and spatial trend of livelihood strategies

The variation of livelihood strategies was significantly explained along the axis 2 of the NMDS diagram (Kruskal-Wallis test, χ^2=102.95, df=3, p<0.001) (Figure 4). The post-hoc analysis revealed the significant difference between 1999-2004, 1999-2013, and 2008-2013. No difference was observed between 2004 and 2008. Overall, from 1999 to 2013, there was a clear trend from land-based activities (crops) towards more natural resource dependence involving fishery and forestry. It thus illustrated that more and more households were turning towards fishing, aquaculture, timber and non-timber forest products.

Table 1. Cluster composition and share from 1999 to 2013.

Cluster	**1999**		**2004**		**2008**		**2013**	
	n	**%**	**N**	**%**	**n**	**%**	**N**	**%**
C1	81	54	20	12	27	24	4	3
C2	27	18	89	54	39	35	79	51
C3	14	9	30	18	18	16	46	30
C4	27	18	25	15	27	24	25	16
Total	**149**	**100**	**164**	**100**	**111**	**100**	**154**	**100**

The geographical cluster maps (Figure 4) provide a clearer picture of the temporal trend of the spatial patterns of livelihood strategies. The patterns had shifted from basic agricultural and land-based activities of crops and livestock (cluster 1) to more diversified strategies of farming and natural resources (cluster 2 and 3). Natural resource dependence became more evident in 2013 in which cluster 3, dominated by forestry, had risen. As shown in Table 1, districts driven by crops and livestock had declined from 54 percent in 1999 to 3 percent in 2013, while districts depending on forestry and fishery income had increased from 9 percent in 1999 to 30 percent in 2013. Nonfarm activities remained stable across the four years despite some marginal change in 2008.

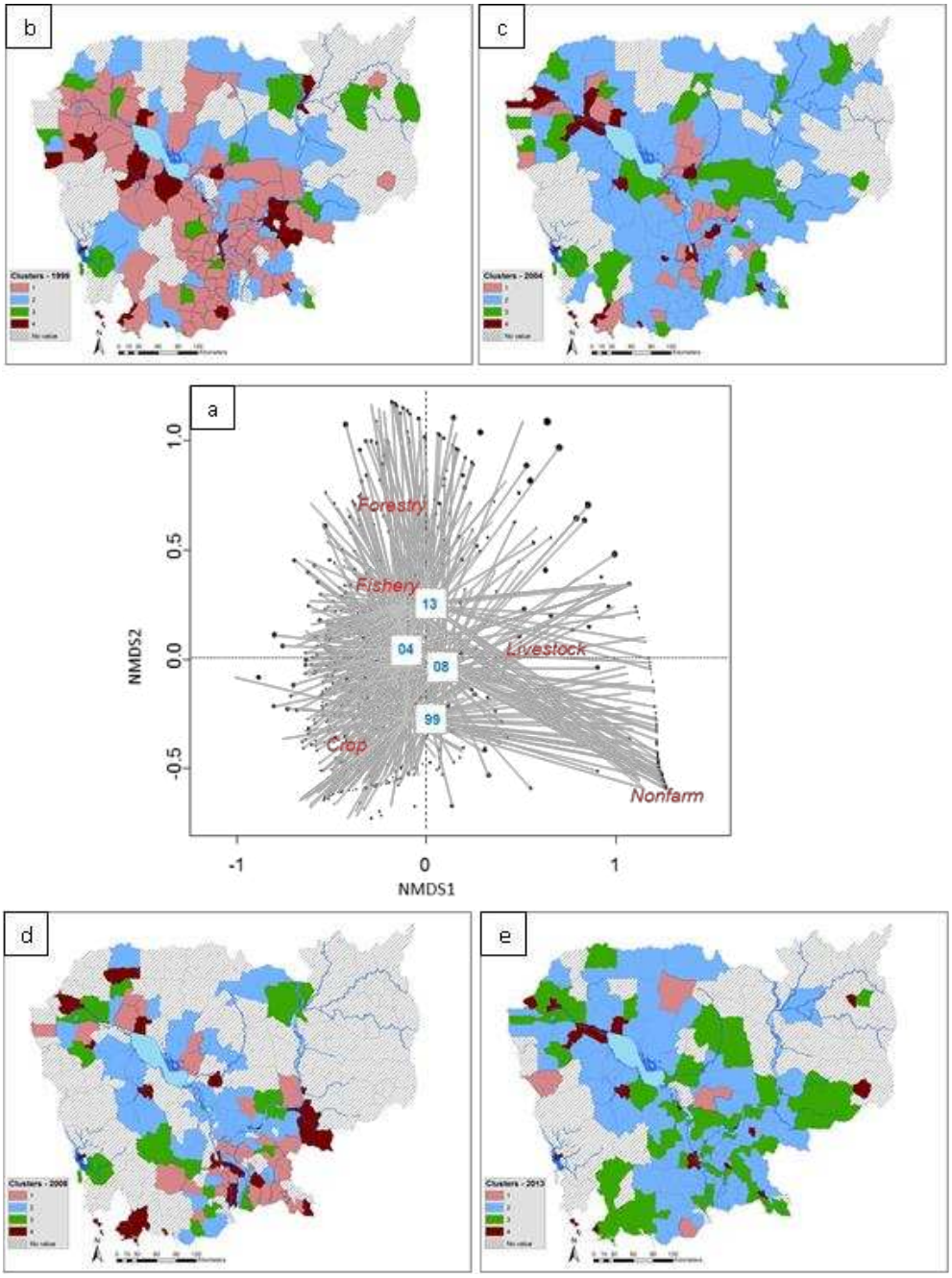

Figure 4. Temporal and spatial patterns of livelihood strategies based on results from NMDS and ArcGIS Mapping; a, temporal trend based on NMDS results; and spatial characteristics of livelihood strategies in 1999 (b), 2003-2004 (c), 2008 (d) and 2013 (e).

3.4 Discussion

3.4.1 Livelihood diversification and spatial dependence

The results revealed four distinct livelihood groups associated with farming, natural resource, and nonfarm activities. The cluster 1 is highly dependent on land for crops as a primary livelihood strategy. Livestock is also integrated into household's choice of

strategy or being adopted by other households depending on a range of socio and ecological factors. For cluster 2 and 3, the livelihood strategies are mixed but turn towards more resource dependence. The cluster 2 is highly dependent on both land and natural resources. Land is an important capital for crops and other activities such as livestock and aquaculture. In addition, households also rely on capture fishery and watershed forests along the plain area, mountains, and foothills as a way for survival. Cluster 3 is those districts which are highly dependent on natural resource income, especially forestry. Timber and non-timber forest products contribute significantly to household's income share and access to those resources is more economically important than the land ownership. Finally, cluster 4 was concerned with districts less dependent on land resources, which are characterized as nonfarm and livestock.

The pattern explained the relative strength of links between the livelihood strategies and the ecosystem. People rely on products, services, or land from nearby resource areas and establish the conditions for actions to satisfy their livelihood needs. The rice fields, rivers and forests have supported the livelihoods of Cambodian population for centuries. Local people depend on the traditional ways of living from rice farming, fishing, and extracting forest resources, mainly for subsistence purposes. Households become more or less diversified (i.e. crops, fishery, forestry) depending on the degree of interactions of the adjoining ecosystems. The results show that Cambodian households remain highly dependent on agriculture-related strategies. The sector employs more than half of Cambodia's total labor forces (Yu & Diao, 2011). On top of this, crops play a prominent role to varying degrees, contributing to clusters 1, 2, and 3, and accounting for more than 80 percent of the total samples.

For instance, Barrett et al. (2001) and Reardon et al. (2007) pointed out the geographical attributes among all other incentive and capacity variables as one of the key

elements in driving diversification into nonfarm income by households. The proximity to urban centers drives up demand and consumption for nonfarm products and services stirred up by the growth of other sectors such as wage employment, construction, tourism or industry for the case of Cambodia. Another study in Eastern Africa by Cecchi et al. (2010) also stressed the correlation between agro-ecological attribute with different livestock and farming system. The linkage of environmental resources with the choice of livelihood strategies is also evidenced in recent studies in Cambodia. Nguyen et al. (2015) confirmed the significant impact on the level of environmental income by the distance to the extraction area. Similarly, Rahut & Scharf (2012) revealed the positive and negative correlations of farming and nonfarm strategies with different geographical zones such as Phnom Penh, Coast, and Plateau/Mountain.

3.4.2 Primary sector is substantial, but at risk

Over the past two decades, the primary sector (crops, livestock, fishery, and forestry) has played a crucial role in household's income. In cluster 1, crops and livestock contribute 79 percent and 19 percent, respectively, to cluster's income share. In the other two clusters in which livelihood are more diversified and associating to other types of natural resources such as water and forest, the findings indicate a relatively high dependence on environmental income or households seeking to diversify other sources of income for their livelihood. In cluster 2, crops contribute 52 percent to total income share, followed by forestry (26%), fishery (15%) and livestock (6%). On the other hand, the contribution from forestry is as high as 69 percent in cluster 3, while livestock, fishery, and crops make up a share of 13 percent, 12 percent and 6 percent, respectively. The results suggest the importance of land, water, and forest to the majority of the Cambodian population in the post-conflict era especially in rural areas and

indicate the high level of vulnerability if there is change in the resource systems. Combined fishery and forestry, the overall contribution of both strategies in all clusters is 31 percent, which includes the aquaculture activities. That is consistent with recent studies in Cambodia and other developing countries. Nguyen et al. (2015) shows that the contribution of environmental income to household's total income is 27 percent, in which 19 percent is from capture fishery and 8 percent from forestry resources. Similarly, a study of 24 developing countries of 8,000 households by Angelsen et al. (2014) indicates the contribution of environmental income to household total income is 28 percent.

Even though income from wage employment and remittances is not included in this study, the average contribution of forestry income of 31 percent for the entire country and 69 percent in cluster 3 are still much higher than the findings by Nguyen *et al.* (2015). Further, it may be consistent with other global studies, in which overall contribution of forestry income is 24 percent (20 percent in Asia, 21 percent in Africa and 28 percent in Latin America) (Angelsen et al., 2014). As the forestry income share varies across sites, other specific areas constituting high forest income reliance are in Bolivia (64% percent) and Cameroon (59% percent) which have a similar pattern with cluster 3 (Duchelle, Almeyda Zambrano, Wunder, Börner, & Kainer, 2014).

The nonfarm self-employment is skewed towards cluster 4, comprising 61 percent and livestock constituting 35 percent. This shows that the role of nonfarm activities is still marginal relative to other strategies. On one hand, the study explains the importance of agriculture and natural resources to Cambodian livelihoods. On the other hand, however, it raises uncertainties on the future of the resource-dependent households over the issue of sustainability, especially relevant to natural resource use and extraction.

Similar to other war-torn country, Cambodia is known for weak formal institution and enforcement of rules, particularly when dealing with environmental resources (Clements et al., 2010; Travers et al., 2011). Within the forestry sector, for example, Cambodia is classified as having among the world's highest rate of deforestation. A study by Hansen et al. (2013) on global forest cover change between 2000 to 2012 showed that Cambodia has one of the world's top forest loss. The overall trend of environmental resource availability is on the decline as confirmed by several recent studies in Cambodia (T. T. Nguyen et al., 2015; Poffenberger, 2009; Strange, Theilade, Thea, Sloth, & Helles, 2007). The post-conflict population growth, degradation of environmental resources and increasing commercial interest in the resources resulting from the structural transformation may lead to more income vulnerability. That is because the scale of depleting resource extraction by households may not be compatible, particularly in the case of weak enforcement of rules as in Cambodia, with long-term sustainability and it thus would lead to a downward spiral by further reducing income of the households (Cleaver & Schreiber, 1994). The World Bank (2014) also stresses the high density of vulnerability indicating that one-fifth Cambodians are living close to the poverty line and are at risk to be pulled back to under poverty due to simple shocks.

3.4.3 Diversification in natural resources

In the early period of peacebuilding (1999), the livelihoods were primarily associated with crops and livestock. That is because people had been restricted access to other livelihood strategies by landmines. The landmines were often planted in rural areas and undermine the livelihoods of the rural population; limiting access to roads, land, water and forest resources. The National Landmine Impact Survey in 2002 indicates that all provinces or 2.5 percent of the country's surface are contaminated by landmines and

cluster munitions (GeoSpatial International Inc, 2002). More than 45 percent of the population is at risk and over 46 percent of Cambodian villages are contaminated, with 23.7 percent rated as very severe, 24.2 percent as severe and 52.1 percent less severe. The intensive demining efforts in the past decades have shaped the livelihood patterns and impacted the rural poverty challenge.

Second, it is a push factor or coping strategy to diversify income from other sources to overcome livelihood insecurity. Land is an important asset for both crops and livestock. However, arable land per capita has continued decreasing since 1999 (World Bank, 2016). In Cambodia, land is not equally distributed especially among the poor population. It is estimated that about one-third of Cambodia's land is owned by only 1 percent of the population (UNCDF, 2010). The failure to address property rights and tenure results in increased land disputes across the country since the early 2000s and 2012 is the peak in the decade (NGOF, 2015). The average farmland is one and a haft hectares; 48 percent of rural households own land of less than one hectare, and 20 percent of rural population has no land access (World Bank, 2006, 2015a). With an average household size of five, the majority of the rural population faces a high level of vulnerability. Still as high as 70 percent of the population depend on natural resources, of which almost 60 percent for subsistence, (McKenney & Prom, 2002); households, thus, diversify into other income alternatives as an adaptation strategy based on available resources and capacities to maintain income. The resource vulnerability and the strong links between the livelihood strategies and land-based resources are evidenced through increasing cases of land disputes and landlessness since the early 2000s (NGOF, 2015).

Third, it is a pull factor which attracts households to engage more in natural resource-based strategies. The development of market economy increase demand for nat-

ural resources. Extracting fishery and forestry products may be strategically complementary to other activities, more lucrative, fast economic return, less risk due to shocks and seasonality, and requires less capital investment for family scale operations. Aquaculture may require access to credit. Other resource extraction strategies are less dependent on loans to operate as compared to crops and livestock. Access to credit in Cambodia is still challenging for the rural population in terms of loan size, collaterals, and interest rates. Furthermore, the natural resource exploitation becomes more convenient in the condition of weak enforcement of rules in the post-conflict setting as evidenced in several countries.

The variation in primary sector especially forestry reveals an important story. In the most recent year (2013), the extracting of resources is linked to areas where there is no substantial forest. This implies that households in non-forest zone may engage in forest-related strategies.

3.4.4 Nonfarm is almost static

There is almost no variation in nonfarm self-employment in terms of overall dependency from 1999 to 2013 despite some geographical patterns of change. During the transformation process, agriculture share will gradually decline and the surplus of resources will flow to facilitate the expanding industrial and service sectors (Chenery & Syrquin, 1975; Timmer, 1988). Nevertheless, the sectoral shift in Cambodia is a different case. Despite the relationship observed in other countries, such as India (Hazell & Haggblade, 1990), Nigeria and Malaysia (Hazell & Roell, 1983) and Sub-Saharan Africa (Haggblade, Hazell, & Brown, 1989), the results give no evidence of impact linkages between nonfarm activities and agriculture-based strategies, even though micro level households may undertake multiple strategies to diversify income.

In Cambodia, the nonfarm is still largely an urban phenomenon and is marginal in rural areas. With the majority of the population undertaking livelihood activities for self-sufficiency and a high poverty incidence, the transfer of surplus resources from agriculture to nonfarm activities is unlikely to substantially take place. The growing role of nonfarm is usually seen in zones of rapid growing agricultural productivity. That is because increased farm income and savings are used by households as capital investment in nonfarm activities. In addition, the increased agriculture income creates demand for agriculture inputs (machinery, fertilizers, seeds, feeds, etc.) and other goods or services, which is the cornerstone of local trade and commerce and ultimately supports the growth and emergence of entrepreneurial activities. In Cambodia, the highest poverty incidence is centered in areas where households are more primarily dependent on agriculture and natural resources such as Tonle Sap, the plateau and mountain areas (Varis, 2008; World Bank, 2006, 2014). The crops, fish catch, and aquaculture harvests are generally to smooth consumption and address food insecurity. Among the poorest households, food consumption represents two-third of household's total expenditure (van Brakel & Ross, 2011).

No significant variation in nonfarm is associated with low participation in the sector. The agriculture labor share gradually declined since 1999 (FAOSTAT, 2016). Members of farming families are attracted by higher and more regular pay in garments and construction in urban areas instead of undertaking entrepreneurial activities (World Bank, 2015a). For example, the labor force in the garment sector has increased from 19,000 in the mid-1990s to 564,000 in 2014 (ILO, 2015; Vixathep & Matsunaga, 2012).

3.5 Conclusion

This study reveals that livelihood is context specific and suggested four distinct clusters relating to different types of resource dependency. The choice of household's strategies is associated with a range of socio and ecological factors.

The primary sector in Cambodia is substantial for the majority of the population, particularly in rural areas. People now rely more on natural resources than before while the cultivation land per capita continues to decline. Thanks to the uniqueness of the ecosystems and abundance of natural resources. The resource abundance can be both a blessing and a curse. On one hand, it indicates the significant role of environmental income in household livelihoods. On the other hand, it shows a high level of vulnerability of resource-dependent households when resources become depleted or are unsustainably managed. Nonfarm self-employment is still principally an urban phenomenon and rural nonfarm is marginal. The role of rural nonfarm will soon become more significant with continued growth in agriculture and tourism, rapid urbanization and regional economic integration.

The missing element in the peacebuilding process in Cambodia is the absence of protecting property rights and tenure and sustainable management of natural resources, as it can make the peace fragile. Cambodia is now beginning to see the effects of land tenure issues which sometimes turn violent. Even though the poverty has sharply declined in the last two decades, almost a quarter of the population is at risk of returning into poverty because of the high dependency on natural resources and wage employment from the low-skilled labors in very few sectors. In the past decades, Cambodia has put considerable efforts into accelerating growth and attracting foreign investments rather than protecting property rights and improving resource conservation. There is a fear that with increasing commercial interests and development of a market economy,

the economic value of products or services is given more weight than the value of ecosystem services. If that pathway continues to follow with the conditions of weak property rights and governance mechanisms, Cambodia might face costly resource conflicts, increasing rural vulnerability, a widening social gap and division, and a poverty situation back where it was in the 1990s.

In crafting policies, it needs to be kept in mind that there are close interactions among different ecosystems. For instance, maximizing one resource system productivity (i.e. crops) may undermine the outputs of other resource systems (i.e. fishery or forestry) or vice-versa. Thus, the people may become more vulnerable through experiencing the downward spiral effects by further reducing their income from this resource system.

The results of this study can be used in several ways. Identifying socioeconomic determinants in livelihood strategies and factors contributing to success or failure of farming or natural resource-based strategies would enable households to better cope with shocks and drivers of change in each ecological zone and provide policy makers with appropriate information to feed into a more targeted poverty reduction strategy. Furthermore, investigating the governance effectiveness of natural resources would help to prevent overexploitation, maintain the balanced ecosystems and sustainable supply of natural resources.

CHAPTER IV: LIVELIHOODS DURING THE ECONOMIC TRANSFORMATION: DETERMINANTS OF HOUSEHOLD CHOICES AND INCOME

Ratha Seng[1,2], Tongtong Fang[1], Krishna KC[3], Evan Fraser[3], Sovan Lek[1,2]

1. Laboratoire Evolution & Diversité Biologique, Université Paul Sabatier – Toulouse III, 31062 Toulouse, France.

2. Research and Development Center, University of Battambang, 020302 Battambang City, Cambodia.

3. Department of Geography, University of Guelph, N1G 2W1 Guelph, Canada

[under preparation]

4.1 Introduction

After full restoration of peace in 1998, Cambodia has experienced a rapid economic growth. Between 1999 to 2013, Cambodia's economy has grown at an average rate exceeding 8% per annum. The period from 1999 to 2008 was particularly fast, achieving a two-digit economic growth rate, placing Cambodia among the world's top performers and as one of only 46 countries which have achieved an average 7% annual growth rate for 14 consecutive years (Guimbert, 2010). The Cambodian growth rate is one of the fastest among post-conflict and developing economy standards, and only below a few high performance countries such as China, Hong Kong and Singapore for some selective decades since the 1960s (Guimbert, 2010; Hill & Menon, 2014). Furthermore, Cambodia has tripled income per capita over the past two decades and recently graduated to lower-middle income economy. Meanwhile, the poverty rate has declined sharply from the early 1990s of more than 50% to 20% in 2011 (World Bank, 2014).

The growth rate has resulted in rapid structural change. During the early 1990s, Cambodia was primarily engaged in subsistence agriculture, dominated by rice, and its allied activities such as forestry and fishery. Almost 80% of total labor force is engaged in agriculture (Acharya et al., 2003). Although agriculture continues to grow, its share of GDP has been on the decline from over 50% to just about 30% over the past two decades and the share is offset by increasing role of services and industry which is principally dominated by tourism, garments and construction. At the same time, there is a rapid increase in the level of rural-urban migration. For instance, Phnom Penh's population has increased by 70% from about 1 million in the 1998 to 1.7 million in

2013 (Asian Development Bank, 2014). A study in 2011 in 375 villages across Cambodia reveals that half of rural migration is to Phnom Penh and one-third is to other countries, mainly Thailand (MoP, 2012).

Households in developing countries and in Cambodia in particular pursue a variety of livelihood activities like crops, livestock, fishing, forestry, and nonfarm (Babulo et al. 2009; Ellis 2000; Nielsen et al. 2013; Soltani et al. 2012) as a way to ensure economic viability and a basis for adaptive strategy to cope with change. As in other developing countries, the transformation process to potential nonfarm livelihood option has been widely recognized (Davis(Davis, 2003; Deininger & Olinto, 2001; Smith, Gordon, Meadows, & Zwick, 2001). Households decide to diversify their livelihood strategies depending on varying socio-economic factors (Eneyew & Bekele, 2012; Tesfaye, Roos, Campbell, & Bohlin, 2011).

The aim of the study is to use various socio-economic variables taking from the Cambodian Socio-Economic Survey in 2013 to identify the determinants of livelihood choices and total income for households in Cambodia. In this study, we adapted the Sustainable Livelihoods Analysis (SLA) approach as the framework of analysis (Chambers & Conway, 1991). The Chamber's model emphasized interactions between asset base (human, natural, physical, financial and social) and livelihoods. Poor households are often constrained access to and control of these assets in one form or another (G. M. N. Islam, Yew, Abdullah, & Viswanathan, 2011). Scholars have used the concept of SLA to study different topics of livelihood in rural development, poverty, fisheries and natural resources management (Allison & Horemans, 2006; C. Barrett & Swallow, 2004; Ellis, 2000; Erenstein et al., 2010; Solesbury, 2003).

This study examines livelihood strategies from different resource dependencies. The linkages between farm/resource-based and nonfarm strategies have recently become more popular among scholars and development practitioners, particularly in a transitional and developing economy (Djurfeldt, 2012; Hitayezu et al., 2014; T. T. Nguyen et al., 2015). The detailed analysis of different livelihood strategies, hence, provides a good understanding of the socio and ecological interactions and how different factors might affect household's choices and income. In addition, it adds to existing literature on the role of nonfarm self-employment in rural economies of developing countries. In recent literature, the nonfarm sector is recognized to play a vital role in addressing rural-urban migration and contributing to national income growth (Lanjouw & Lanjouw, 2001). Further, this study intends to investigate the relationship between migration income with different livelihood strategies. Empirical evidences from Kenya and China show that migration remittances induce the growth of nonfarm activities in rural areas (Francis & Hoddinott, 1993; Taylor, Rozelle, & de Brauw, 2003).While some studies focus on a particular area, especially by Nguyen et al. (2015) and Rahut et al. (2012) in the context of Cambodia, here the analysis covers the entire country and thus contributes to the generalization of the findings.

The cross-sectoral analysis taking into account a broader view of multiple capital assets provides a useful framework for better understanding of household's livelihood choices and factors contributing to household's total income. By doing so, it offers policy makers useful information to feed into development initiatives for improving efficiency of policy interventions.

4.2 Materials and methods

4.2.1 Data description and study area

Our data was from the Cambodian Socio-Economic Survey 2013 (CSES). The survey was first conducted in 1993/1994 aiming to collect statistical information about living conditions and extent to poverty of the Cambodian population. It was used to monitor the Cambodian National Strategic Development Plan (NSDP) and to measure progress towards global development goals (i.e. Millennium Development Goals and Sustainable Development Goals). The survey was conducted intermittently between 1993/1994 to 2004 and it was until 2007 that it has been annual. CSES 2013 was the 13th survey of its kind. The sampling procedures and field operations manual were detailed in NIS (2016). The survey was composed of a total of 3,138 households representing entire Cambodia.

Cambodia is divided into four main agro-ecological zones, namely Plateau/Mountain, Plain, Coast, and Tonle Sap (Yu & Fan, 2011). The Plateau/Mountain zone includes the northeast Cambodia and Kampong Speu province in southwest bordering the coastal provinces is dense in forests and with low population density. The coastal zone consists of a very small portion of the country located in the Southwest. Crop cultivation, mostly rice, is mainly in the Northwest-Southeast corridor, known for a high population density. Thus, the northwest areas bordering Thailand around the Tonle Sap zone and southeast areas bordering Vietnam in the Plain zone are the main producers of rice. Dry season rice is mostly grown in the Plain zone, accounting for 70% of total land area of the country.

In our study, five household livelihood choices were selected: crops, livestock, fishery, forestry & hunting and nonfarm self-employment. Adapting SLA concept, key

variables (Table 2) considered to be the important determination of household's choices and income were identified: (i) human capital (age of household head, household size, female percentage in household, education and non-formal education, illness, food and non-food expenditure), (ii) natural and economic capital (land size, value of land), (iii) social capital (pension, remittance), and (iv) physical capital (values of agriculture, transportation and durable goods).

4.2.2 Data analysis

The analysis of livelihood strategies of households involved several steps. In the first stage, household net income from each livelihood strategy was calculated. As evidenced in recent literature in which income share is used to measure standard of living, poverty and livelihood strategies, net income from each livelihood strategy was calculated to gain an understanding of how different socioeconomic factors influencing household's choices of livelihoods and total income (Babulo et al., 2008; de Sherbinin et al., 2008; Soltani et al., 2012). The income share method has been long recognized as an important factor to measure economic performance, especially in evaluation of household's livelihoods and to enable direct and straightforward comparison across several different years. In computing the net income from each livelihood strategy, a standard income method was followed as below:

$$\text{Net Income} = \text{Total Revenue} - \text{Total Cost}$$

The value of income or revenue is nominal. Net income in this study is equivalent to net profit accounting for both variable production and selected fixed costs, but not all. Data on some fixed expenses (depreciation) at household level were not available particularly associating with valuation of assets and their cost classification. Total revenue was calculated as Quantity of Production x Selling Price. Total cost was the sum of all cost items of each livelihood strategy.

Crops: Include all types of crops, fruits and vegetables.

Livestock: Include both livestock and poultry and by-products.

Fishery: Include aquaculture and captured fishery.

Forestry and hunting: Associate with resource extracting activities including timber and non-timber forest products.

Nonfarm self-employment: Associate with enterprise and business activities in secondary and tertiary sectors.

All statistical analyses of the data were performed using R 3.2.5. Multinomial logit regression (MNL regression) was used to identify the determinants in livelihood strategy choice because the choice is a polychotomous variable. In the MNL regression, *mlogit* function in *mlogit* package (Croissant, 2013) was used to carry out the analysis and crop strategy was set as reference strategy as majority of Cambodian rural labor force engaging crop production strategy. Therefore, data in other strategies were all compared with this reference strategy.

The key strategy means the main livelihood strategy that households choose to earn the maximum income, normally as the resource of pursuing the main income. Therefore, key strategy, used as the response variable, could be explained by a list of explanatory socioeconomic variables. Those explanatory variables provided lots of evidences from different points of view in explaining household livelihood strategy preferences. Therefore, the coefficients in MLR, effects of each explanatory variable contributing to the probability on choosing the specific livelihood strategy relative to crop strategy, could be observed.

Furthermore, in order to see the determinants in household's total income, ordinary least-squares regression (OLS regression) was carried out using *glm* function in stats package (R Core Team, 2016).

Table 2. Description of the explanatory variables used in regression analysis.

Explanatory variables	Definition	Measurement
Human capital		
Age of household head	Age of the head household member	Years
Household size	Total number of household members	Number
Female percentage	The percentage of female adult in the household	Ratio
Education	The average of the highest education level ever accomplished for	Category
Non-formal education	Number of people who received non-formal education in the	Number
Illness	Number of day absent from work in the past month	Days
Natural and economic capital		
Non-food expenditure	Non-food expenditure in the past three months	Riel
Food expenditure	Food expenditure in the past three months	Riel
Land size	The area of owned farmland in the household	m^2
Land value	The current price of the farmland owned in the household	Riel
Social capital		
Pension	Pension from the government or other sources	Riel
Remittance	Remittance from other family members	Riel
Physical capital		
Agriculture equipment	Total value of the agriculture equipment in the household	Riel
Transportation	Total value of the transportation in the household	Riel
Household equipment	Total value of the household equipment	Riel

Note: Riel is the official monetary unit in Cambodia.

4.3 Results & Discussion

4.3.1 Characteristics of livelihood strategy

Table 3 presents summary statistics for both dependent and independent variables we plan to use in the regression. The statistics of each variable is listed separately by the five main livelihood choices we discussed before and therefore the difference among the livelihood choice categories for those variables could be clearly seen.

Let's first focus on the dependent variables. For annual income in each livelihood category (the first column), obviously that the income in the corresponding category (the first row) is the highest among other categories. For example, the mean in annual crop income is the highest in the crop livelihood category. That is natural due to the

definition of key livelihood strategy. One interesting point is that for annual nonfarm income, the distribution among different categories is extremely unbalanced, implying that the income source for those households is quite unique. They are unlikely to have a secondary livelihood strategy apart from nonfarm livelihood strategy.

Second, for the annual household total income, the one in forestry category is the lowest while that in nonfarm category is the highest. See also Figure 5 (upper) for this. The density peak for forestry strategy, blue curve, is at the most left side and the non-farm strategy, purple curve, is at the most right-side. The direction going from left to right side means higher annual income. Besides, from Table 3, we observe that the standard deviation (sd for short in Table 3) in nonfarm category for annual household total income differs a lot from others, performing the highest among all the categories. Therefore, for households adopting mainly the nonfarm livelihood strategy, the income can be a lot difference across households.

When turning to study independent variables, two of them, land size and land value catch our interest. Both of them have a similar trend in distribution. Let's take land size (Figure 5, the middle one) as an example. From the figure, we can observe three patterns: one pattern works for crop and livestock categories, one stands for fishery and forestry & hunting strategies, and the last one applies to nonfarm strategy.

For the first pattern, from a starting point, the density increases to a peak and slowly decreases after that. Therefore, only few households selecting crop and livestock strategy do not have much land and most of them have large land size, 21,782 m^2 in average (Table 3). Table 3 also shows households in these groups having the largest land size with the highest land value.

In the second pattern, the curve reaches the peak at the very beginning and gradually decreases. Thus, most households adopting fishery and forestry as key livelihood strategy do not have land or own only small size of land, usually lower than 5,500 m^2. Households owning large land size is rare.

In the last pattern, for nonfarm dominant households, we notice some small peaks in the density in Figure 5, which means the owning of land size and land value in nonfarm group is of inequality.

Table 3. Summary statistics of variables (by household key livelihood strategy clusters)

	Overall samples (n = 3138)		Crop (n = 821)		Livestock (n = 231)		Fishery (n = 157)		Forestry (n = 578)		Nonfarm (n = 1351)	
Variables	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Dependent variables												
Annual crop income ('0000 riels)	129	473	400	837	85	102	20	54	17	42	32	173
Annual livestock income ('0000 riels)	35	166	15	92	335	431	5	33	2	17	15	104
Annual fishery income ('0000 riels)	26	135	23	31	18	24	265	541	14	21	6	27
Annual forestry income ('0000 riels)	39	60	48	33	48	34	40	23	79	111	15	28
Annual nonfarm income ('0000 riels)	725	4404	16	87	23	87	5	29	1	21	1669	6594
Annual household total income ('0000 riels)	954	4412	501	875	509	502	336	554	113	150	1737	6599
Independent variables												
Human capital												
Age of household head	47.2	13.3	47.5	13.2	49.9	13.8	43.8	14.0	46.3	15.0	47.3	12.3
Household size	4.6	1.7	4.7	1.7	4.5	1.6	4.8	1.7	4.4	1.8	4.6	1.7
Female percentage	0.4	0.2	0.4	0.2	0.4	0.2	0.3	0.1	0.4	0.2	0.4	0.2
Education	6.9	2.9	6.2	2.5	6.5	2.7	5.2	2.1	5.7	2.5	8.2	3.0
Non-formal education	0.2	0.6	0.1	0.4	0.1	0.4	0.0	0.3	0.1	0.4	0.4	0.7
Illness	1.1	5.1	1.0	4.5	1.6	6.9	1.0	4.0	1.5	6.2	0.8	4.6
Natural and economic capital												
Non-food expenditure ('0000 riels)	595	651	472	436	511	519	394	242	383	368	799	827
Food expenditure ('0000 riels)	871	400	761	319	761	311	751	268	698	281	1044	444
Land size (m^2)	9811	27871	21782	48805	12960	18077	5265	9512	5732	9180	4271	11268
Land value ('0000 riels)	1916	6719	4161	9839	3161	12300	772	2203	860	1870	923	3650
Social capital												
Pension ('0000 riels)	6	46	3	32	7	56	1	11	4	40	8	55
Remittance ('0000 riels)	53	342	63	333	83	791	102	637	51	170	37	193
Physical capital												
Agriculture equipment ('0000 riels)	86	452	186	582	88	196	32	118	28	116	55	496
Transportation ('0000 riels)	449	1127	261	626	272	969	149	220	109	237	775	1527
Household equipment ('0000 riels)	131	328	65	164	70	125	36	40	37	79	233	458

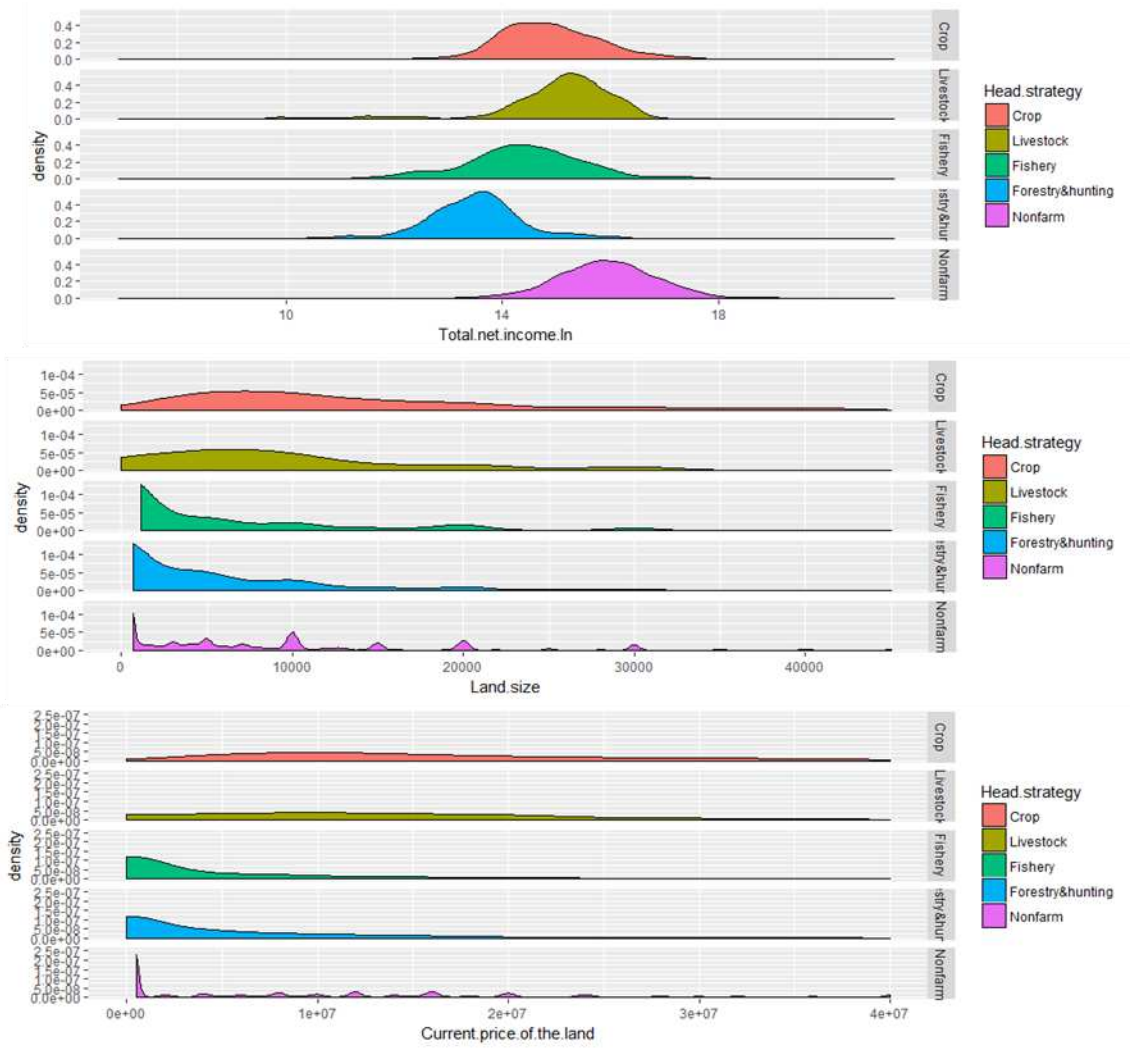

Figure 5: Distribution of total net income (upper), land size (middle) and current land value (bottom) by livelihood strategy clusters.

4.3.2 Determinants in livelihood strategy choices

Results from MNL regression in Table 4 with crops set as a reference strategy present that among fifteen hypothetical explanatory variables, twelve variables were found to significantly influence the choices of household's head strategy of livestock, fishery, forestry and nonfarm.

Human capital

Overall, the results (Table 4) suggest five variables which have significant association with different livelihood strategies, namely household size, education, percent-

age of female adults, non-formal and age of household head. Household size has positive association with fishery and forestry and negative relationship with nonfarm. The study further reveals that age of household head and female percentage negatively affects fishery strategy. Education was found to negatively correlate with natural resource-based strategies (i.e. fishery and forestry) in opposite to non-formal education which negatively affects nonfarm strategy.

The positive impact of household size on fishery and forestry illustrates that with more available labor resources, households tends to choose natural resource-based activities in contrasting to crop strategy. The tendency to undertake natural resource-based strategies with available labor resources associates with the land tenure. Land is an important asset for crops. However, arable land per capita has continued decreasing since 1999 (World Bank, 2016). In Cambodia, land is not equally distributed especially among the poor population. It is estimated that about one-third of Cambodia's land is owned by only one percent of the population (UNCDF, 2010). Overall, the average farmland is less than a hectare and with an average household size of five, the majority of the population faces a high level of vulnerability especially in rural areas. In the case of households primarily dependent on fishery and forestry strategies, the average farmland is even as small as half a hectare. And, therefore, undertaking resource extraction and its related activities and especially among unskilled labor forces who are unable to tape more lucrative opportunities in nonfarm is viable economic option to meet increased consumption demand.

The negative impact of education on fishery and forestry relates to productivity of resource cultivation. Educated members are less willing to allocate time for either fishing or collecting and therefore are less efficient. Instead, the labor input is more allocated to more secured job opportunities such as crops or either nonfarm wage and self-

employment. The results correspond with several studies in Africa and Asia confirming the negative effect of education on natural resource harvesting (Chen, Heerink, & van den Berg, 2006; Fisher, 2004; Jogo & Hassan, 2010; Narain, Gupta, & Veld, 2008). Finally, the highest poverty incidence in Cambodia is centered in areas where households are more primarily dependent on natural resources (Varis, 2008; World Bank, 2006, 2014). Therefore, the poor resource or less educated households may have limit ability to improve knowledge and skills and access to various opportunities.

Further to education, the positive relationships between non-formal education and nonfarm show an important story of farm exit. With more members attending non-formal education, it is more likely that households exit crop cultivation into different subcategories of nonfarm employment. Among those attended the programs, only 2.1% participated in agricultural-related trainings contrary to foreign languages accounting for 86.7%. The figure is even lower than vocational training and computer literacy representing 5.9% and 3.5%, respectively. The factors influencing the nonfarm choice associate with income security which has been constrained in crop cultivation.

The significantly negative effect of female percentage on fishery strategy implies that the strategy is more likely to be chosen by households with less female percentage comparing to crops. A number of socio, economic and cultural taboos shape the participation of women in fisheries and its related activities., in the synthesis of 83 global gender fisheries studies, Kleiber et al., (2015) showed men are more representative in number and better perform in terms of catch biomass, fishing effort and catch per unit effort (CPUE). Secondly, women are restricted in decision making power in the management of fishery resources and aquaculture activities which therefore deprive access to and economically benefit from the resources (Harrison, 1995; Heck, Béné, & Reyes-

Gaskin, 2007; Sze Choo, Nowak, Kusakabe, & Williams, 2008) .Thirdly, the physicality, dangers and family roles (Brickell, 2011) limit women's ability to travel long and far and female fishers likely to choose habitats which are close to home (Arce-Ibarra & Charles, 2008; Béné, Steel, Luadia, & Gordon, 2009). In addition, women may also be further narrowed by the use of fishing methods and gears as compared to their male counterparts. In Cambodia, different ecological characteristics define the gender participation in fishing and fish farming. Women in Tonle Sap Great Lake are more active in fish processing and fishing in resource grounds nearby their home, and in coastal areas engage in collecting aquatic resources, while those in the Mekong River floodplain region travel along with their husband since the fishing activities are concentrating in a short period between September to December (Béné & Friend, 2011; FA/MAFF & CBNRMLI, 2008). In some areas, where fishing is carried out at night, women do not participate in the fishing.

The positive relationship between age of household head and fishery strategy can also be explained by the willingness to supply labor input to use in resource harvesting. Fishing requires travelling to resource ground and therefore elder people prefer to stay at or nearby home which enable them to take care home and young children in the family and allow other working age family members to work off-farm. The results are supported by the findings of Shi et al., (2007) in China, reporting that older people are more likely to work in agriculture and local nonfarm employment while the younger labors prefer to migrate or work away from home.

Natural and economic capital

For natural and economic measure, land and expenditure on food and non-food items have significantly affect the four livelihood choices (Table 4). For food and non-

food expenditure, the positive correlations were found to be associated with nonfarm and livestock while forestry was negatively influenced by food expenditure.

Regarding how expenditure patterns might influence household's choice of key strategy, the positive effect of non-food expenditure on livestock and nonfarm indicates that the two strategies are likely chosen by the better-off households in opposite to crop cultivation. Furthermore, the positive effect of food expenditure on nonfarm also explain the household decision associating own consumption, food expenditure and land constraint. From the food intake perspective, the increased food consumption for nonfarm choice may indicate the level of income which allows households to purchase foods to meet their needs. Other reasons associate with urban areas where households are less likely food producers or in rural areas where households face land constraint and therefore push them to undertake nonfarm as their primary choice. Similarly, the negative relationship between food expenditure and forestry shows that households with sufficient food production may not engage in forestry. The constraint in food production because of limited farmland tenure and the energy requirement to meet their basic needs enable households to choose forestry strategy instead of farming.

The results showing the statically significant correlations between both land size and value and the four livelihood strategies indicate the importance of land tenure in household's choices of strategy in Cambodia. Households with larger farm size are less likely to invest in other strategies such as livestock, forestry or nonfarm. The results correspond to evidence in Nigeria that households with large farm size reduce their participation in off-farm (Fabusoro, Omotayo, Apantaku, & Okuneye, 2010).

Similarly, there is also similar pattern for land value variable. The total land value reflects both the size and monetary value of the land owned by households. The monetary value indicates the capacity of households to access to credit or convert the assets

into financial capital to further invest or expand the existing crop production activities. The financial capital is important for farmers to access to technology and improve specialization or expand the current production capacity which in turn contributes to generate higher income. Consequently, those with larger farm size are less likely to make a choice in other strategies considering the level of returns derived from crop cultivation. The finding also provides important implication why some household might exit the traditional on-farm job and seek alternative options in off-farm employment.

Social capital

Among the two social capital measures, only remittance was found to be statistically significant associating with fishery strategy and nonfarm (Table 4). Remittance positively correlates with fishery and has negative effect on nonfarm.

The positive relationship between remittance and fishery strategy revealed that the fishery households are more dependent on migration income than those of crops. Fishery-dependent families send more members out for other employment as it can be observed from Table 3 that average migration income receipt was the highest among all other strategies. The declining environment resources and economic uncertainty force members in fishery-dependent households to diversify income sources to support their needs. On the other hand, the pattern is opposite for nonfarm in which households are less dependent on migration income. That is because nonfarm is considered to be more lucrative and secure and less risk than both crop and fishery strategies.

Physical capital

The effects of various physical capital on the choices of livelihood strategies were found to be statistically significant associated with forestry and nonfarm (Table 4). For both livestock and fishery, the influencing factors were similar to crop strategy. The

result showing the negative effect of agriculture equipment on nonfarm is as expected. However, the strong correlation between household durable goods with nonfarm strategy indicates the difference of durable goods consumption behavior and income between crop and nonfarm dependent households. The more ownership of durable goods of nonfarm households reflects the higher income level because the ownership of goods associating with income change or rise which enables households to have more possession of goods as presented in Table 3 and Figure 5.

For forestry households, the result shows a different situation from nonfarm strategy. The negative effect of transportation on forestry strategy highlights that the households making a decision to participate in forestry are short of transportation ownership compared to those in crops.

Table 4. Determinants of livelihood strategies (the multinomial logit regression)

Dependent variables	**Livestock**	**Fishery**	**Forestry**	**Nonfarm**
Independent variables				
Human capital				
Age of household head	1.605	-2.230 *	-1.281	-0.613
Household size	0.147	1.982 *	2.716 **	-2.019 *
Female percentage	0.218	-3.496 ***	-1.072	0.734
Education	0.807	-4.441 ***	-2.835 **	-0.441
Non-formal education	0.663	-1.885	1.325	2.638 **
Illness	0.160	0.573	1.910	-1.773
Natural and economic capital				
Non-food expenditure	2.121 *	1.560	-0.380	5.968 ***
Food expenditure	-0.386	-1.143	-1.976 *	3.887 ***
Land size	-2.179 *	-1.285	-3.751 ***	-5.313 ***
Land value	-5.099 ***	-5.343 ***	-6.280 ***	-6.149 ***
Social capital				
Pension	0.226	0.252	0.520	0.098
Remittance	0.721	2.423 *	1.896	-2.223 *
Physical capital				
Agriculture equipment	0.458	-1.660	-1.906	-2.939 **
Transportation	0.738	1.302	-2.179 *	1.208
Household equipment	0.826	0.433	0.071	7.913 ***
McFadden's R^2 0.2951				

Note: Crop strategy is the reference category; *, **, *** mean statistically significant at 10%, 5% and 1% level, respectively.

4.3.3 Determinants of household income

Crops as key strategy

For households following crop strategy, the determinants of household income are various (Table 5). The increase of land size and value, age of household head and agriculture equipment contribute to higher income whereas the increase of remittance and female percentage negatively affect household's total income.

As land is the primary productive capital for crop cultivation, land size indicates the scale of farming operation. The larger farm size enables household to cultivate and produce more and ultimately results in a higher return. Owning a large land size and high land value is also another incentive for farming households. In developing countries, including Cambodia, land-rich households use land as a collateral for loans to finance their farming investment (Rahman & Akter, 2014). The loans are used for farming operation costs, purchasing tools and machinery or expanding the investment to generate more household income.

The positive relationship between age of household head and total income associate with improved specialization through the number of years engaging in crop production. Specialization is a key for farming success as it enables households improve productivity and increase production income.

The positive impact of farm machinery on household's total income is not surprising as the mechanical tools increase overall crop output. The reason is because the mechanical system improves crop productivity and efficiency during both pre and post-harvest and it is important for Cambodia farmers of which a significant percentage are resource-poor, lacks access to agriculture equipment and still operates manually.

It is surprising to note that remittance negatively affect total income of crop dependent households. The migration income was thought to improve farming productivity and ultimately contribute to increased household income. The migration income may influence the reallocation of labor or resources out of farming. In some cases, the trend may lead to farm discontinuation as it depends on the share of remittance income. This holds true when the agriculture labor share has gradually declined since 1999 (FAOSTAT, 2016). Members of farming families are attracted by higher and more regular pay in garments and construction in urban areas (World Bank, 2015a).

The reason of negative impact of number of female on total income is related to gender difference in overall productivity and access to resources. Several studies in developing countries reveal that plots managed by females are less productive than those managed by their male counterparts (Andrews, Golan, & Lay, 2014; Kilic, Palacios-López, & Goldstein, 2015). However, Alene et al.(2008) stressed that gender difference in productivity is not associated with the technical and allocative efficiencies, but on how female farmers access to various capital assets. A large and growing volume of studies confirmed that women are constrained access to land, education, labor, credit and extension services (Bindlish & Evenson, 1993; Birkhaeuser & Evenson, 1991; Doss, 2001; Quisumbing, 1996) and therefore affect their crop output and income.

Livestock as key strategy

As in the livestock category, land value has a significant positive effect on household total income whereas education has a negative relationship (Table 5). Land ownership does not only provide the production base which eventually turns into higher income, but it offers means to access to capital investment. Samkol et al.,(2015) high-

lights that one of the main constraints in livestock production is financial capital. Therefore, for households owning high land value are more accessible to credit or financial capital for the production. Furthermore, the total high land value also reflects the zones usually situated close to the cities and towns where are fast growing and have higher demand for meat consumption. As majority of Cambodian livestock farms are small-scale, the urban and peri-urban areas accommodate larger and more advanced commercial operation farms with higher economies of scale and therefore enable them to achieve higher rates of return.

Associated with the effect of education on total income, the educated members have a tendency to work outside the farm even though livestock might be the primary income for the household. The tendency holds true among young family members who are attractive to wage employment or nonfarm self-employment. Therefore, educated individuals make less contribution to livestock income compared to those with lower literacy. The finding contrasts with other studies showing that education is instrumental in enabling households to better respond to shocks and is considered one of the key factors for livestock production success (Birhanu, Girma, & Puskur, 2014; Cooper & Wheeler, 2016)

Fishery as key strategy

In the case of households whose key strategy is fishery, education affects income negatively and ownership of transportation affects positively (Table 5). Higher education is associated with possibility of higher skilled and more secured employment. Therefore, fishery income is not considered as the most favorable economic option and households seek employment from other more secured sources. As explained earlier, the overall low output of natural resource collection is associated with more educated

households because of job preference, efficiency and labor allocation (Chen et al., 2006; Jogo & Hassan, 2010).

In contrast, transportation provides mean to better access to fishing ground and market and to less depend on the middlemen and therefore contribute to generation of higher household income. When the availability of environmental resource become scare, the transportation (i.e. fishing boats and other vehicles) plays a critical role to maintain household income as fishers may need to travel further from the normal resource ground for fishing or access inputs for fish farming.

The results are supported by the findings of Nguyen et al., (2015) providing evidence that education negatively affect environmental income while fishing boats and proximity to resource ground have a positive impact.

Forestry as key strategy

Turning to households with forestry & hunting as key strategy, the total income is influenced by household size, land size, agriculture equipment, non-food expenditure and durable goods (Table 5). The first three indicators have positive effects whereas the two latter have negative effects on total income.

The positive influence of household size on forestry total income reveals the availability of labor resources engaging in forestry activities which thus enable households to generate more income for the households.

As majority of natural resource based households are still subsistence, diversification into farming is a viable means to ensure household income stability. Especially among the poor households who are unable to seek more other lucrative jobs such as nonfarm. Therefore, land and agriculture equipment enable them to diversify into farming which contribute to increased income especially when the environmental resources

become scare. The finding is consistent with global comparative study by (Angelsen et al., 2014) showing the positive correlation between agriculture land with forest and environmental income. However, it is contrary to evidence found by Nguyen et al. (2015) in Cambodia and Kamanga et al. (2009) in Malawi, in which no correlation were found between land size and forest income.

The negative impact of non-food expenditure and household assets on total income for forestry households reflects how forestry income are influenced by different levels of wealth of households. The higher expenditure on non-food items and more ownership of assets indicate a better human well-being. Therefore, the better-off category of households might not make best use of available labor resources for forestry as earlier explained. The forestry and its related income come from most of the poor households.

Nonfarm as key strategy

For households mainly involved in the nonfarm employment, food and non-food expenditure and durable goods have positive effect on total income while age of household head, non-formal education and illness have the negative relationship (Table 5). The findings show that human capital plays a key role in influencing income from nonfarm. Households with better human capital and with more assets have better coping (short-term) and adapting strategies (long-term) than those in the opposite situation. Therefore, they have greater access to nonfarm jobs and earn more income. Nevertheless, education, one important indicator of human capital, shows no significant relationships for both choice and income of households, contrasting previous literature arguing the significant influence of education on nonfarm (Corral & Reardon (2001); Rahut & Micevska Scharf (2012)).

The positive effect of food and non-food expenditure and durable goods show that wealth is important in the present economic structure of Cambodia in which entrepreneurs are generally constrained by access to investment capital. Even credit can be easily accessible, the interest rate remains high and sometimes limit the opportunity to be competitive.

On the negative relationships, the significant effect of age of household head highlights that younger entrepreneurs might be more successful than the older head in the Cambodian economy which is rapidly developed and changed. While older head might have more experience and better resources, the younger counterparts are more willing to take risk and more responsive to emerging opportunities in the rapidly transforming economy. Associated with non-formal education, the negative impact on total income highlights a gap in the skill building programs to promote non-farm self-employment in which the majority of people took foreign languages ahead of others. This suggests that people prefer the wage employment in foreign countries instead of entrepreneurial activities (MoP, 2012; World Bank, 2015a). Finally, the illness variable shows that nonfarm total income is negatively affected by the number of day family members absent from work. Nonfarm is mainly associated with urban areas and the residents suffer more illness and injuries than those in the rural areas.

Table 5. Determinants of household total income

Dependent variables	Crop	Livestock	Fishery	Forestry	Nonfarm
Independent variables					
Human capital					
Age of household head	2.181 *	1.924	0.879	-1.059	-3.483 ***
Household size	0.264	0.981	-0.757	4.443 ***	0.491
Female percentage	-2.887 **	-1.238	-1.244	-1.285	1.015
Education	-0.362	-2.872 **	-2.224 *	-1.416	1.867
Non-formal education	0.247	-0.980	0.718	-1.186	-2.449 *
Illness	0.283	0.002	-1.442	-0.803	-2.877 **
Natural and economic capital					
Non-food expenditure	-0.111	-0.452	0.773	-3.899 ***	5.566 ***
Food expenditure	1.278	0.564	1.247	1.613	4.358 ***
Land size	9.364 ***	1.158	0.627	2.769 **	0.520
Land value	5.567 ***	2.032 *	-0.602	-1.784	-0.182
Social capital					
Pension	-0.039	-0.172	-0.956	-1.044	-1.485
Remittance	-3.620 ***	-0.364	-0.174	0.353	-0.507
Physical capital					
Agriculture equipment	2.328 *	0.266	0.598	3.686 ***	1.157
Transportation	1.432	0.969	2.395 *	0.547	0.006
Household equipment	0.169	1.074	-1.134	-3.363 ***	6.914 ***
Pseudo-R^2	0.3440	0.5500	0.1554	0.2365	0.2312

Note: *, **, *** mean statistically significant at 10%, 5% and 1% level, respectively.

4.4 Conclusion

Our findings mainly reveal two aspects: the determinants of the household's livelihood choices and household's total income derived from such choices in Cambodia. Using the sustainable livelihood framework, this study contributes to understanding how different household capitals influence household's decision to undertake relevant livelihood strategies and the factors affect the overall household income based on the choice being made.

4.4.1 Household choices of strategy

Various elements of livelihood assets affect household's choices differently comparing to crop cultivation. Household size, food and non-food expenditure, education and female percentage are found to be important human capital which influence or dis-

courage the participation in either livestock, fishery, forestry or nonfarm. Other significant variables are age of household head and non-formal education. Livestock has similar human capital characteristics with crops except the expenditure pattern associating with non-food expenditure, which indicates that livestock households are economically better through the evidence of larger share of non-food consumption. Resource-based strategies of fishery and forestry mainly differentiate from crops in terms of lower education level and larger household size. This suggests that the resource-dependent households are more vulnerable than those of crops because of lower capacity to respond to unexpected changes should they occur and higher consumption needs. This can be further observed among the forestry households in which those who afford higher food expenditure are less likely to engage in resource harvesting. Lastly, increased food and non-food expenditure, better non-formal education access and smaller household size are significant indicators of nonfarm self-employment. This reflects a difference in overall human wellbeing and access to opportunities among crop and non-farm households.

Access to land cultivation is considered to be very important dimension of natural and economic capital, reducing household participation in non-crop strategies in which statistically significant relationships were found in almost every strategy for both land size and land value. Forestry households are found to be most restricted in land accessibility, showing highest negative regression coefficient values in both land size and value cases.

Remittance is found statistically important for forestry and nonfarm but in an opposite situation. The negative effect of migration income on household's decision to participate in non-farm self-employment is as expected because of high returns from the strategy. However, the positive relationship between remittance and fishery choice

of strategy reveals an important evidence associating with increasing economic pressure of the households in which more members are being forced to leave home for alternative employment.

The results draw the following important policy implication. First, development interventions with special attention to resource poor households, aiming to improve human capital and asset ownership would enable them to enhance their potential for employment in farm or nonfarm sectors and minimize the potential risks from the environment pressure because higher risk of vulnerability associating with livelihood inequality, lower human capital and productive assets (i.e. land).

Second, land is an important livelihood capital which strongly influence household's decisions to participate every choice of strategy. The missing element in the Cambodia's development process is the absence of protecting property rights and tenure. Cambodia is now beginning to see the effects of land tenure issues which sometimes turn violent. Even though the poverty has sharply declined in the last two decades, almost a quarter of the population is at risk of returning into poverty because of the high dependency on natural resources and wage employment from the low-skilled labors in very few sectors, and low capacity to respond to unexpected environmental events. In the past decades, Cambodia has put considerable efforts into accelerating growth and attracting foreign investments rather than protecting property rights and improving resource conservation. There is a fear that with increasing commercial interests and development of a market economy, the pathway might be continued. With the conditions of weak property rights and governance mechanisms, Cambodia might face costly resource conflicts, increasing rural vulnerability, a widening social gap and division, and a poverty situation back where it was in the 1990s.

Lastly, promoting non-formal education geared towards skill building and entrepreneurial development activities will enable households to diversify non-environmental income (i.e. nonfarm) which is more financially rewarding and secure.

4.4.2 Household's total income

Different policy options apply since household's livelihood strategies are shaped by specific socioeconomic and agro-ecological contexts. We should avoid enhancing a one-size-fit prescription without consideration a wide range of influencing factors.

Of households with crop as a key strategy, improving household's land ownership (land size and value), productive assets (i.e. agriculture equipment) and farmer experience contribute to increased total income. On the other hand, the increased female participation in crop cultivation and remittance negatively affect the household's total income. The findings suggest that the policy should aim to increase farm income (not just for subsistence purposes) by improving specialization, labor efficiency, assets (land), machinery and access to credit. Raising value of land may provide the financial capital for the crop cultivation, but it affects the land accessibility because of increased price. Improved farm income enables households to less depend on migration income which may contribute to farm exit.

For livestock depending households, land value being significant in influencing total income indirectly suggest that improving access to financial capital would help to address major challenges faced by livestock producers. Access to credit especially among livestock smallholders is crucial in addressing typical production constraints such as animal nutrition and health, which are not only main barriers to profits and improving production process, but also to new entry.

The positive relationship of transportation and negative impact of education on fishery households suggest that improving physical ownership (i.e. fishing boats) is more desirable (perhaps in the short-term) than addressing education. Transportation such as fishing boats provides means to access to resources and market and therefore affect household's income. Nevertheless, education is still important for households to income diversification. Education remains important in enabling households to better adapt to climate variability based on their biophysical and socioeconomic circumstances.

For households with forestry as a key strategy, land and household sizes have positive impact on total income while non-food expenditure and other durable goods have negative relationship. The results clearly suggest that improving more land access would significantly contribute to improving income and livelihood of the households. With poor resource governance, the increased commercial interest of land would undermine the land accessibility among the poor. We do suggest the targeted poverty reduction strategies should aim to improve land access for those living under the poverty line. Furthermore, measures to improve productivity for non-timber forest products, including post-harvest losses and market effectiveness would not only improve current production, but provide potential opportunities to diversify into farm income and other earning opportunities.

For nonfarm, food and non-food consumption and durable goods were found to be important to household's total income while age of household head, non-formal education and illness were the opposite factors. The results suggest that the success of nonfarm self-employment differs according to household wealth. Richer households are more profitable because of better financial strength. Other actions which contribute to increase nonfarm income include minimizing health risks and non-improving formal

education programs as earlier discussed. Furthermore, government should formulate policies aiming to establish precondition for rural nonfarm growth such as effective decentralized decision systems and improved supporting infrastructure, insurance and credits. Promoting growth of rural nonfarm is not only beneficial for the poor and rural economy, but it gradually helps to improve specialization and a large benefit falls on national economy as a whole.

CHARPTER V: THE ECONOMIC IMPACT OF ADAPTIVE RESPONSES TO SCENARIOS OF FUTURE SOCIO-ECONOMIC AND ECOLOGICAL CHANGE IN THE TONLE SAP ECOSYSTEM

Louise Teh[1 *], Natachia Bond[2], Krishna KC[2], Evan Fraser[2], Ratha Seng[3], U Rashid Sumaila[1]

1. Institute for the Oceans and Fisheries, University of British Columbia, V6T 1Z4 Vancouver, Canada.

2. Department of Geography, University of Guelph, N1G 2W1 Guelph, Canada

3. Laboratoire Evolution & Diversité Biologique, Université Paul Sabatier – Toulouse III, 31062 Toulouse, France.

* Corresponding author's email address: l.teh@oceans.ubc.ca

[under review] Human Ecology

5.1 Introduction

Tonle Sap Lake is the largest and most important freshwater lake in the Mekong basin, and the center of Southeast Asia's freshwater biodiversity. It is particularly crucial for supporting livelihoods, food security, and trade for Cambodian society (Baran, 2005; Cooperman, Kaufman, Mccann, & Winemiller, 2012; Keskinen, 2006), where 80% of animal protein consumed by humans is derived from freshwater animals (Hortle, 2007), the majority of which comes from the Tonle Sap (Baran et al., 2014). Fishing and agricultural activity around the Tonle Sap is driven by the flood pulse from the Mekong River, which inundates the floodplain every year for several months.

Tonle Sap fishery resources have decreased substantially over time due to a growing rural population and illegal and unsustainable fishing activities (Nguyen et al., 2015; Travers et al., 2011). Consequently, rural livelihoods have become increasingly impaired, and many fishing households remain entrenched in poverty (Johnstone et al., 2013). Climate change and ongoing dam construction in the Mekong River Basin is projected to alter water levels and modulate the river's flood-pulse, thereby impacting fish biodiversity and ecosystem productivity across the entire Basin (Arias et al., 2014; Arias, Cochrane, Norton, Killeen, & Khon, 2013; Ziv, Baran, Nam, Rodriguez-Iturbe, & Levin, 2012). Livelihoods dependent on the Tonle Sap floodplain ecosystem are thus likely to be adversely impacted by future socio-economic, policy, ecological, and climate change (Arias et al., 2014; Salmivaara et al., 2016). This is of concern given that the Tonle Sap Zone already has a higher poverty incidence than the national average (JICA, 2010).

Within the global change literature, the extent to which people are vulnerable to climate and socioeconomic change is dependent on one's exposure (likelihood of being impacted), sensitivity (dependence on natural resources), and capacity to adapt to likely

impacts (Adger, 2006). Cambodia is classified as being highly vulnerable to the effects of climate change on fisheries (Allison et al., 2009). Poverty, marginalisation, and lack of alternative livelihoods impede fishing communities' ability to cope with changes in fishery productivity (Baran et al., 2009). A prior survey of the Tonle Sap Lake area found that up to 90% of respondents were extremely vulnerable to shocks, and 50% of households would fall in extenuating circumstances in the event of heavy rainfall, floods, or local droughts (GFA Consulting Group, 2007). Hence, building up adaptive capacity of natural resource dependent livelihoods is imperative to help reduce this vulnerability. Addressing vulnerability can also incentivize participation in more sustainable resource management (Baran et al., 2009).

Developing adaptation strategies to overcome vulnerability requires an understanding of how people will respond to future changes. The research directly addresses this issue from an economic perspective by investigating the benefits and costs of Tonle Sap inhabitants' adaptive responses to four scenarios of future socio-economic and climate change. We analyze these economic outcomes by different livelihood groups and village zones in order to understand which groups are most vulnerable and hence have the least capacity to adapt to future change.

Tonle Sap fisheries

Approximately 2 million people participate in the Tonle Sap Lake fishery (So & Song, 2011), which targets multiple species using a wide variety of gears. The dominant gears are gillnet, cast net, hook line, and small traps, while the main targeted fish species include lesser silver mud carp (*Henicorhynchus lobatus*), striped snakehead (*Channa striata*), snail eating barb (*Puntioplites proctozysron*), and blackskin catchfish (*Clarias meladerma*) (Bond, 2015). Fisheries in the lake are essentially open access (Ratner, 2006a). Fisheries deregulation in 2012 turned over all commercial fishing lot licenses

to community managed fishing areas. Nevertheless, poor enforcement and management capacity has resulted in the persistence of intense competition for fishery resources, leading to intense exploitation and chronic illegal fishing (Johnstone et al., 2013). Declining fish size, catch per unit effort, the elimination of large and commercially valuable species and increasing prevalence of less desirable species are all indicators that the sustainability of Tonle Sap Lake fisheries has deteriorated (Cooperman et al., 2012; Enomoto et al., 2011). Further, a rapidly growing population, up-river dam development, an expanding agro-industry in the upper watershed, and climate change will almost certainly impose further pressures on fish populations in Tonle Sap Lake (Cooperman et al., 2012), posing a threat of fisheries collapse.

Households in the vicinity of Tonle Sap Lake primarily engage in small-scale artisanal and subsistence fishing, with supplemental income from agriculture, raising livestock, aquaculture, off-farm work, and remittances (Bond, 2015; Keskinen, 2006). Yet, many of the poorest households depend on one livelihood, which is generally fishing (Nuorteva et al., 2010). Floating villages are particularly dependent on fisheries resources, and their limited access to land resources, education, and livelihood options make them especially vulnerable to ecological change (Nuorteva et al., 2010). Almost 70% of floating households on Tonle Sap Lake were classified as being low-wealth (Bond, 2015), where wealth was an index measuring household location, diet diversity, and livelihood strategy. Lower income Tonle Sap fishers, therefore, exemplify a vulnerable population. In contrast, richer households were typically not as reliant on fishing as their main income source (Bond, 2015). While inhabitants around the Lake have adapted to seasonal changes of the lake, they have poor capacity to react to irregular environmental events (Nuorteva et al., 2010).

A previous survey of Tonle Sap fishing households found that fish catch was not perceived to be decreasing, but there had been a noticeable decrease in sizes and diversity of the fish caught (Bond, 2015), indicating that fish populations are under stress (McCann et al., 2016; Pauly, 1998). However, most households were not able, or willing to change their livelihood strategy because they did not have the necessary resources to adapt to long-term changes in their livelihoods (Bond, 2015). Based on spatial analysis and qualitative interview data, Bond (2015) showed that many fishing households, especially those in floating villages and at lowest wealth levels, faced uncertain futures because they will not have alternative livelihoods to turn to for income and subsistence in the event Tonle Sap Lake fisheries collapse. We add an economic perspective to these findings by conducting an economic analysis of fishing households' adaptive responses to scenarios of future socioeconomic and environmental change.

5.2 Materials and methods

5.2.1 Field interviews

Interview data used in this study were based on field work carried out in Cambodia in 2014, and is detailed in Bond (2015). Briefly, household surveys were conducted in three districts of Pursat province (Krakor, Kandieng, and Bakan). Pursat is located in western Cambodia, and has one of the largest coastlines along Tonle Sap Lake (Figure 6), as well as the third highest density of fishers around the Lake (Baran et al., 2014). Poverty is widespread, as 40% of the population in Pursat is below the absolute poverty line (JICA, 2010). This province was chosen because it is an important tributary and fishing location, and remains largely untouched by tourism and development. Fishing is the primary livelihood for a large portion of the Pursat population, making them particularly vulnerable to changes in the flood pulse and degradation of lake resources. As the aim of Bond's (2015) study was to understand peoples' adaptation to changing fish

populations in the Tonle Sap, villages in the three districts were selected if they had a Fish Dependency Score[1] (J. Nasielski et al., 2013) of 0.5 or higher. Based on this criteria, 26 villages were selected; each village contained households which either fished in the lake, in a main tributary, or in the floodplain during the wet season.

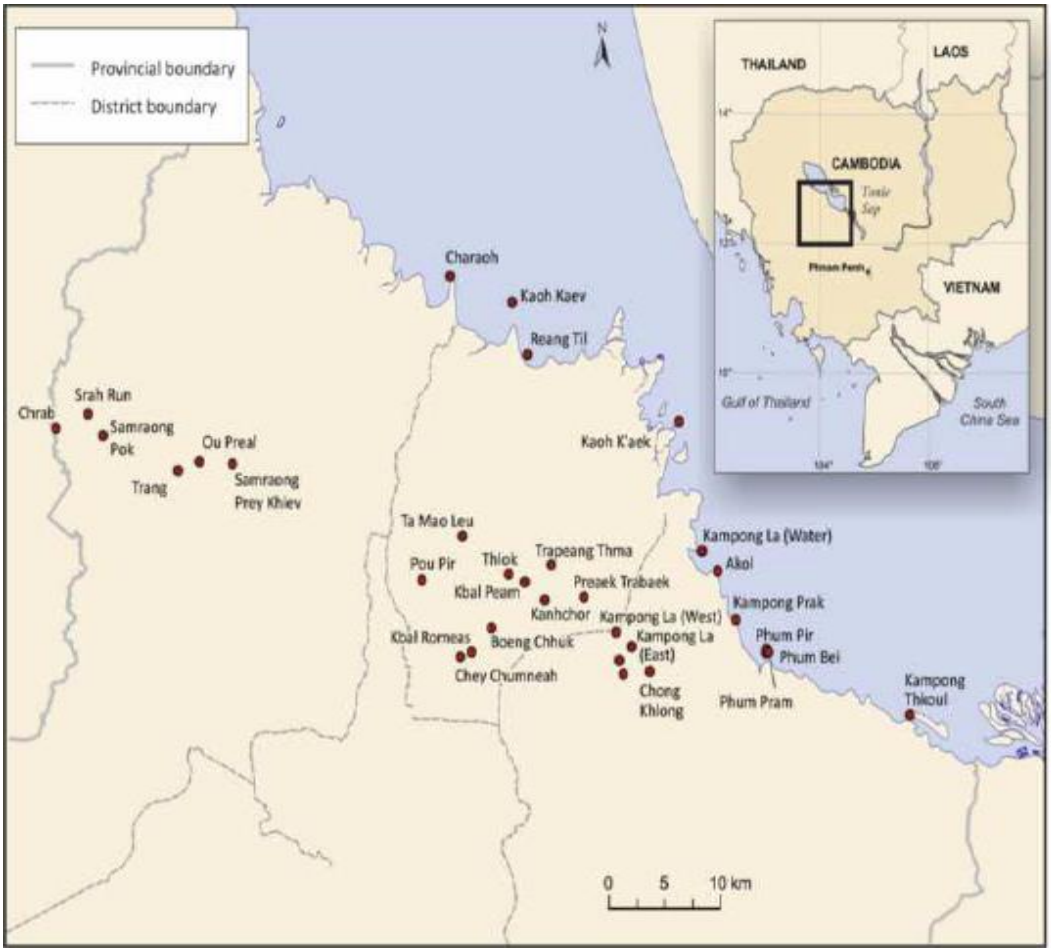

Figure 6. Map of Pursat Province showing the location of village sites where interviews were conducted. Map source: Bond (2015), with basemap from JICA & MPWT (2003)

Selected villages were all located between the Tonle Sap Lake and National Road #5, which is 4-40 km from the Lake. The selected villages were located along the Pursat River, on the water (floating villages), and in the floodplain. Villages were categorized into 5 zones according to their distance from the National Road (Table 6). The

[1] The Fish Dependency Score indicates the probability of randomly selecting a fishing household in a village. It is calculated by multiplying the ratio of fishers: total village population by the village's poverty score (Nasielski et al.2013).

distance range covered by each zone was subsequently allocated to achieve as equal a distribution of villages as possible within each zone.

Table 6. Categorization of village zones and the list of study villages within each zone.

Zone	Distance from National Road	No. of villages	Village names
A	0-5 km	5	Chong Khlong, Kampong Thkoul, Phum Bei, Phum Pir, Phum Pram
B	5.1-7 km	5	Chey Chumneah, Kbal Romeas, Peak Trabeak, Pou Pir, Samrong Pok
C	7.1 – 10 km	6	Boeng Chhuk, Chrab, Kampong Prak, Ou Preal, Srah Run, Trang
D	10.1 – 20 km	6	Kanchor, Kbal Peam, Samraong Prey Khiev, Tamao Leu, Trapeang Thma, Kampong La
E	> 20 km	4	Charaoh, Kaoh Kaev, Kaoh Krak, Reang Til

At each selected village, household names were randomly selected from village lists to complete the surveys. A total of 181 households surveys were conducted, based on a sample size requirement of S= N/(n*2), where S = number of households that had to be selected in a village, N = the total number of village households, and n = the number of households needed. In total, 67% (n=122) and 33% (n=59) of surveyed households were located on water and land, respectively.

The surveys aimed at understanding household demographics, livelihood strategies, and perceptions of change around the lake and the adaptive capacity of households. This study focuses on the questions pertaining to livelihood strategies and future scenarios of the Tonle Sap. As the surveys conducted by Bond (2015) focused on understanding fishing activities on the Lake, we grouped respondents into three groups according to their reliance on fishing: Group 1 = Fishing only; Group 2 = Fishing + Farming and/or Off-farm work; Group 3 = Non-fishing work.

It is noted that this division resulted in unbalanced groups, with 55, 114, and 12 respondents in groups 1, 2, and 3, respectively. In general, respondents involved in farming lived in the floodplain parallel to National Road #5, while non-farming respondents lived closer to the lake, parallel to Pursat River. Those involved in fishing

only tended to live in the middle of the lake, whereas those that were involved in both fishing and other work lived on the shoreline of the lake or in the floodplain (Bond 2015).

5.2.2 Economic analysis

We first estimated the net income from respondents' current livelihoods and compared this to net income derived from reallocating their livelihood activities under 4 scenarios depicting future change. We then investigated patterns of respondents' net income under two vulnerability indicators- livelihood diversification and village distance to the National Road. Livelihood multiplicity is a common measure of vulnerability of fishing and other natural resource dependent communities (Badjeck, Allison, Halls, & Dulvy, 2010; Cinner et al., 2012; Hahn, Riederer, & Foster, 2009; M. M. Islam, Sallu, Hubacek, & Paavola, 2014; McClanahan et al., 2009). Distance from the National Road was used as a vulnerability indicator because people located closer to the National Road were found to in a better situation than those living closer to Tonle Sap Lake in terms of being able to reduce their vulnerability, i.e., they had more livelihood options, better education, wealth, and agricultural land ownership (GFA Consulting Group, 2007).

Net income from current livelihood activities

To estimate the net income each respondent obtained from their current livelihood activities, revenue and cost data were extracted from the household surveys for 3 non-fishing livelihood activities: i) agriculture (wet rice, dry rice, maize, cassava, beans, other vegetables); ii) raising livestock (cattle, buffalo, pigs, poultry); and iii) aquaculture.

Revenue (R) obtained from each activity was calculated as:

R = P x Q, Where P = selling price and Q = quantity; and

Net income Nt,a, at time t (0 for current, 1 for future), and for livelihood activity a was calculated as:

Nt,a = Rt,a – Ct,a, Where C was the production cost associated with each livelihood activity (e.g., seed, fertilizer, transportation, labor).

Note that no fixed costs were collected in the survey; therefore, net income in this study is equivalent to net revenue. An exception was off-farm income, which was represented by the annual salary reported by respondents during interviews. Net fishing income was calculated differently because no fishing cost data were collected. First, fishing revenue was calculated by multiplying the average annual fish catch by the average selling price (Riel/kg) provided by each respondent who fished. If a respondent did not provide price information, an overall average price (i.e., average of all respondents' selling price) was applied.

We first checked a global fishing cost database (Lam, Sumaila, Dyck, Pauly, & Watson, 2011) for Cambodia specific data, but none were available. Subsequently, we estimated fishing costs from Cambodian case studies, in which total fishing costs ranged from approximately 55% to 59% of fishing revenue (Hap & Bhattarai 2006[2]; Sinh et al. 2014). The midpoint of this rate was applied to fishing revenue to obtain net fishing income.

Economic impact of future scenarios to the Tonle Sap Lake

Hydropower development, climate change, and urban migration were identified as major drivers of change to the future of Tonle Sap Lake's ecosystem and inhabitants. Increased development of hydropower dams, reservoirs, and irrigation schemes was expected to result in higher dry season water levels and lower flood peaks (Matti

[2] Hap and Bhattarai (2006) conducted an analysis of fishing profitability for 3 Cambodian studies. We used the results for Kampong Chhnang, which is adjacent to Pursat and located next to Tonle Sap Lake. The other two provinces were located in northern and southern Cambodia, away from Tonle Sap Lake.

Kummu & Sarkkula, 2008); these flow alterations would likely result in ecological disruptions, as they would affect crucial biological factors such as fish migration and tree seed germination. Meanwhile, future scenarios of water infrastructure development and climate change projected reduced spatial extent of seasonally flooded habitats and forests while favoring rain-fed irrigated agricultural areas (Arias et al., 2012).

Hydrological changes were expected to have a drastic impact fisheries production in the Lake – for instance, Sarkkula & Koponen (2010) found that there was a high risk that all migratory fish would vanish if mainstream dams were built. Moreover, it was estimated that migratory fish biomass would decline by up to 51% by 2030 under different scenarios of hydrological development (Ziv et al., 2012). The anticipated decline in fish catches, decreased farm productivity, and landlessness were expected to reduce livelihood opportunities and increase migration from Tonle Sap Lake to urban centers (Heinonen, 2006), with Phnom Penh being the most sought out destination of both rural and urban migrants (MoP, 2013).

To reflect changes in the flood pulse and the potential outcomes from ongoing hydrological development in the Upper Mekong Basin, climate change, and urbanisation, four hypothetical scenarios were developed. Respondents were told that each scenario occurred in the future, although there was no specific time frame associated with the scenarios. The four scenarios were:

Scenario A (Less fish) – A 50% reduction in fish production in Tonle Sap Lake.

Scenario B (More farm land) – An increase in agricultural land due to changes in flood plain habitats.

Scenario C (Urbanization) – The creation of more jobs due to urbanization and increased economic activities in urban centers, particularly in Phnom Penh.

Scenario D (Stagnation) – The status quo is retained, i.e., same situation as today.

Estimating net income for future scenarios

The following process was used to estimate the net income derived from livelihood activities under each future scenario:

1. For every scenario A-D, each respondent provided: a) whether they would continue with their current livelihood strategy; and b) how they would reallocate their time (*t*) to different livelihood options (Table 7). If in (a) the respondent did not change their current livelihood allocation, their current livelihood net income (N0,a) was assigned to that scenario.

2. The net income of each livelihood activity the respondent chose under each future scenario (N1,a) was calculated as:

$N1,a = \Sigma (N0,a * t1,a)$, where *t* is the proportion of time allocated to each future activity. If an individual chose a new livelihood that he/she did not currently participate in (i.e., no current net income data was available for that activity), then a net income averaged across all respondents who currently participated in that activity was assigned. For example, if a group 1 respondent who currently only fishes chose to start farming, then his/her future farming income would be equivalent to the current average farming income obtained by group 2 and 3 respondents. Although we recognise that future scenarios will involve cost of living increases and price fluctuations, we did not account for these adjustments when estimating future net income because there was no explicit timeframe associated with our scenarios.

3. There were 2 scenario options for which no current benefits and costs data were available – renting land to farm, and upland farming. Subsequently, the economic benefits from these activities were calculated as follows:

3a. Renting new land – Based on literature, an extra 33% was added to total crop farming costs to account for rental cost. This was estimated based on a socio-economic assessment of rice farming conducted in 3 Cambodian provinces (Asian Development Bank, 2012). The study provided average rental cost per area, and average rented areas for well-off, medium, and poor households. We applied the rental data for poor households.

3b. Upland farming – Upland farming costs are expected to be different from lowland farming because average upland farm sizes tend to be larger, and the farming system used also differs from lowland farming (Farquharson, Scott, & Chea, 2008). A 2006 study on improving upland crop technology in 5 districts in Battambang and Kampong Cham Provinces (close by to Tonle Sap) estimated that on average, the per hectare variable costs for growing non-rice crops accounted for approximately 79% of revenue (Farquharson et al., 2008). Across all districts, the average gross margin (revenue – variable costs) was 2.4 million Riel. As no fixed cost was provided, we used gross margin as the best estimate of net income from upland farming.

Table 7. Summary of livelihood options that respondents could reallocate labor and time resources to. A different set of options was presented to each respondent depending on the type of livelihood activities they were currently engaged in.

	Current livelihood activities respondent is engaged in		
	Fishing only	Fishing & farming	Fishing & off farm activities
Livelihood options for reallocating labour and time resources	a. Start farming activities b. Start off-farm activities c. Change to farming only d. Move to off farm jobs only	a. Increase farming/ fishing activities b. Start off-farm activities c. Change to farming only d. Move to off-farm jobs only e. Rent farm land	a. Changing the proportion of fishing and off-farm activities b. Start farming activities c. Increase farming activities d. Increase off-farm activities e. Move to off farm jobs only f. Change to farming only

5.3 Results

5.3.1 Demographics and current time allocation to livelihoods

The average household size was 5.2, with 62% of households having 5 or fewer members. Group 3 respondents had fewer household members (3.7) than groups 1 and 2, which both had an average of 5.3 household members. The majority of household heads were male, with 41% headed by women. The average age of respondents was 45. Most respondents (83%) had primary school education, with only 2% having completed secondary school. Three quarters of respondents were ethnic Khmer, 22% were Vietnamese, and the remaining 3% were Cham. Thirty-four percent of respondents undertook one livelihood activity only. Of these, the majority were engaged in fishing only (90%), with the remainder engaged solely in either farming or off-farm work. Across all respondents, the most time (average 47%) was currently allocated to fishing activities, followed by agriculture (31%), off farm work (18%), and lastly to aquaculture (4%).

5.3.2 Net income from current livelihood activities.

Fishing was the livelihood activity with the highest participation rate (93% of all respondents), and provided on average an annual net income of 1.8 million Riel (USD 440). Vegetable crop farming and off-farm work had the lowest participation rates, at 3% and 16%, respectively. Off-farm work also provided the lowest average net annual income. The highest average net income was derived from livestock rearing (about 2.1 million Riel or USD 514 annually), but less than half the respondents participated in this activity (Figure 7).

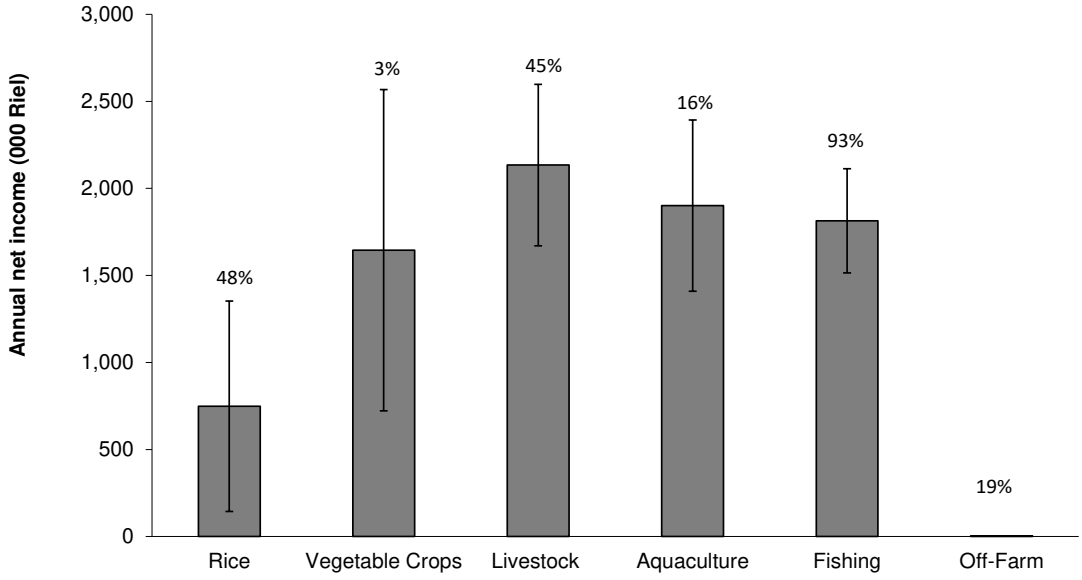

Figure 7. Current annual average net income (000 Riel) (± standard error) of different livelihood activities, with the percentage of respondents participating in each activity indicated at the top of each bar. The 2014 average exchange rate was 4037.5 Riel/USD (World Bank, 2015b).

The overall average annual net income from all livelihood activities was 3.6 million Riel (USD 892). Both livelihood groups 1 (fishing only) and 2 (fishing + other activity) had comparable annual net income levels of 3.9±0.6 and 3.7±0.9 million Riel, respectively. Average net income for group 3 (non-fishing livelihood) was only about one third the level of the other two groups (1.3±0.6 million Riel), but the difference between groups was not statistically significant (Figure 8).

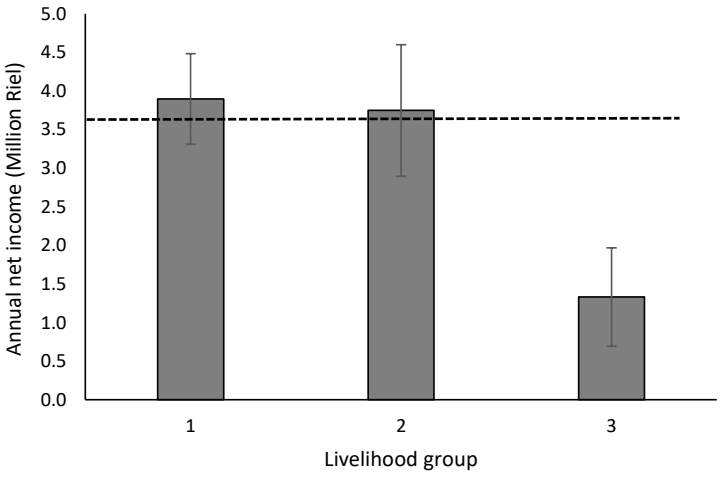

Figure 8. Current average annual net income (± standard error) for each livelihood group (1=fishing only, 2= fishing + other activity, 3= non-fishing activities). The dashed line indicates the overall average annual net income across all livelihood groups (3.63 million Riel).

5.3.3 Net annual income under future scenarios

Change in livelihood allocation

For all scenarios, the majority of respondents chose to retain their current livelihood allocation. Scenario C (Urbanization) resulted in the highest proportion of respondents (47%) changing their current livelihood allocation; both scenarios A (Less fish) and D (Stagnation) had the least number of respondents changing (25%), while 35% of respondents changed livelihood allocation in scenario B.

Estimated net income

In general, respondents chose options that resulted in fairly similar net income outcomes under each future scenario. Across all scenarios, responses to scenario A (Less fish) resulted in the highest 13 average (± standard error) net income per respondent (3.6 ± 0.6 million Riel or ~USD 892), followed by scenario D (Stagnation, 3.5 ± 0.5 million Riel or ~USD 867), B (More farm land, 3.1 ± 0.5 million Riel or ~USD 768), and scenario C (Urbanization, 3.0 ± 0.6 million Riel or ~USD 743). On average, responses to all scenarios generated net income that was below current levels. The average net income for different scenarios within each livelihood group did not vary much across scenarios (Table 8). The exception was scenario A (Less fish), which, relative to other scenarios, generated much higher net annual income for livelihood group 2, but resulted in lower net income for group 3 (Table 8).

Table 8. Average net annual income and percentage change in net income for scenarios A to D according to livelihood groups (1=fishing only, 2=fishing + other activity, 3=non-fishing activities)

	Net Income			% Change in Net Income		
	Livelihood Groups					
Scenario	1	2	3	1	2	3
A	3,355,251	3,859,466	993,245	-16	-1	-10
B	3,328,193	3,068,706	1,225,183	-18	-6	-3
C	2,995,872	3,084,989	1,205,783	-30	-18	-9
D	3,670,293	3,662,301	1,211,800	-6	-11	10
Average	**3,337,402**	**3,418,866**	**1,159,003**	**-17**	**-9**	**-3**

Estimated economic gains and losses under future scenarios

Relative to current conditions, the greatest loss in net income was expected to occur under Scenario C (Urbanization) for group 1 (fishing only), while the greatest gain was expected under scenario D (Stagnation) for group 3 (non-fishing activities) (Table 8). Averaged across all scenarios, livelihood group 3 was the least negatively affected, while group 1 (fishing only) was the most negatively affected (Table 8). Scenario D (Stagnation) resulted in the least loss in net income relative to the present (-2%), while Scenario C resulted in the largest loss (-19%). In fact, a much larger number of respondents would potentially experience a decrease instead of increase in net income under each scenario (Figure 10). For all scenarios, only about 7% of all respondents made choices that resulted in a positive gain in net income, whereas the majority of respondents chose to retain the same livelihood allocations (Figure 10). Scenarios A (Less fish) and D (Stagnation) had the largest proportions of respondents choosing to retain their current livelihood allocations (Figure 9).

Scenario C (Urbanization) had the largest proportion of respondents (39%) who made choices which resulted in net income losses. This was primarily due to group 1 respondents reducing their allocation from 100% fishing to a combination of either fishing and off-farm jobs, or fishing and upland farming. Scenario C was also the scenario that resulted in the largest proportion of decreased 14 benefits among livelihood group 2. Among these respondents, the majority (84%) chose to decrease their fishing allocation while increasing their agricultural or off-farm work, or shifting from lowland to upland agriculture.

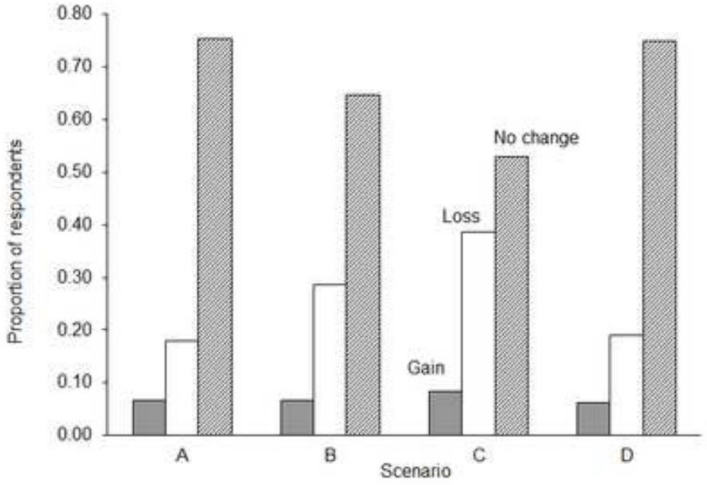

Figure 9. Proportion of responses that resulted in a gain, loss, or no change in average net annual income under each scenario

Net income by single vs multi-livelihood groups under current conditions and future scenarios

The majority of respondents (66%) engaged in more than one livelihood activity. Current average annual net income for both single and multi-livelihood groups was almost identical, at 3.6 and 3.7 million Riel (USD 891- 916), respectively. When faced with future scenarios, the multi-livelihood group generally made choices that resulted in slightly higher average net annual income, although the differences were not statistically different (Figure 10). The multi-livelihood group experienced the largest net income difference under scenario A (Less fish), while scenario B (More farm land) resulted in almost identical net income for both groups (Figure 10).

The single livelihood group chose responses that resulted in greater net income loss (relative to the present) than those engaged in multiple livelihood activities for all scenarios except scenario D (Figure 11). The difference in percentage loss between single and multi-livelihood groups was significant under scenario A ($F_{1,179} = 5.52$, $p < 0.05$).

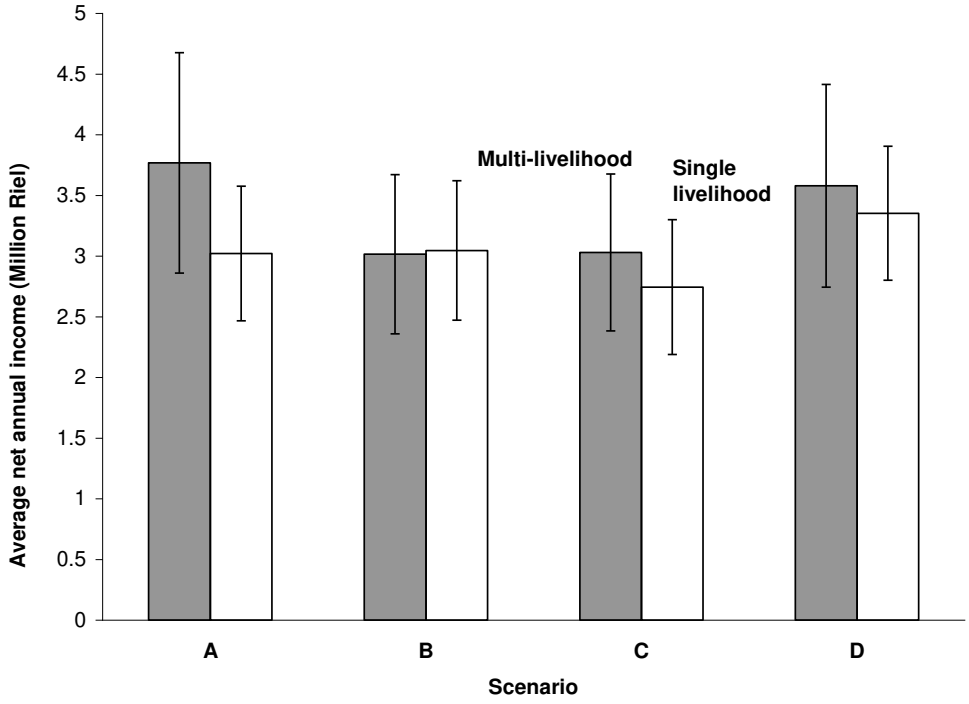

Figure 10. Average net annual income (± standard error) for single (lined bar) and multi-livelihood (grey bar) groups under Scenarios A to D.

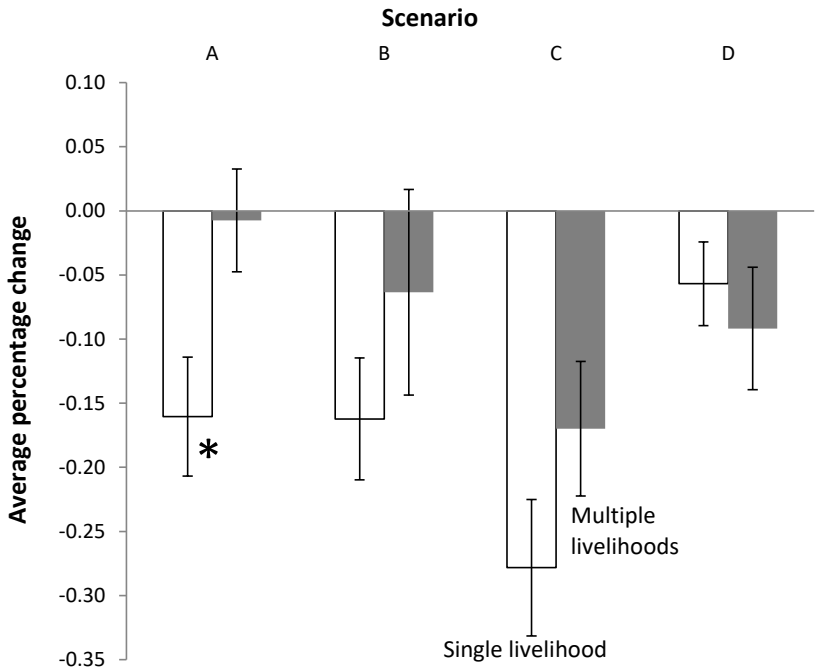

Figure 11. Average percentage change in net income relative to current levels under each scenario, broken down by single or multi-livelihood groups. Asterisk indicates a significant difference between single and multi-livelihood groups ($F_{1,179} = 5.52$, $p < 0.05$)

Net income under current conditions and future scenarios by village zone

Respondents living in zone a (closest to the National Road) had the highest current average annual net income, while those living in zone b (5-7 km from the National Road) had the lowest (Figure 12). Among the respondents with single livelihoods, the majority (86%) were from either zones e (48%) or a (38%), which were the villages furthest and closest to the National Road, respectively. None were from zone b, while 10% and 5% were from zones c and d, respectively. In contrast, the majority of respondents (74%) with multiple livelihoods were from zones located between 7 and 20 km of the National Road, i.e., zones c (43%) and d (31%).

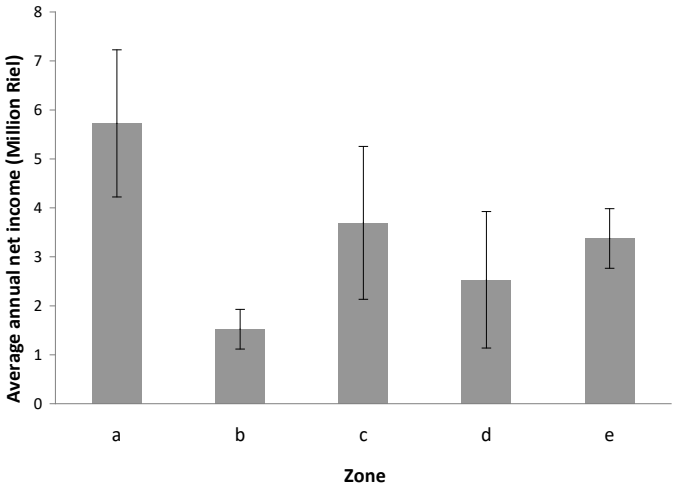

Figure 12. Current average net annual income (± standard error) from all livelihood activities by zone.

Multi-livelihood groups across all zones and under all scenarios had consistently higher average net annual income than single livelihood groups, but these differences were not statistically significant. Aggregating all respondents, the change in annual net income under each scenario varied widely across zones, although none of the differ-

ences were statistically significant. The largest losses in average net annual income occurred most frequently in zones b and e across all scenarios, except for Scenario D (Stagnation), in which zone c respondents had the greatest loss (Table 9).

Table 9. Average percentage change in net annual income (relative to the status quo) for each scenario, broken down by village zone.

Scenario	Zone				
	a	**b**	**c**	**d**	**e**
A	1	-30	1	-1	-21
B	-16	-17	-15	18	-24
C	-13	-20	-23	-13	-33
D	-1	-6	-15	-9	-4

5.4 Discussion and conclusion

This study aimed to investigate the economic consequences of Tonle Sap inhabitants' current livelihood strategies and their responses to socio-economic and environmental scenarios in order to understand their current and future vulnerability. We found that respondents who were not engaged in fishing, (i.e., group 3) appeared to be the most vulnerable under current conditions, as they had the lowest net annual income among all groups. This could stem from their lack of access to fishery resources. At the same time, group 3 respondents tended to have slightly smaller household sizes than groups 1 and 2, so the impact of a lower income may not be as severe on a per household member basis.

Respondents who only fished (group 1) had slightly higher income than those who fished in conjunction with other activities (group 2). This suggests that based solely on income, it may be a good strategy for fishers to focus on fishing only, as there may be economic gains from specialization. Although this strategy may appear to contradict the push for diversified livelihoods, it may still be beneficial for fishers to switch to secondary livelihood activities when seasonality is taken into account and environmental conditions change. In fact, having additional livelihood sources is an important coping and adaptation strategy for people living in the Tonle Sap Lake area (Nuorteva et

al., 2010). Thus, there is a trade-off between obtaining higher income from one livelihood activity only, or accepting lower income but diversifying livelihood risk. For instance, both Abson et al., (2013) and Fraser et al., (2005) found that it made more sense to specialize in times of relative socio-economic and environmental stability, whereas during periods of change it made more sense to diversify.

Access and proximity to roads can generally increase peoples' capacity to respond to environmental and economic shocks(GFA Consulting Group, 2007; T. T. X. Nguyen, Bonetti, Rogers, & Woodroffe, 2016), and respondents living closest to the National Road (zone a) indeed had the highest average annual net income under current conditions, an indication of lower vulnerability. This supports a prior study which found that those living closest to Tonle Sap Lake were less well off than those living closer to National Roads (Keskinen 2006). It also supports other studies which indicated that being closer to well-developed infrastructure provides better market access and hence higher income for natural resource dependent communities (T. T. Nguyen et al., 2015; Sinh et al., 2014). This is particularly the case for highly perishable goods such as fish, and makes sense since the majority (64%) of respondents living in zone a were from group 1 (fishing only). Zone e respondents (furthest from the National Road) would, therefore, be assumed to have the lowest income and higher vulnerability; however, they had unexpectedly higher annual net income than those in zone b (relatively closer to National Road).

Three quarters of the respondents living in zone e were only engaged in fishing (group 1), while those in zone b engaged in multiple livelihoods (fishing plus other activities). Zone e villages are located on the water, while those in zone b are located further inland. This again suggests an income livelihood diversification trade-off, as zone e respondents may be more restricted in the livelihood options available to them,

but are compensated by higher income, whereas zone b respondents have more livelihood options but obtain lower income from the diversified activities. Importantly, zone b respondents tended to allocate the majority of their time to non-fishing activities, with only 10-50% of their time spent on fishing, whereas the majority spent 60-90% of their time on agricultural activities. The lower economic returns associated with farming may be due to low agricultural productivity, as it was previously found that low soil fertility minimized the potential contribution of rice farming to poverty alleviation in the Tonle Sap area (Johnstone et al., 2013).

Interestingly, both zones a and e consist of floating villages, and thus contradicts the expectation that floating village inhabitants are the most vulnerable and have lowest adaptive capacity (Bond, 2015; Nuorteva et al., 2010). Indeed, people in floating villages located in other parts of the Tonle Sap Lake have shown adaptive capacity by engaging in seasonal snake hunting as a means of diversifying their income sources(Brooks, Reynolds, & Allison, 2008). However, despite this seasonal adaptive behaviour, people may still be vulnerable to future change because they are not equipped to respond to unexpected or unusual environmental changes, especially to changes related to fish and water resources (Nuorteva et al., 2010). In particular, lack of education and access to land and capital may restrict opportunities for the poorest to diversify their livelihoods (Bond, 2015; Johnstone et al., 2013). The relatively higher incomes observed in zones a and e floating villages may also be related to the former's proximity to markets (nearest to the National Road) and the latter's close access to fishing grounds; this pattern is consistent with the finding that environmental income of households in rural northeastern Cambodia was closely linked to distance from natural resource grounds (T. T. Nguyen et al., 2015).

Although group 1 respondents (the dominant livelihood group in zones a and e) appear to be doing relatively well economically under current conditions, this may not hold in the future. In fact, across all future scenarios, the biggest losses are likely to be experienced by group 1. Further, those living in zone e (furthest from National Road) are expected to experience the largest losses in net annual income relative to current conditions. In contrast, group 3 (non-fishing activities) and zone d respondents experienced the least losses across all future scenarios. The majority of zone d 18 respondents engaged in two or more livelihoods; thus, although the economic situation for all respondents appears to deteriorate under future scenarios, our results imply that future income losses may be lower for those with diversified livelihoods compared to single livelihoods.

Across all livelihood groups, scenario C (Urbanization) resulted in the biggest income loss relative to current levels. Group 1 (fishing only) experienced the largest losses under scenario C, which was primarily due to the respondents reallocating their time spent on fishing to either off-farm work or upland farming. Off-farm work and upland farming are new activities to group 1, therefore suggesting that respondents may not fully understand the costs associated with switching to new livelihood activities. Alternatively, they may lack the education and technical skills to take advantage of future economic opportunities, thereby resulting in economic losses. Overall, this indicates low adaptive capacity among respondents at least in terms of their ability to take advantage of off-farm employment opportunities. It is noted that the interviews conducted by Bond (2015) and on which this study is based focused on fishing households. Therefore, switching to agricultural activities may still be economically beneficial for households that are not as strongly fishing oriented as those that participated in this study.

Among all scenarios, respondents' choices generated the best economic outcome under scenario D (Stagnation). This may indicate that respondents were capable of coping with conditions similar to the present, but were unlikely to make appropriate decisions given future scenarios that they were unfamiliar with. This reinforces the concern expressed by Bond (2015) about households' lack of ability or willingness to change, especially if fisheries collapse. This inability to anticipate and consider the long term reflects myopic behaviour which likely stems from respondents' poor socioeconomic conditions and daily struggle to meet present needs (Pauly, 1997). Their focus on the immediate and short term horizon is equivalent to having a high time preference (Teh, Teh, & Rashid Sumaila, 2014) ,which is not conducive for conservation outcomes (Clark, 1973; Sumaila & Walters, 2005). This suggests that future policies for increasing adaptive capacity will have to focus on strengthening the welfare and socio-economic conditions of local residents.

A consistent pattern across all future scenarios is that the majority of respondents chose to retain their current livelihood strategy. Of those who did change their livelihood allocation, a very small proportion (< 10% under every scenario) actually experienced a gain in economic benefits. This again suggests that respondents may not have the capacity to adapt to future conditions, or cannot anticipate the costs associated with changing their present livelihood practices in the future. Indeed, lack of knowledge and skills about farming and livestock raising practices were already among the main problems faced by farmers in the Tonle Sap area (Asian Development Bank 2012, p. 52); hence, it is not surprising that they would be reluctant to switch to entirely new livelihood activities. While fishers, who are the major livelihood group in this study, can make changes to their current fishing practices (e.g., using different gear, targeting different species, fishing at different locations), this still ties their future well-being to the

condition of fisheries and lake resources, and underlines the urgency for improving the present poor state of Tonle Sap fisheries management (Keskinen & Varis, 2012).

This study contributes to the growing body of research that examines the degree to which vulnerable societies in developing countries are likely to be impacted by human and environmental driven change to fisheries resources(Allison et al. 2009; Cinner, McClanahan, Graham, et al. 2012). We find that in the present time, the highest net income was obtained by those involved in fishing only; this surprisingly contradicts the expectation of livelihood diversification as a strategy to reduce vulnerability. However, faced with future uncertainties, Tonle Sap inhabitants are likely to experience a general loss in net income across their livelihood activities under all future scenarios of socio-economic and environmental change. This is a worrying result given that the Tonle Sap Zone already has the second highest poverty incidence in Cambodia (JICA, 2010). Those engaged in single livelihood activities are the most vulnerable, especially under a scenario of reduced fish catch, as they have the 20 largest losses while having the least capacity to adapt. Our findings fill an important knowledge gap because while numerous other studies have similarly highlighted the vulnerability and poor adaptive capacity of rural inhabitants in Cambodia (Baran et al., 2009; Nguyen et al., 2015), this is one of the few to actually quantify the consequences in terms of income loss. By doing so, our study can help to direct adaptation policies towards minimizing the economic impact of future changes on the most vulnerable segment of society, thereby contributing towards long-term sustainability of human and ecological communities tied to the Tonle Sap Lake floodplain ecosystem.

CHAPTER VI: DETERMINANTS OF IMPACT OF COMMUNITY FISHERIES IN THE TONLE SAP GREAT LAKE OF CAMBODIA

Ratha Seng[1,2, *], Robert S. Pomeroy[3], Peng Bun Ngor [1,4], Di Yang [3], Sovan Lek[1,2]

1. Laboratoire Evolution & Diversité Biologique, Université Paul Sabatier – Toulouse III, 31062 Toulouse, France.

2. Research and Development Center, University of Battambang, 020302 Battambang City, Cambodia.

3. Connecticut Sea Grant/Department of Agricultural and Resource Economics, University of Connecticut-Avery Point, 06340-6048 Groton, CT USA.

4. Fisheries Administration, No. 186, Preah Norodom Blvd., Khan Chamcar Morn, Phnom Penh, Cambodia

* Corresponding author's email address: ratha.seng@gmail.com , Telephone: +85595429647

Running head: IMPACT OF COMMUNITY FISHERIES IN CAMBODIA

[accepted] International Journal of Water Resources Development

6.1 Introduction

The Tonle Sap and its associated river system is the largest lake in Southeast Asia and one of the most productive freshwater fisheries in the world supporting large numbers of small-scale fishers. Fish from the Tonle Sap provide an essential source of protein and micronutrients critical to the health of families in a country still plagued by high rates of childhood malnutrition, as well as livelihoods (Baran et al., 2014; Hortle, 2007; Lamberts, 2006; Sunil & Sagna, 2015). The food security and livelihoods of people depending on the lake ecosystems are affected by future social and ecological changes (Salmivaara et al., 2016).

Over the last decade, there has been substantial fisheries policy reform in Cambodia's inland fisheries involving community fisheries (Charles & Nasuchon, 2010; Kurien, Baran, & So, 2006; Levinson, 2002; Mansfield & MacLeod, 2002; Ratner, 2006b; Tep et al., 2007; Thay, 2002). This was largely explained by the need to safeguard fish stocks, ensuring local food security, and the increasing conflict between family-scale fishers and fishing lot operators, who, despite the law, prevented subsistence fishers from accessing the resource through intimidation, violence and false imprisonment.

The Sub-Decree on Community Fisheries Management No: 25/OrNor Kror/BorKor in Chapter 2: Establishment of Community Fisheries in Article 6 states: "All Cambodian citizens have the rights to form Community Fisheries in their own local area on a voluntary basis to take part in the sustainable management, conservation, development, and use of fisheries resources. A community fisheries as mentioned in this Sub-Decree is a group of physical persons holding Khmer citizenship who live in or near the fishing area, voluntarily established and taking the initiative to improve their own standard of living by using and processing fisheries resources sustainably to contribute to economic

and social development and poverty alleviation. The Fisheries Administration and local authorities or Commune/Sangkat councils, shall cooperate together to establish community fisheries."

Community fisheries in Cambodia, as defined by law, is fisheries co-management. The co-management of community fisheries is a partnership between Cambodian citizens and the government, represented by the Fisheries Administration. The co-management partnership is also seen in the Community Fishing Area Agreement signed between the Fisheries Cantonment Chief and the community fisheries committee, with the local commune/sangkat chief signing as witness. The Fishery Law, Royal Decree, Sub-decree and Prakas on community fisheries all provide legal support for co-management of fisheries in Cambodia and the establishment of a partnership between citizens and government to share responsibility and authority for the management of the community fisheries.

This study presents the results of an investigation of the impacts of Community Fisheries (CFi) and the factors contributing to the impacts, in the Tonle Sap Great Lake of Cambodia on both ecological and human well-being. This study assesses the impacts associated with different ecological zones of the Tonle Sap and the size of the community managed area, seeking to understand the links between management arrangements and the ecological characteristics. The size of community area is important after the 2012 fishery reform in which private fishing lots were converted into conservation areas and for public access. Recommendations are made to improve the governance of these important fisheries.

Context

The Tonle Sap Lake ecosystem extends into the central plains, covering about 5 to 8 percent of Cambodia's total land area (MRC, 2003). Connected to the Mekong River by the 120 km long Tonle Sap River, the Tonle Sap Lake's surface area annually fluctuates from 2,500km^2 to over 15,000km^2 driven by seasonal flood pulse from the Mekong River accounting for 53.5 percent of total water inflows into the lake system (M. Kummu et al., 2014).

The lake provides essential ecosystem services and supports livelihoods of at least 2 million people. In Cambodia, more than 80% of animal protein intake comes from fish (Hortle, 2007), of which the majority are from the Tonle Sap (Baran et al., 2014). Due to its unique flood pulse system and huge fish productivity, the Tonle Sap has significant social, economic and cultural values to local people for centuries. People have been adapting their life and livelihoods to the annual variations of the lake's water level and have closely connected themselves and ways of living to the lake and its natural resources. Rice and fish have been fundamental to local residents in the Tonle Sap region. Despite having traditionally adapted to the seasonal changes of the lake, the fishing communities have weak capacity to respond to unusual environment events and are among the poorest and most vulnerable in the Tonle Sap (Nuorteva et al., 2010).

The Tonle Sap is also highly vulnerable to the changes in the Mekong River and the lake itself. Upstream dam development (Arias et al., 2014; M. Kummu et al., 2014); private irrigation structures in the Tonle Sap (Keskinen et al., 2007); and climate change, increasing population and other drivers (Cooperman et al., 2012) have ecological effects on the Tonle Sap fisheries and the sustainability of the resources at risk. Some researchers validate the immediate impact highlighting decreasing high-valued fish species (Enomoto et al., 2011) and resource conflicts (Keskinen et al., 2007).

To address these issues, in 2001 the Community Fisheries Development Office (CFDO) was created in the Fisheries Administration and was put in charge of the process of crafting a sub-decree on CFi. The CFDO is specifically meant to support communities and encourage them to undertake participatory management of the floodplain fisheries in the country. Subsequently, a series of sub-decrees were issued to formalize the release of the fishing lot, and a sub-decree on CFi was formulated and discussed with stakeholders. On 29 May 2005, a Royal Decree on the establishment of CFi was proclaimed and on 10 June 2005, the Sub-decree on Community Fisheries Management was approved by the Prime Minister. On 30 March 2006, this sub-decree was given a more solid legal standing with the approval of the new Fisheries Law by the National Assembly. Finally, it was promulgated by the King on 21 May 2006. The Ministry of Agriculture, Forestry and Fisheries is entitled to allocate part of the fishery domain to the CFi that lies inside or around the fisheries domain as CFi area (Article 60). The CFi area is a Territorial Use Right in Fisheries (TURF) (Article 6).

According to the Fisheries Administration's database, the first CFi in the Tonle Sap was established in 2001. As of 2016, 181 CFis have been established around the five provinces of the Tonle Sap Lake with a total community fisheries area of 355,265 hectares. These CFis highly differ in size, ranging between 23 and 19,044 hectares. In 2012, the government abolished the industrial-scale century-old private fishing lot system covering an area of 270,217 hectares, and re-arranged 35% of the Lake area for conservation and the remaining for open access (Sithirith, 2014). While the decision provides more benefits to the community, concerns are also raised over the capacity of CFi in effectively co-managing the Tonle Sap fisheries given poor institution arrangements, especially at the local level.

6.2 Materials and methods

6.2.1 Community fishery survey

The data used in this study were based on a field survey conducted in the Tonle Sap, Cambodia in 2015. The Tonle Sap is made of the permanent lake and its extensive floodplain. The permanent lake is composed of two major basins. The northwest side of the lake is a large basin while the southeast lake is the smaller one, connecting together by a narrow strait. The lake is surrounded by five provinces: Pursat, Battambang, Siem Reap, Kampong Thom and Kampong Chhnang. The field survey was conducted in Battambang located in the large basin in the northwestern side and in Kampong Thom which situates more on smaller basin of the southeastern lake. The two provinces also exhibit an important fishing-farming ecology in the Tonle Sap and therefore were selected for the field study. While fishing is fundamental in both zones, Kampong Thom reflected a more significant role of farming in which large-scale private irrigation structures were built up to support the rice production systems. In contrast, households in Battambang still largely depend on fishing as their primary livelihood.

The sampling procedure then started with an identification of fish dependent villages in the Tonle Sap. The fish dependent villages were based on fish dependency scores computed as detailed in Nasielski et al. (2012). Only villages classified as medium, high and very high fish dependency were selected for the next step of the sampling. By doing so, it helped to reduce the heterogeneity in the population.

The next stage of the sampling process involved determining the characteristics of the selected villages. The villages were categorised into either water, water and land, or land based. Water villages are the floating villages situated in the lake for the whole year. Water and land based villages are referred to any villages which are under water

for at least three months a year. Finally, the land based villages situate on land, but households still primarily depend on the fishery resources. Water villages are closer to fishing ground while land villages are better connected to National Roads and developed infrastructure. The categorization of village type also reflects proximity and access to resource ground and developed infrastructure, which indicates the levels of economic status and adaptive capacities to respond to environmental or economic shocks (Keskinen, 2006; Nuorteva et al., 2010). This procedure helped improve understanding of the impact of CFi by accounting for both economic and ecological factors in the Tonle Sap. Then, 45 of 113 villages were randomly selected by sampling proportionally to each village characteristic (water, water & land, and land).

Table 10. List of 26 Community Fisheries (CFi) in Tonle Sap and sample size.

Battambang CFi	N	Kampong Thom CFi	N
Ang Cheung	13	Anlong Kahach	7
Ansang Sak	12	Anlong Lat	9
Bak Prea	17	Beoung Pralit	47
Boeng Tuem	19	Beoung Spong	15
Doun Tri	30	Beung Chang Beung Prang	9
Kach Roteh	27	Doun Sdaeng	4
Kampong Prahok	20	Neang Sa Ngeach	7
Kampong Preah	24	Phat Sanday	10
Kaoh Chiveang	14	Prek Kampong Cham	14
Kouk Doung	14	Samaki Kampong Kor	20
Preaek Toal	29	Sampoar Meanchey	6
Rohal Soung	16	Ta Mun Mean Leap	4
Svay Sa	22		
Thvang	28		
Battambang Total	285	Kampong Thom Total	152

Lastly, 26 CFis (Table 10, Figure 13) were identified for the field survey. The lesser number of CFi selected was because there was no existence of CFi in some villages. In some cases, a CFi was composed of members from more than a village, depending on the community arrangements and geographical characteristics. All 26 CFis from the 45 villages were registered and recognized by the Fisheries Administration. In each CFi, 20% and 5% members of CFi Committee (CFC) and CFi, respectively, were randomly selected for the interview with a total of 437 respondents. The interview sought to understand the CFis' perceptions of operation, impact, successes and challenge. The goal was to assess the performance of CFi in managing fishery resources in Tonle Sap lake, in which the survey questions were split into management and operation, roles of CFC and impact of CFi.

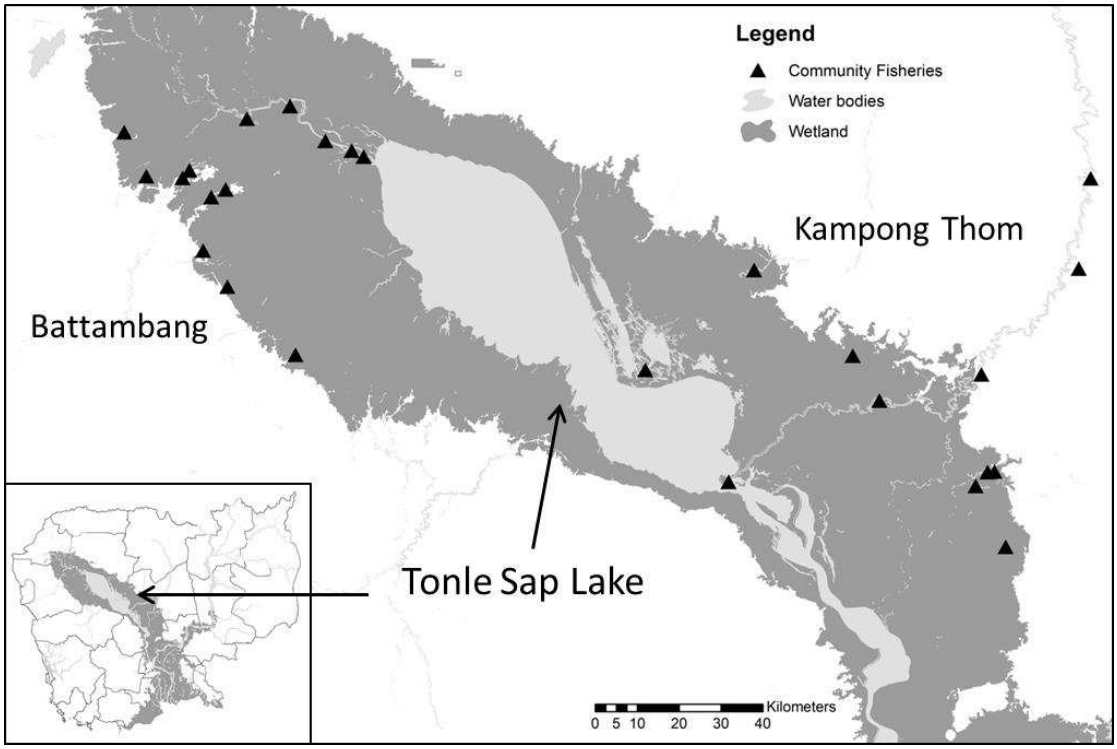

Figure 13. Map of Community Fisheries study area.

6.2.2 Data analysis

The analysis of determinants of governance impact of CFi involved two steps. Figure 14 presented a flowchart of analytical steps in the study. First, the classification

and regression trees (CART) analysis (Breiman et al., 1984) was carried out to assess the impact of CFi in association with different zones of the Tonle Sap and the size of the community area. The CART model has been found useful in many fields of natural, social and other applied sciences. The International Food Policy Research Institute (IFPRI) used CART to improve understanding of famine vulnerability at household level and to identify indicators for effective targeting interventions (Webb, Richardson, Seyoum, & Yohannes, 1994). Further, Thys et al., (2005) also applied CART to assess socio-economic factors influencing urban households in livestock keeping in Western Africa. The tool is considered efficient and effective in handling the complexity of data and practical development issues, and in aiding policy and intervention decisions. For instance, Yohannes & Webb (1999) developed a technical manual for setting up CART-based information systems to help identify key indicators of vulnerability to famine, chronic food insecurity and other failure of entitlements, aiming to better address the multifaceted nature of food security. Thus, the outputs from CART provide a list of most significant impact indicators relevant to ecological zones and the size of community area in the Tonle Sap (CART output); these were inputted into a next step of analyses.

In the second step, logistic regression was implemented to find the driving factors of the impact of the CFi based on the CART model results by using a set of explanatory governance variables (management and operation of CFi, and roles of CFC). Thus, management and operation of CFi and role of CFC were used to predict the CART output variables identified in earlier analyses in the regression models. All statistical analyses of the data were conducted in R software, version 3.2.5.

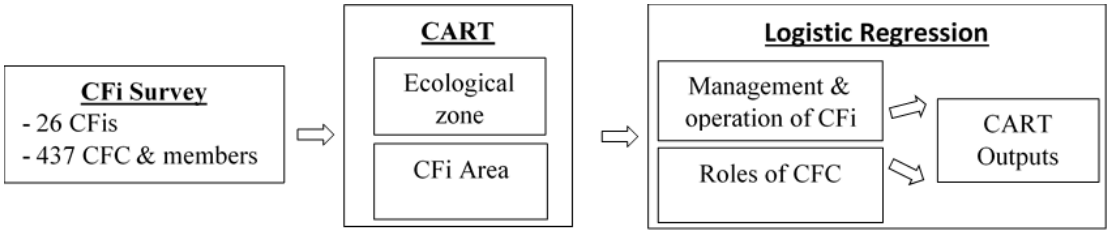

Figure 14. A flowchart of statistical analyses.

Classification and regression trees (CART)

CART is a non-parametric technique and works well with both categorical (classification) and continuous (regression) variables. Both dependent and explanatory variables can be a mixture of categorical and continuous variables. Table 11 presents a list of dependent and independent variables for the CART analysis. As explained by Breiman et al. (1984), the CART model first grows a large classification tree according to the splitting rule and then prunes itself to the right size by applying a goodness of split criteria. Each node represents the dependent variable or splits of the independent variable. Through the CART process, the aim is to search for the optimal splits to produce the most homogenous subsamples of the dependent variable.

In the first stage of the CART analysis, a set of impact measures was used to predict the ecological zone to understand the impact associating with each ecological area of the lake. In the second stage, the same set of explanatory variables was applied to determine the impact of CFi in association with the size of the community area.

CART analyses were performed using R function's *ctree* in package *partykit* (Hothorn & Zeileis, 2015). In the case of binary prediction (ecological zone), cross validation estimate of error and a confusion matrix were carried out to assess performance of the pruned tree and to examine individual class errors. Kappa Index (KI) was also computed to measure agreement of all elements in CART's confusion matrix, by applying *Kappa* function in *vcd* package (Meyer et al., 2006). The KI value provided an

indication of performance of CART model and the interpretation of the value was detailed in Landis & Koch (1977). The Pearson correlation was used to estimate the value of coefficient of determinant in the case of continuous variable (community area), implementing *cor* function in *stats* package (R Core Team, 2016).

Logistic regression models

From the CART's results, the five statistically significant variables were identified in association with ecological zone and community area: fishing ground, shared benefits, income, livelihood, and fishery condition. To do the logistic regression analyses, three multinomial response variables were transformed into binomial: fishing ground (larger vs. same/smaller), livelihood (better vs. same/worse) and fishery condition (good/very good vs. same/bad/very bad). Two sets of governance explanatory variables were run separately to predict the above five outcome variables: (i) management and operation of CFi, and (ii) roles of CFC (Table 12).

The regression analyses were performed using *glm* function in R's *stats* package (R Core Team, 2016) with "logit" link of binomial family. McFadden's Pseudo-R2 measures were computed applying *pR2* function in *pscl* package (Jackman, 2015) to test the goodness of fit of the models.

Table 11. Impact predictor and target variables for the CART model.

Variables	Descriptions
Dependent variables	
Ecological zone	*Battambang (Northwest), Kampong Thom (Southeast)*
CFi area	*Hectares*
Independent impact variables	
Fishing ground	Current fishing ground. *Bigger, Same, Smaller.*
Livelihood	Overall livelihood since the CFi. *Better off, Same, Worse off.*
Benefits	Benefit from CFi. *Yes, No.*
Shared benefits	Benefits shared by all people in the CFi. *Yes, No.*
More fish	More fish since the CFi. *Yes, No.*
More income	More income since the CFi. *Yes, No.*
More market	More fish market since the CFi. *Yes, No.*
Alternative livelihood	Provide alternative livelihood since the CFi. *Yes, No.*
Improved access	Improved fishery access since the CFi. *Yes, No.*
Fishery condition	Current fishery condition. *Very bad, Bad, Same, Good, Very Good.*
Living standard	Impact of CFi on standard of living, *Yes, No.*

Table 12. Descriptions of explanatory variables used in logistic regression analyses.

Variables	Descriptions
Management and operation of CFi	
Years of CFi establishment	*Number of years.*
Members	*Number of CFi members.*
Institutional support for establishment of CFi	Has some organization or government supported the establishment of community fishery? *Yes, No.*
CFi Area Agreement	Is there a Community Fishery Area Agreement? *Yes, No.*
CFi Area Management Plan	Is there a Community Fishery Area Management Plan? *Yes, No.*
Rules and regulatiuon for fisheries management	Are there rules and regulations for fisheries management? *Yes, No.*
Six-month activity plan	CFi has an activity plan for the next six months? *Yes, No.*
Conservation area	CFi has a conservation area? *Yes, No.*
CFi resolves conflict	CFi helps to resolve conflict in the fisheries? *Yes, No.*
Illegal fishing	Is illegal fishing a problem? *Yes, No.*
Persons committed illegal fishing	Who conducts the illegal fishing? *Inside village, outside village, both inside and outside village.*
Rule enforcement against illegal fishing	*Yes, No.*
Govenrment reduces illegal fishing	Government's effective action to reduce illegal fishing. *Yes, No.*
CFi reduces illegal fishing	CFi works to reduce illegal fishing. *Yes, No.*
CFi's regular patrol	Does the CFi do regular patrolling? *Yes, No.*
Community Fisheries Committee (CFC)	
CFC drafts by-law and management plan	*Yes, No.*
CFC represents CFi in conflict management	*Yes, No*
CFC manages finance	*Yes, No*
CFC participates in consultations	*Yes, No*
CFC reports violations	*Yes, No*
CFC manages fisheries	*Yes, No*
CFC coordinates with commune council	*Yes, No*
CFC develops network	*Yes, No*
CFC engages with women in community	*Yes, No*
CFC develops capacity of members	*Yes, No*
CFC manages community development projects	*Yes, No*
Open and transparent election	*Yes, No*
Transparent fisheries management	*Yes, No*
Transparent decisions	*Yes, No*
Represent all affected groups	*Yes, No*
Accountable decision making	*Yes, No*
Women participate in CFC	*Yes, No*
Women actively participate in CFi activities	*Yes, No*
CFC regularly meet	*Yes, No*
Members consulted decisions	*Yes, No*
Members informed decisions	*Yes, No*
Members can examine finance	*Yes, No*

6.3 Results

6.3.1 Impact of community fisheries

Ecological attribute

Results from the CART model (Figure 15) show the impact of CFi associated with two ecological zones of the Tonle Sap: Battambang and Kampong Thom. Among the 11 explanatory impact indicators, the CART model retained the following variables in order of influence: fishing ground, fishery condition, and income. The overall cross validation accuracy is 0.77 and class errors were 0.12 for Battambang and 0.44 for Kampong Thom. The Kappa test result was 0.46, indicating the moderate agreement. The first split was the fishing ground variable, which divided the total samples by two main branches – one on the left accounted for 86% of the total samples, and another on the right made of the remaining 14%. The left branch associates with larger fishing ground and further splits into additional three groups (node 3, 5 and 6), while the right branch links to smaller or unchanged of fishing ground and is composed of two sub-groups (node 8 and 9).

The larger fishing ground was further split into subgroups of respondents perceiving fishery condition as poor (node 3) and those considering it as more positive (node 5 and 6). The group perceiving larger fishing ground and poor resource quality represented more than half of the samples (249 respondents) and the patterns were more observed in Battambang than in Kampong Thom. In contrast, the fishing ground in Kampong Thom was generally considered as smaller or unchanged after the CFi's establishment as shown in node 8. Another important variable is income. The positive impact of CFis on member income occurred more in Battambang than in Kampong Thom (i.e. node 6 and 9).

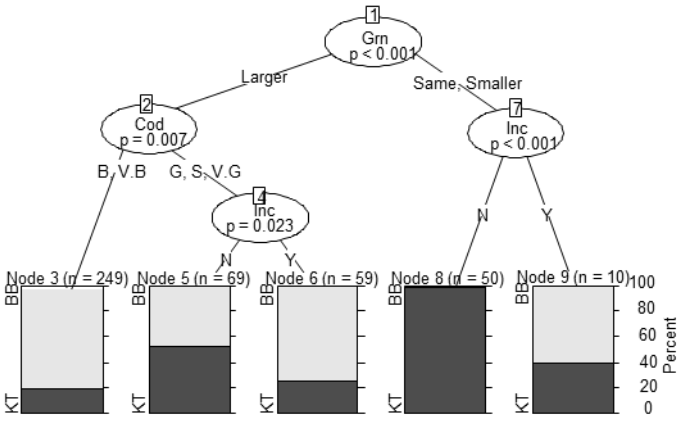

Figure 15. Classification and regression trees (CART) with an ecological zone as a target variable: BB: Battambang, KT: Kampong Thom, Grn: fishing ground, Inc: income, Cod: fishery condition, B: bad, V.B: very bad, N: no, Y: Yes

Areas of community fisheries

In association with the size of community fisheries area, the results from the CART analysis (R^2=0.31) selected five significant variables: fishery condition, livelihood, benefit, fishing ground and income with eight response values on the leaves of the tree (Figure 16). The size of community managed area is an important indicator reflecting the CFi capacity in effective management of fishery resources. The CART results show that the fishery condition was the most important variable, in which the total samples divided into two main groups. On the left branch, the impact on fishery condition was mixed, but generally encompassed more positive attributes (bad, same, good and very good) and it represented 92% of the total sample. In contrast, the remaining 8% perceived the resource quality as very bad and was associated with the right branch of the tree.

Among all the eight groups or nodes, node 8 (35% of the total sample and the largest) produced the most positive impact associating with fishery condition, livelihood, fishing ground and income and with the average community size of 2,310 hectares. Smaller or larger than this size, the impact of CFi was less favourable, depicted one or more negative attributes. For instance, when the average community size was 2,141

hectares (node 7) or the smallest (684 hectares, node 10), there was no change in income or fishing ground access after the CFi interventions. Similarly, the larger or largest community managed areas (i.e. node 6, 12, 14 or 15) revealed no improvement in income, livelihood or benefit sharing and resource quality was classified as bad or very bad.

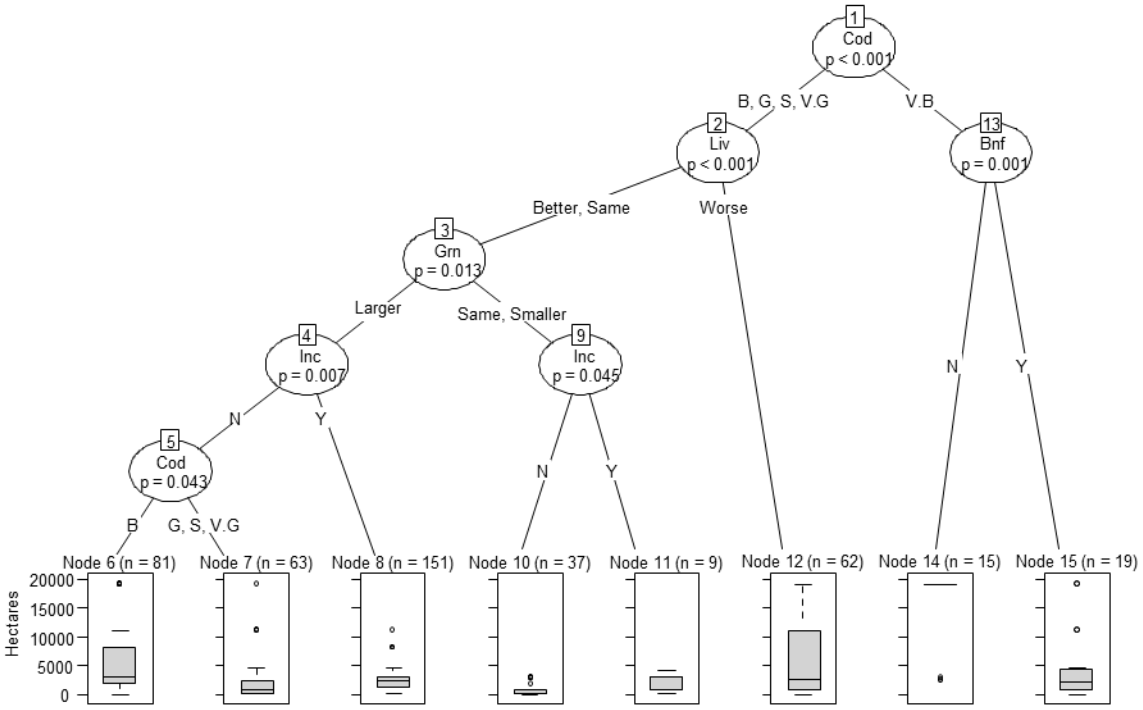

Figure 16. Classification and regression trees (CART) with a community area as a target variable: grn: fishing ground, liv: livelihood, bnf: shared benefits, inc: income, cod: fishery condition, B: bad, G: good, S: same, V.G: very good, N: no, Y: yes.

6.3.2 Factors affecting the impact of community fishery

The CART models (Figure 15 & 16) identified five statistically significant variables associated with ecological zones and community managed areas: fishing ground, livelihood, income, benefit, and fishery condition. For management and operation of CFi explanatory variables, the regression analysis predicting each measure explained between 24 to 35 percent (McFadden's R^2 in Table 13). With the CFi committee as the

predictive variable, the regression model explained between 25 to 50 percent (McFadden's R^2 in Table 14). Due to low R^2 value, for fishery condition variable, both management and operation and CFi committee variables were run together, which therefore resulted in the same R^2 value for this particular variable.

Results from the regression in Table 13 showed that among 16 management and operation explanatory variables, nine variables were found to significantly influence each impact measure. The variables include number of years CFi established, membership size, institutional support, activity planning, existence of illegal fishing, illegal activities committed by village members, rule enforcement and CFi efforts in reducing illegal activities. The significant effects on the five impact variables primarily associate with functionality of CFi, community mobilization, compliance and experience in fishery management.

The six-month activity plan was found to have a highly significant effect on every impact variable; positive correlations associated with fishing ground, livelihood, income change and shared benefits, while negative impact was on fishery condition. It demonstrated that the organisational planning process improved members' specific fishery concerns, but did not address broader fishery issue such as overall fishery condition. Further, the institutional support in establishment of CFi positively affected livelihood and income. The result showed that institutions supporting CFi successfully contribute to improving members' well-being, but no significant evidence was found for all other indicators.

The finding illustrated that the ability of the community to get organized improved overall benefits for members as it was found that membership size positively correlated with fishing ground, livelihood, income and fishery condition. Among the four statistically significant variables, the effect of number of members on fishery condition was

almost non-existent since the regression coefficient value was 0.001. Another interesting result associating with the effect of institutional development and fisheries management experience on resource access and income, in which years of CFi establishment measure was found to have a positive effect on fishing ground and income change.

Associated with compliance, there was a positive sign on the role of the CFi in which the community efforts in reducing illegal activities positively affected livelihood, income and benefits. Moreover, when the CFi did regular patrol, the benefit sharing among community members was improved. However, it was important to note that the existence of illegal activities within the community led to perceptions of improved resource access and income. The illegal activities could be a result of lack of enforcement and therefore create opportunities for illegal fishing practices and poaching. In some cases, income may also be improved through illegal practices. While illegal fishing can be both from people residing in the village and outside the community, the result showed that the fishing ground was negatively impacted by presence of local abusers and no evidence was found associating with outsiders.

Table 13. Results of logistic regression analysis for the determinants of impact of CFi using management and operation of CFi as predictor variables.

Dependent variables	Larger Fishing Ground	Better Livelihood	Income Change	Shared Benefits	Better Fisheries Condition
Independent variables: management and operation of CFi					
Years of CFi establishment	5.186 ***	1.909	4.013 ***	-0.138	-0.037
Membership size	2.405 *	2.782 **	2.432 *	0.167	0.001 *
Institutional support for establishment of CFi	-0.019	2.256 *	2.153 *	0.648	-2.404
CFi Area Agreement	0.274	0.545	0.644	-0.013	-2.228
CFi Area Management Plan	0.906	0.023	0.025	0.194	3.404
Rules and regulatiuon for fisheries management	0.201	-0.024	-0.027	-0.502	14.258
Six-month activity plan	4.322 ***	6.482 ***	8.834 ***	0.999	-1.177 **
Conservation area	0.780	-0.657	0.155	0.393	17.609
CFi resolves conflict	-0.141	0.842	1.348	1.894	1.542
Illegal fishing	2.297 *	0.423	2.116 *	0.575	-2.885
Persons committed illegal fishing - inside village	-2.735 **	0.114	1.567	-0.655	0.589
Persons committed illegal fishing - outside village	-0.879	1.893	1.661	-1.516	-0.939
Rule enforcement against illegal fishing	2.442 **	-0.130	1.408	0.476	19.224
Govenrment reduces illegal fishing	-0.451	1.785	0.737	1.444	0.691
CFi reduces illegal fishing	-1.607	2.242 *	3.172 **	3.648 ***	15.766
CFi's regular patrol	-1.029	1.679	1.378	2.227 *	0.303
McFadden's R^2	0.3513	0.2413	0.3342	0.2425	0.2493

Determinants of impact using roles of Community Fisheries Committee (CFC) variables

Associated with CFC (Table 14), 12 of 22 variables were found to significantly affect various impact variables. CFC developing networks with relevant stakeholders was found to be the most statistically significant variable affecting almost all impact indicators except the fishery condition. External linkage provides means to mobilize support and strengthen institutional capacity and therefore has positive effects on fishing ground, income, livelihood and benefit sharing.

Another important aspect is the functioning of community leadership (committee members) in which their specific activities influence differently on fishery access and human well-being. For instance, managing fisheries, transparent management and meeting regularly have positive effects on fishing ground, income, livelihood and shared benefits. The participation of CFC in drafting by-laws and management plans was also found to positively affected livelihoods. However, when the committee members dealt with fishery conflicts and commune councils, there were negative effects on members' income and fishing ground, respectively.

An inclusive and equitable process of fisheries governance brought positive impacts on member well-being. Engaging women in the leadership or working with them in the community improved their livelihoods and equitable share of benefits. Moreover, ensuring their active participation in CFi activities had strong positive effects on income and livelihoods.

Table 14. Results of logistic regression analysis for the determinants of impact of CFi using Community Fishery Committee (CFC) as predictor variables.

Dependent variables	Larger Fishing Ground	Better Livelihood	Income Change	Shared Benefits	Better Fishery Condition
Independent variables: Community Fisheries Committee (CFC)					
CFC drafts by-law and management plan	1.718	2.035 *	1.954	-1.136	-0.820
CFC represents CF in conflict management	0.042	-1.410	-2.622 **	-0.582	-0.776
CFC manages finance	0.502	0.274	-0.670	-0.642	1.717
CFC participates in consultations	-0.971	-0.877	-1.064	-1.174	0.749
CFC reports violations	0.695	0.234	-0.634	0.087	-0.012
CFC manages fisheries	2.856 **	2.034 *	-0.015	0.599	-0.029
CFC coordinates with commune council	-2.236 *	-1.405	-0.803	-1.597	-1.000
CFC develops network	4.682 ***	2.643 **	4.216 ***	2.715 **	1.399
CFC engages with women in community	-0.286	-1.088	-1.182	2.125 *	-0.638
CFC develops capacity of members	1.018	-1.575	-0.013	-1.095	-0.238
CFC manage community development projects	0.662	0.064	1.107	-0.151	0.010
Open and transparent election	-0.642	1.241	1.523	1.189	1.197
Transparent fisheries management	0.733	3.274 **	2.859 **	-0.419	0.417
Transparent decisions	-1.515	1.275	0.696	1.454	0.550
Represent all affected groups	1.167	-0.653	0.795	2.647 **	0.865
Accountable decision making	-0.294	-1.165	0.816	1.620	0.140
Women participate in CFC	-1.091	2.573 *	1.653	-1.057	-0.014
CFC regularly meet	1.104	3.747 ***	4.854 ***	0.441	0.873
Women actively participate in CF activities	-1.552	3.361 ***	3.194 ***	0.831	-0.796
Members consulted decisions	-1.629	-1.385	-1.254	-0.584	-1.800
Members informed decisions	1.484	-0.418	1.486	1.049	-1.095
Members can examine finance	1.191	1.312	0.790	3.676 ***	1.051
McFadden's R^2	0.3132	0.2507	0.3030	0.5946	0.2493

6.4 Discussion

6.4.1 Impact of community fisheries interventions

In the Tonle Sap, the main significant impacts associated with ecological zones were fishing ground, fishery condition and income. The majority of respondents perceived larger fishing grounds in both zones which indicated an effect of the fishery reforms on cancelling the fishing lots for public use. However, while the reforms provide better resource access, fishery quality and income remain less positive. First, fishery condition is considered to be poor by more than half of the respondents. Small-scale fisheries in the Tonle Sap, as well as in developing countries are dynamic, diverse and complex. The dynamism, diversity and complexity are not only associated with the biological aspects but also economic, social, technological, cultural and political dimensions (Berkes, Mahon, McConney, Pollnac, & Pomeroy, 2001). The healthy aquatic

environment in the Tonle Sap associates with the quantity and quality of water and habitat. However, the Fisheries Administration has little or no direct jurisdiction over the aquatic environment. Other sector development and priorities for water and land use such as irrigation, water supply, hydroelectricity or agriculture affect the overall resource quality (Horlte, Lieng, & Valbo-Jorgensen, 2004). The overlapping and conflicting institutional arrangements on management, conservation and development of the Tonle Sap lead to promoting own agendas and interests, and the significance of long-term future of the Lake's fisheries receives less consideration. Additionally, the CFis have often have limited funds and in many cases the community's activities are donor-driven.

Several studies show overall fish catch increases compared to historical data; however, catch per fisherman has drastically declined, indicating a signal of high exploitation rate (Baran, Zalinge, & Ngor, 2001; Baran & Myschowoda, 2008). The increase in total catch is mainly linked to underestimation of small-scale and subsistence fisheries in the past records (Coates, 2002; Van Zalinge, Nao, Touch, & Deap, 2000). The stable or reduced fishing income in the Tonle Sap in general is primarily influenced by declining fish catch per person, decreasing high-valued species and limited capacity to respond to unexpected environmental change (Nuorteva et al., 2010).

However, it is important to note that in Battambang, where there is the largest fishing lot area in the Tonle Sap, there is more observed positive income change given the better access to the resource ground after the reforms. Before 2000, Battambang covered a total fishing lot area of 146,532 hectares (31 percent of Tonle Sap's total fishing lot area) while Kampong Thom had 127,126 hectares (27% of Tonle Sap's total fishing

lot area) (Johnstone et al., 2013)[3]. In 2001, 30 and 45 percent of fishing lot areas were cancelled in Battambang and Kampong Thom, respectively, while the remaining 70 percent for Battambang and 55 percent for Kampong Thom were completely allocated for public use and fish sanctuaries in 2012. The wider access of fishing ground in former fishing lot areas in Battambang may contribute to poorer resource quality as compared to Kampong Thom's zone because of overexploitation. The findings in this study also contrasts with a synthesis study on the impact of fisheries co-management in developing countries by Evans et al., (2011) which indicated a more positive trend in resource condition and income.

The results may pose questions on the performance and functioning of CFis in safeguarding the resources. However, the data further showed that in areas where the communities are able to regularly patrol the resources and enforce compliance, there are positive effects on income, livelihoods and shared benefits (Table 13). Furthermore, a case study from Kampong Pluk commune in Siem Reap province, one of the most successful CFis in the Lake, indicated that the substantial positive impact on improving resource management and community livelihoods was driven by eight years of efforts on building capacity, trust and support of the community and government units (Evans, Marschke, & Paudyal, 2004). This suggests that the effectiveness of CFis is linked to the degree to which the communities are able to perform their functions and external institutional support. In other words, the performance of CFi primarily depend on a match between the management functions with the scale of resources governed and financial resource in support of the community activities. The CFi or co-management is not an end point, but an evolving and learning process (Armitage et al., 2008;

[3] In this study, the Tonle Sap consists of five provinces of Battambang, Kampong Chhnang, Kampong Thom, Pursat and Battambang. The total fishing lot area in Tonle Sap, excluding Banteay Meanchey before 2000 was 474,975 hectares.

Pinkerton, 1992). It may take substantial time for the co-management to evolve in its development process and deliver its promise (Pomeroy, Katon, and Harkes 2001).

6.4.2 A mismatch of scale?

In evaluating the impact of CFi associated with the community area, the findings suggest that the fishery condition is the most important determinant and that the ideal size of the community area is 2,310 hectares. The size of community area should be appropriately defined and take into consideration the ecology of the area (Pomeroy et al., 2001). The size of community boundaries reflects the scale of management arrangements and effectiveness of resource governance. The poor resource governance affects the overall quality of fisheries and therefore reduces members' resource benefits. In some cases, the constrained access, because of poor resource quality, undermines the casual benefit sharing process within the community, as evidenced in this study (Figure 16, node 14).

A too large physical area makes it difficult to manage because the size may not fit with the management structure and organisational resources. One of the major issues facing local communities is the management of fishing, farming and flooded forests in the area. Addressing priorities of different groups within the community is challenging and sometimes creates internal conflicts among resource users or confrontation with neighbouring communities. A case study from Kampong Pluk in Siem Reap province showed that success of the community is attributed to smaller size and more homogeneous objectives and membership (Evans et al., 2004). As income, livelihood and sustained benefit sharing are all linked to overall quality of fisheries, a larger physical area in the context of resource poor and weak governance of natural resources (Clements et al., 2010; Sodhi et al., 2010; Travers et al., 2011) may provide more negative than the positive outcomes.

Contrary to a larger community area, the smaller size is easier to manage and thus has a better resource well-being. Nevertheless, it is important to note that smaller resource area also limits access to resources and environmental benefits. In defining community size, it is necessary to calculate the number of fish species and economic value of the fish and other environmental benefits along with number of resource users. Otherwise, it poses constraints to members' income and livelihood improvement (Figure 16, node 7, 10 and 11). Other factors which may affect members' income and livelihoods associates with decreasing economically important fish species (Enomoto et al., 2011), and the anticipated effects of growing population, resource availability (Ziv et al., 2012), and policy and ecological change.

6.4.2 Factors contributing to impact of community fisheries

Of the governance indicators, operational planning and developing networks most strongly correlate with impact measures, showing significant relationship with four of the five impact measures. The effects of other factors are varied depending on the cases, of which more positive relationships are observed than the negative ones. Institutional capacity of CFi in managing resources is crucial. Institutional capacity means an ability of CFi to ensure a functioning and transparent community organization. It involves ability to develop external linkages and mobilise financial resources to support the community's mandate and its policy agenda (i.e. fishing ground, income, livelihood and benefits). The networks formed can also be beneficial in counteracting conflicts and often powerful interests outside the community (White et al., 1994). The external support is critical for the success of Cambodian CFi which often face inadequate budget to operate. The funding supports conservation and patrolling activities and thus enable positive change in benefit sharing, income and livelihoods.

Addressing fishery issue in the Tonle Sap is challenging especially when trying to balance social, economic and ecological uses of the natural resources. It requires participation of multiple parties. Thus, it is evident that regular planning and meeting within the community have effects on human well-being, but not the overall fishery quality (Table 13 and 14). It primarily links to different expectations and understanding of stakeholders. The overlapping and conflicting institutional arrangements (Sokhem & Sunada, 2006) and the institutional rivalries in the Tonle Sap lead to promoting own agendas and interests, often at the expense of others (Keskinen & Varis, 2012). Moreover, The political affiliation of some CFC members with the commune councils and imbalance of power may lead to a compromise decision and in some cases making the co-management to become fragile (Ngor et al., 2010; Plummer & FitzGibbon, 2006).

The significance of institutional development is further supported by the finding that number of years CFi establishment or length of operational experience has a positive effect on income and fishing ground. The empowerment process gradually builds economic and political power of the community and enables them to have more influence and control over resources. Evidence from Cambodian fishing communities shows that there are changes in thinking and behavior among CFC and CFi members, leading to a ` more sustainable community (Marschke & Sinclair, 2009).

Size of community membership is considered influential in promoting the community's policy agenda (i.e. fishing ground). The larger group brings out stronger collective action to better address resource accessibility. However, at the early stage of organisational development, the size of community should not be too large to facilitate and enhance supervision, control and management (Pomeroy et al., 2001). Because the close interaction of ecosystems in the Tonle Sap, it is important to include members which are less diverse in terms of resource dependency (i.e. fish, water or forest) to

avoid conflicts. Successful communities are from those who are more homogeneous than the heterogeneous ones (Evans et al., 2004).

Integrating gender perspective, acknowledging women's position and facilitating their full participation in co-management process is critical in uplifting economic conditions of fishers in the Tonle Sap as it proves positive effects on income, livelihood and benefit sharing. The findings advocate for more mobilizing women in natural resource management despite previous studies have found that woman participation was observed to have less impact on project efficiency or success and particularly in a male-dominated sector. First, women in the Tonle Sap generally subsidise men in fishing activities and more engage in land-based livelihoods or fish processing and trading. Second, woman participation is considered additional burden or costs on top of their hectic regular duties due to unequal distribution of responsibility in society and thus results in generally observed passive involvement (Narayan, 1995; Resurreccion, 2006). Finally, Prokopy (2004) found that there was no relationship of female participation with project success in an assessment of water-related projects assisted by the World Bank (Prokopy, 2004). Evidence from the Tonle Sap is contrary to the previous notion that promoting gender equality can hardly be achieved due to complex social-cultural context which inhibits their full participation (Resurreccion, 2006). Continue encouraging women and their full participation in fisheries management will promise improved economic benefits.

Ninety-eight percent of respondents believe that illegal fishing is still a problem in the Tonle Sap. It confirms that even though there are some levels of enforcement, the effort is still insufficient and more needs to be done. The motives for widespread illegal activities associating with weak enforcement of rule and a trade-off between benefits and risks of violations (Pomeroy et al., 2001). If the measured benefit is higher than the

calculated risk, therefore there is likely a non-compliance of regulations. More respondents believe that the efforts in reducing illegal activities were more associated with CFis than the government units (91 percent vs. 57 percent). CFis' roles in reducing illegal activities were found to have significant effects on income, livelihood and benefits. This suggests the important role of CFi in fisheries management and should be further strengthened.

6.5 Conclusion

The study provides important understanding of the impact of CFi in the Tonle Sap, especially after the 2012 fishery reform and during the significant socio-ecological change around the lake. It further suggests the appropriate scale of the CFi area to be managed and depicts important factors contributing to improving the effectiveness of CFi governance in the Tonle Sap.

The perception of having larger fishing ground in the Tonle Sap is indicative of the effect of fishery reform. Meanwhile, poor fishery condition was also observed in area where there is improved access. This may provide a mixed perception on the performance and roles of CFi in managing and controlling over the resources. This implies that there is an immediate need to redefine the community area to match with community management and resource arrangements. A match between resource scale, management arrangement and level of institutional support is a prerequisite important condition to ensure effective operating performance of CFi. When redefining or rezoning community area, we need to bear in mind that too small area may affect the level of income of members in the community as well. Thus, valuation of environmental benefits in each community areas to match with population is necessary.

Moreover, the role of CFi should be further supported and strengthened and more engagement of government units in community activities are needed especially when

dealing with illegal fishing activities and elite groups in the Tonle Sap. The findings from regression results showed that a well-functioning, transparent and gender inclusive CFi have positive effects on fishing ground, income, livelihoods and benefit sharing.

Two indicators which are the most important factors contributing to positive impact of CFi are six-monthly planning and networking with external stakeholders. Amid complexity of Tonle Sap's fisheries as previously discussed and conflicting institutional arrangements, community's capacity to manage planning is critical for the success of CFi, as it can help to improve coordination and harmonise objectives to address multi-dimensional, multi-level issues in the Tonle Sap. Moreover, the significance of networking indicates the need to continued community capacity and leadership development and for financial resources to support community's activities (i.e. patrolling and rule enforcement).

Co-management is a learning and transforming process. Promised results take time, efforts and continued commitments from all stakeholders. The findings proved that in areas where the communities are able to well function, positive impact exists.

CHARPTER VII: CONCLUSIONS AND PERSPECTIVES

7.1 Summary

In Cambodia, fish and fishing activities have been primary sources of nutrition and income. Majority of fish supplies are from the Tonle Sap. The lake provides essential ecosystem services and supports livelihoods of at least 2 million people as well as a large number of small-scale fishers. However, the decades of conflicts and the change in socioeconomic, ecological, policy, climate and fishery governance structures and systems have put the Tonle Sap's inhabitants at high of vulnerability because their low level of capacity to respond to unfamiliar events.

Thus, this study intends to assess the livelihood strategies of fishing communities in the Tonle Sap in the face of change by looking specifically to the following objectives:

1. assess spatial and temporal characteristics of livelihood strategies in Cambodia;
2. analyze the current livelihood strategies and measure the economic impact to future scenario change in the Tonle Sap;
3. assess the impact of community fisheries and the drive factors in the Tonle Sap.

The SLA and co-management principles were proposed as the framework in the analyses and four case studies were developed. First, the study on livelihood dynamics focused on spatial and temporal variations of livelihoods of Cambodian households from 1999 to 2013 by using cluster analysis, NMDS and ArcGIS Mapping visualization of the patterns. Second, multinomial and OLS regressions were applied to identify the determinants of household's livelihood choices and income using the CSES data in 2013. The third case study aimed to measure economic impact of adaptive responses to future scenario change in the Tonle Sap. The four future scenario conditions were established (less fish, more farmland, urbanization and stagnation) and the benefit-cost analysis was carried to identify which groups might be most vulnerable to future

change. Lastly, the study on CFis intended to investigate the impact of CFis associated with different ecological zones of the Tonle Sap and the size of community managed area, by seeking to understand the links between management arrangements and the ecological determinants. The CART and logistic regressions models were applied to answer the research questions.

7.1.1 Livelihood dynamics

The results show four distinct livelihood clusters associating with different types of resource dependency: (i) crops and livestock; (ii) dominated by crops and a mixture of forestry, fishery and livestock; (iii) dominated by forestry and a mixture of fishery, livestock and crops; and (iv) nonfarm and livestock. Over the past decades, there has been significant contribution of the primary sector (crops, livestock, fishery and forestry) to the livelihoods of Cambodian population despites some variations of dependency within this sector. There has been a shift from crops and livestock in the 1990s to diversification into natural resource strategies in the present time. The motives relate to both the push and pull factors. The push factor associates with decreased arable land per capita. The pull factor is motivated by improved resource accessibility through landmine clearance, and increasing demand of natural resources as a result of development of market economy. Lastly, nonfarm remains marginal and static over the past decades because agriculture-based households (both crops and natural resource based) are more attracted by wage employment instead of self-employment opportunities.

7.1.2 Determinants of livelihood choices and income

The findings indicate that various elements of livelihood assets influence households' decision to participate in livestock, fishery, forestry and nonfarm differently compared to crops as a reference strategy. The decision to participate in livestock is positively influenced by human capital (i.e. non-food expenditure) and is discouraged

by increased availability and value of land (natural and economic capital). Within the human capital, age of household head, female percentage and education discourage households' participation in fishery livelihoods. Moreover, households with higher total land value are less likely to depend on fishery. In contrast, the availability of labor force (human capital) and remittance (social capital) encourages the fishery participation. For forestry strategy, household size, education, and total land value have similar patterns and influences as on fishery livelihoods. Furthermore, food expenditure (human capital), land size and transportation (physical capital) encourage the participation in crop instead of forestry strategy. Lastly, nonfarm is influenced by all livelihood capitals. Food and non-food expenditure, non-formal education (human capital), durable goods (physical capital) have positive relationship with nonfarm employment. On the other hand, household size, land size and value, and agricultural equipment discourage households' participation in this strategy.

Associating with factors influencing households' total income, age of household head, land size and value, and agricultural equipment positively affect total income of crop households whereas female percentage and remittance have negative effects. Income of livestock households can be improved by increased access to financial capital. To increase income of fishery households, it is imperative to address access to transport assets (i.e. fishing boats) whereas education is unlikely to improve households' income. Income of forestry households can be increased through more availability of labor force, land size and agriculture equipment while non-food expenditure and durable goods decrease the income. Human well-being (i.e. wealth and health) is an important factor contributing to income of nonfarm households than that of capacity development and experience as this can be observed of negative effects of age of household head and non-formal education on households' total earnings.

Land is found to be most important capital influencing household's decision in livelihood participation and total earnings.

7.1.3 Economic impact to future scenario change

Under current conditions, the group of individuals who do not participate in fishing have the lowest net income. In contrast, individuals who solely fished had higher average net income than those with multiple livelihoods, suggesting that there may be gains from livelihood specialization. The majority of respondents chose to retain their current livelihood strategy under all future scenarios. Of those who did change their livelihood allocation, less than 10% actually experienced a gain in economic benefits. Thus, on average, a loss in net income is expected under all future scenarios, with those engaged in single livelihoods experiencing an average loss of 18% across all scenarios compared to 9% for the multi-livelihood group. Respondents' choices generated the best economic outcome under a status quo scenario. This indicates that respondents were capable of coping with current conditions, but were unlikely to make appropriate decisions when faced with future scenarios that they were unfamiliar with.

7.1.4 Impact of CFis

Overall, the significant impact in Tonle Sap associates with fishing ground, fishery condition and income and with mixed effects. Fishing ground is positive, fishery condition is generally worse and income remains unchanged. Generally, Battambang is observed to have more positive outcomes than in Kampong Thom, especially associating with fishing ground and income. In the Tonle Sap, the ideal size of community area is 2,310 hectares. Larger or smaller size may result in less positive outcome.

In predicting factors influencing fishing ground, livelihood, income, shared benefit and fishery condition, the findings suggest that regular operational planning, developing networks, and ensuring a functioning, transparent and gender inclusive community

organizations yield positive outcomes. However, illegal fishing, fragmented objectives and conflicts are roadblocks for the co-management to flourish.

7.2 General conclusion and perspectives

The overall outcomes of the study suggest that there is a close relationship between livelihood, natural resources and conflict as evidenced in the literature. Households from post-conflict states largely depend on agriculture and natural resources and their livelihoods are highly vulnerable to many factors. First, it is the damage to livelihood capital which leave households with limited coping capacities to unexpected events. As we can see from the results that even the Tonle Sap's inhabitants have been living and adapting their life to the seasonal events in the lake for many years, they are unlikely to make appropriate decisions about unfamiliar situation. The most imperative loss of livelihood resources is land tenure. The decreased in arable land per capita force households to seek alternative employment, mostly in natural resources and wage employment. Second, it is the damage to governance systems which generally lead to conflicts and resource depletion. Third, post-conflict development policies may aim to accelerate growth or short-term improvement income but fail to consideration the long-term impoverishment and productivity of resources or social equity in which people have equal access to minimum standard of quality of life. Land, governance system and post-conflict policies have significant impact on resources and user livelihoods. Additional pressure on natural resources can be seen and their livelihoods are likely to be impacted by degrading resources as a result of overexploitation or any combined effects (i.e. climate change). The post-conflict development policies should integrate sustainability perspectives into the agenda which address its four dimensions: economic, socio, institutional and environmental sustainability. As policy reform has always its implications for local livelihoods, continue close monitoring the productivity and performance of

livelihood systems is imperative; for example, how they have changed over time and what impact of the policy adjustments have occurred.

The variations of livelihood strategies over time from crops and livestock associate primarily with lower human capital, limited land ownership and constrained financial capital. Therefore, households are forced to more engage in natural resource strategies. As shown in the case study on livelihood determinants, fishery and forestry households have lower education compared to those from crop families and with average land size of half a hectare. Furthermore, those engage in nonfarm are generally better-off and it is the main reason why there have been almost no variations over the past decades in terms of non-farm self-employment because a significant percentage of population remains resource poor and are unable to diversify into entrepreneurial activities, but instead chose resource-based strategies or non-farm wage employment. This can be further supported by the finding showing significant relationship between remittance and fishery strategy.

Overall, the factors which contribute to improving households' income associates with land access, asset ownerships, availability of labor resource and household's financial capital. Thus, policy implications to improve livelihood participation and maximize the long-term economic and social benefits for household should consider special attention to resource poor households, increase household's wealth and assets, and design and implement effective resource conservation programs.

From the case study on economic impact to future scenario change, the findings show the importance of specialization in Tonle Sap. Under current conditions, households pursuing single fishery strategy have higher average income than those undertaking multiple livelihoods. However, as Tonle Sap is prone to changes occurring around the lake and surrounding systems, it may not be economically sustainable to encourage

households' specialization in a single fishery strategy in the Tonle Sap as it can lead to more resource pressure and overexploitation and definitely results in negative economic impact in the long-term. Even majority of the Tonle Sap's inhabitant are likely not to change their current strategies and there is average net income loss in all future scenarios, we can learn that those undertaking multiple livelihood options have lower average income loss compared to those depend a single strategy. This suggests that promoting livelihood diversification in the Tonle Sap is a viable economic option. Understanding which groups are most vulnerable to future change helps to direct adaptation policies to appropriate groups and interventions, thereby minimizing the economic impact of future changes on the most vulnerable households dependent on the Tonle Sap floodplain ecosystem. In developing adaptive responses in the Tonle Sap, the multidimensional SLA approach is considered appropriate which help to improve understanding and address vulnerability and adaptive capacities from multiple angles of problems, such as vulnerability and policy setting, livelihood resources and strategies, and institutional processes.

The impact of CFis in Tonle Sap is mixed across different communities around the lake and the overall outcomes are less satisfactory except fishing ground which may be attributed to the fishery reform in 2012. However, there are significant roles the CFis have played since the 2000s associating with mobilization of community members, rule enforcement, co-managing fisheries resources, developing networks and building institutional capacity. Although there is a variation of the impact of CFis, one should note that CFis vary across years of experience and community size. As previously mentioned, co-management is a learning process which may take time to evolve, develop

and deliver its promise. Continue building the CFis' strengths and address their challenges would enable greater impact on fishers' livelihoods and well-being as well as resource quality and sustainability.

Furthermore, community area should be redefined which appropriately reflect the scale of management arrangements, the ecology of specific area, and level of institutional support. This would help to address the remaining challenges associating with existence of illegal fishing and resource conflicts, coordination and strategic planning.

Lastly, co-management can be integrated as an institutional intervention into the SLA to achieve desired community outcomes, such as improved income, livelihoods and resource access, and reduced vulnerability. Co-management can be an effective means to influence policy reform within the broader context of the SLA framework which may impact the livelihoods of the local people/fishers. Further, it can be used to assess how co-management effort might influence various livelihood capitals of households. The integration of co-management principles with sustainable livelihoods enables holistic understanding of household vulnerability and helps to design appropriate interventions to address both present and future livelihood constraints.

REFERENCE

Abson, D. J., Fraser, E. D., & Benton, T. G. (2013). Landscape diversity and the resilience of agricultural returns: a portfolio analysis of land-use patterns and economic returns from lowland agriculture. *Agriculture & Food Security*, *2*(1), 2.

Acharya, S., Kim, S., Chap, S., & Meach, Y. (2003). *Off-farm and Non-farm Employment: A Perspective on Job Creation in Cambodia*. Phnom Penh. Retrieved from http://www.cdri.org.kh/webdata/download/wp/wp26e.pdf

Acheson, J. M. (2006). Institutional Failure in Resource Management. *Annual Review of Anthropology*, *35*(1), 117–134.

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281.

Ahmed, M., Hap, H., Ly, V., & Tiongco, M. (1998). *Socioeconomic Assesment of Freshwater Capture Fisheries in Cambodia*. Retrieved from http://pubs.iclarm.net/resource_centre/RP_13129.pdf

Alene, A. D., Manyong, V. M., Omanya, G. O., Mignouna, H. D., Bokanga, M., & Odhiambo, G. D. (2008). Economic Efficiency and Supply Response of Women as Farm Managers: Comparative Evidence from Western Kenya. *World Development*, *36*(7), 1247–1260.

Allan, J. D., Abell, R., Hogan, Z., Revenga, C., Taylor, B. W., Welcomme, R. L., & Winemiller, K. (2005). Overfishing of Inland Waters. *BioScience*, *55*(12), 1041.

Allison, E. H., & Ellis, F. (2001). The livelihoods approach and management of small-scale fisheries. *Marine Policy*, *25*(5), 377–388.

Allison, E. H., & Horemans, B. (2006). Putting the principles of the Sustainable Livelihoods Approach into fisheries development policy and practice. *Marine Policy*, *30*(6), 757–766.

Allison, E. H., Perry, A. L., Badjeck, M. C., Neil Adger, W., Brown, K., Conway, D.,

… Dulvy, N. K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, *10*(2), 173–196.

Andre, C., & Platteau, J.-P. (1998). Land relations under unbearable stress: Rwanda caught in the Malthusian trap. *Journal of Economic Behavior & Organization*, *34*(1), 1–47.

Andrews, M. J., Golan, J., & Lay, J. (2014). Inefficiency of male and female labor supply in agricultural households: Evidence from Uganda. *American Journal of Agricultural Economics*, *97*(3), 998–1019.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S., … Wunder, S. (2014). Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. *World Development*, *64*, 12–28.

Arce-Ibarra, A. M., & Charles, A. T. (2008). Inland fisheries of the Mayan Zone in Quintana Roo, Mexico: Using a combined approach to fishery assessment for data-sparse fisheries. *Fisheries Research*, *91*(2–3), 151–159.

Arias, M. E., Cochrane, T. a., Kummu, M., Lauri, H., Holtgrieve, G. W., Koponen, J., & Piman, T. (2014). Impacts of hydropower and climate change on drivers of ecological productivity of Southeast Asia's most important wetland. *Ecological Modelling*, *272*, 252–263.

Arias, M. E., Cochrane, T. A., Norton, D., Killeen, T. J., & Khon, P. (2013). The flood pulse as the underlying driver of vegetation in the largest wetland and fishery of the mekong basin. *Ambio*, *42*(7), 864–876.

Arias, M. E., Cochrane, T. A., Piman, T., Kummu, M., Caruso, B. S., & Killeen, T. J. (2012). Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin. *Journal of Environmental Management*, *112*, 53–66.

Armitage, D., Marschke, M., & Plummer, R. (2008). Adaptive co-management and the paradox of learning. *Global Environmental Change*, *18*(1), 86–98.

Asian Development Bank. (2012). *Cambodian Climate Change Resilient Rice Commercialization: Socio-economic assessment and gender analysis*.

Asian Development Bank. (2014). *Cambodia: Country Poverty Analysis 2014*. Manila. https://doi.org/Uppsala Research Reports in Cultural Anthropology, No 15

Ayers, A. L., & Kittinger, J. N. (2014). Emergence of co-management governance for Hawai'i coral reef fisheries. *Global Environmental Change*, *28*(1), 251–262.

Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Deckers, J., & Mathijs, E. (2008). Household livelihood strategies and forest dependence in the highlands of Tigray, Northern Ethiopia. *Agricultural Systems*, *98*(2), 147–155.

Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Deckers, J., & Mathijs, E. (2009). The economic contribution of forest resource use to rural livelihoods in Tigray, Northern Ethiopia. *Forest Policy and Economics*, *11*(2), 123–131.

Badjeck, M.-C., Allison, E. H., Halls, A. S., & Dulvy, N. K. (2010). Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, *34*(3), 375–383.

Baran, E. (2005). *Cambodia inland fisheries: facts, figures and context*. Phnom Penh, Cambodia: WorldFish Center and Inland Fisheries Research and Development Institute.

Baran, E., Ly, V., Nasielski, J., Saray, S., Touch, B., Tress, J., … Tan, S. (2014). Fish resources in Cambodia (2001-2011). In *Atlas of Cambodia - Maps on socio-economic development and environment* (pp. 37–48). Phnom Penh: Save Cambodia's Wildlife.

Baran, E., & Myschowoda, C. (2008). Have Fish Catches Been Declining in the Mekong River Basin ? *Production*, 55–64.

Baran, E., Schwartz, N., & Kura, Y. (2009). Climate change and fisheries: vulnerability and adaptation in Cambodia. *Issues Brief No. 2008*.

Baran, E., Zalinge, N. Van, & Ngor, P. (2001). Floods, floodplains and fish production in the Mekong Basin: present and past trends. In Ahyaudin et al. (Ed.), *Proceedings of the Second Asian Wetlands Symposium* (pp. 920–932). Penang, Malaysia: Penerbit Universiti Sains Malaysia. Retrieved from https://www.researchgate.net/profile/Eric_Baran/publication/237328171_FLOODS_FLOODPLAINS_AND_FISH_PRODUCTION_IN_THE_MEKONG_BASIN_PRESENT_AND_PAST_TRENDS/links/00b4952c62f34cc2bb000000.pdf

Barrett, C. B., Reardon, T., & Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics, and policy implications. *Food Policy*, *26*(4), 315–331.

Barrett, C., & Swallow, B. M. (2004). Dynamic Poverty Traps and Rural Livelihoods. In F. Ellis & H. A. Freeman (Eds.), *Rural Livelihoods and Poverty Reduction Policies*. London.

Béné, C., & Friend, R. M. (2011). Poverty in small-scale fi sheries: old issue, new analysis. *Progress in Development Studies*, *11*, 119–144.

Béné, C., Steel, E., Luadia, B. K., & Gordon, A. (2009). Fish as the “bank in the water” - Evidence from chronic-poor communities in Congo. *Food Policy*, *34*(1), 108–118.

Berkes, F. (2009). Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management*, *90*(5), 1692–1702.

Berkes, F., Mahon, R., McConney, P., Pollnac, R., & Pomeroy. (2001). *Managing Small-scale Fisheries. Alternative Directions and Methods*. *International Development Research Center*. Retrieved from http://www.idrc.ca/EN/Resources/Publications/openebooks/310-3/index.html

Bindlish, V., & Evenson, R. (1993). *Evaluation of the Performance of T & V Extension in Kenya*.

Birhanu, M. Y., Girma, A., & Puskur, R. (2014). Determinants of success and intensity of livestock feed technologies use in Ethiopia: Evidence from a positive deviance perspective. *Technological Forecasting and Social Change*.

Birkhaeuser, D., & Evenson, R. E. (1991). The economic impact of agricultural extension: A review. *Economic Development & Cultural Change*, *39*(3), 607. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=9105202609&site=ehost-live

Bond, N. (2015). *Examining Adaptations to Changing Fish Populations of Tonlé Sap Lake in Cambodia : A Case Study of Pursat Province , Cambodia*.

Breiman, L., Friedman, J. H., Olshen, R. A., & Stone, C. J. (1984). *Classification and Regression Trees*. Belmont, California: Wadsworth.

Brickell, K. (2011). The “stubborn stain” on development: gendered meanings of housework (non-)participation in Cambodia. *Journal of Development Studies*, *47*(9), 1353–1370.

Brooks, S. E., Reynolds, J. D., & Allison, E. H. (2008). Sustained by snakes? Seasonal livelihood strategies and resource conservation by tonle sap fishers in Cambodia. *Human Ecology*, *36*(6), 835–851.

Bruch, C., Jensen, D., Nakayama, M., & Unruh, J. (2012). Human Conflict: Targeting

Natural Resources. *SCIENCE*, *337*(6092), 291–292.

Butler, J. R. A., Young, J. C., McMyn, I. A. G., Leyshon, B., Graham, I. M., Walker, I., … Warburton, C. (2015). Evaluating adaptive co-management as conservation conflict resolution: Learning from seals and salmon. *Journal of Environmental Management*, *160*, 212–225.

Canagarajah, S., Newman, C., & Bhattamishra, R. (2001). Non-farm income, gender, and inequality: Evidence from rural Ghana and Uganda. *Food Policy*, *26*(4), 405–420.

Carney, D., Drinkwater, M., Rusinow, T., Wanmali, S., & Singh, N. (1999). *Livelihoods Approachs Compared*.

Cecchi, G., Wint, W., Shaw, A., Marletta, A., Mattioli, R., & Robinson, T. (2010). Geographic distribution and environmental characterization of livestock production systems in Eastern Africa. *Agriculture, Ecosystems & Environment*, *135*(1–2), 98–110.

Chambers, R., & Conway, G. (1991). Sustainable rural livelihoods: practical concepts for the 21st century. *Ids Discussion Paper*, *296*(Brighton: Institute of Development Studies, University of Sussex), 33.

Charles, A., & Nasuchon, N. (2010). Community involvement in fisheries management: Experiences in the Gulf of Thailand countries. *Marine Policy*, *34*, 163–169.

Chen, L., Heerink, N., & van den Berg, M. (2006). Energy consumption in rural China: A household model for three villages in Jiangxi Province. *Ecological Economics*, *58*(2), 407–420.

Chenery, H., & Syrquin, M. (1975). *Patterns of Development 1950-1970*. London.

Cinner, J. E., McClanahan, T. R., Graham, N. A. J., Daw, T. M., Maina, J., Stead, S.

M., … Bodin, O. (2012). Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change*, *22*(1), 12–20.

Clark, C. W. (1973). The Economics of Overexploitation. *Science*, *181*(4100), 630–634.

Cleaver, K. M., & Schreiber, G. A. (1994). *Reversing the Spiral: The Population, Agriculture, and Environment Nexus in Sub-Saharan Africa*. Washington DC.

Clements, T., John, A., Nielsen, K., An, D., Tan, S., & Milner-Gulland, E. J. (2010). Payments for biodiversity conservation in the context of weak institutions: Comparison of three programs from Cambodia. *Ecological Economics*, *69*(6), 1283–1291.

Coates, D. (2002). Inland capture fishery statistics of Southeast Asia: current status and information needs. RAP Publications 2002/11. *RAP Publication*, *11*, 1–114.

Conway, G. R. (1985). Agroecosystem analysis. *Agricultural Administration*, *20*(1), 31–55.

Cooper, S. J., & Wheeler, T. (2016). Rural household vulnerability to climate risk in Uganda. *Regional Environmental Change*, *17*(3), 1–15.

Cooperman, M. S., Kaufman, L., Mccann, K. S., & Winemiller, K. O. (2012). A watershed moment for the Mekong: newly announced community use and conservation areas for the Tonle Sap Lake may boost sustainability of the world's largest inland fishery. *Cambodian Journal of Natural History*, *2*, 101–106.

Corral, L., & Reardon, T. (2001). Rural Nonfarm Incomes in Nicaragua. *World Development*, *29*(3), 427–442.

Costello, C., Ovando, D., Hilborn, R., Gaines, S. D., Deschenes, O., & Lester, S. E.

(2012). Status and solutions for the world's unassessed fisheries. *Science*, *338*, 517–520.

Croissant, Y. (2013). {mlogit: multinomial logit model}. Retrieved from https://cran.r-project.org/package=mlogit

Davis, J. R. (2003). *The rural non-farm economy , livelihoods and their diversification*.

de Sherbinin, A., VanWey, L. K., McSweeney, K., Aggarwal, R., Barbieri, A., Henry, S., … Walker, R. (2008). Rural household demographics, livelihoods and the environment. *Global Environmental Change*, *18*(1), 38–53.

Deininger, K., & Olinto, P. (2001). Rural nonfarm employment and income diversification in Colombia. *World Development*, *29*(3), 455–465.

Di Franco, A., Thiriet, P., Di Carlo, G., Dimitriadis, C., Francour, P., Gutiérrez, N. L., … Guidetti, P. (2016). Five key attributes can increase marine protected areas performance for small-scale fisheries management. *Scientific Reports*, *6*, 38135.

Djurfeldt, A. A. (2012). Seasonality and farm/non-farm interactions in Western Kenya. *The Journal of Modern African Studies*, *50*(1), 1–23.

Doss, C. R. (2001). Designing agricultural technology for African women farmers: Lessons from 25 years of experience. *World Development*, *29*(12), 2075–2092.

Duchelle, A. E., Almeyda Zambrano, A. M., Wunder, S., Börner, J., & Kainer, K. A. (2014). Smallholder Specialization Strategies along the Forest Transition Curve in Southwestern Amazonia. *World Development*, *64*(S1), S149–S158.

Ellis, F. (2000). The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics*, *51*(2), 289–302.

Eneyew, A., & Bekele, W. (2012). Determinants of livelihood strategies in Wolaita , southern Ethiopia, *1*(June), 153–161.

Enomoto, K., Ishikawa, S., Hori, M., Sitha, H., Song, S. L., Thuok, N., & Kurokura, H. (2011). Data mining and stock assessment of fisheries resources in Tonle Sap Lake, Cambodia. *Fisheries Science*, *77*(5), 713–722.

Erenstein, O., Hellin, J., & Chandna, P. (2010). Poverty mapping based on livelihood assets: A meso-level application in the Indo-Gangetic Plains, India. *Applied Geography*, *30*(1), 112–125.

Evans, L., Cherrett, N., & Pemsl, D. (2011). Assessing the impact of fisheries co-management interventions in developing countries: A meta-analysis. *Journal of Environmental Management*, *92*(8), 1938–1949.

Evans, P., Marschke, M., & Paudyal, K. (2004). *Flood Forests, Fish and Fishing Villages:Tonle Sap, Cambodia*. (M. Poffenberger & K. Smith-Hanssen, Eds.). Bohol, Phillippines: Asia Forest Network.

FA/MAFF, & CBNRMLI. (2008). *Gender implication in CBNRM - the roles, needs and aspirations of women in community fisheries.*

Fabusoro, E., Omotayo, a. M., Apantaku, S. O., & Okuneye, P. a. (2010). Forms and Determinants of Rural Livelihoods Diversification in Ogun State, Nigeria. *Journal of Sustainable Agriculture*, *34*(4), 417–438.

FAO. (2016). *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all*. Rome. Retrieved from http://www.fao.org/3/a-i3720e.pdf

FAOSTAT. (2016). FAO Statistics. Retrieved June 8, 2016, from http://faostat.fao.org/site/666/default.aspx

Farquharson, B., Scott, F., & Chea, S. (2008). Upland crop technologies in Cambodia: economic evaluations and some adoption issues. In *52nd Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra,*

Australian Capital Territory, 5-8 February 2008 (p. 23).

Ferrol-Schulte, D., Wolff, M., Ferse, S., & Glaser, M. (2013). Sustainable Livelihoods Approach in tropical coastal and marine social-ecological systems: A review. *Marine Policy*, *42*, 253–258.

Fisher, M. (2004). Household welfare and forest dependence in Southern Malawi. *Environment and Development Economics*, *9*(2), 135–154.

Francis, E., & Hoddinott, J. (1993). Migration and differentiation in western Kenya: a tale of two sub- locations. *Journal of Development Studies*. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0027713812&partnerID=tZOtx3y1

Fraser, E. D. G., Mabee, W., & Figge, F. (2005). A framework for assessing the vulnerability of food systems to future shocks. *Futures*, *37*(6), 465–479.

Fritzsch, J. (2012). Is non-farm income diversification a feasible option for small-scale farmers? An assessment using a composite fuzzy indicator. *Post-Communist Economies*, *24*(3), 403–417.

GeoSpatial International Inc. (2002). *Cambodia National Level 1 Survey: Final Report*. Retrieved from http://www.sac-na.org/pdf_text/cambodia/

GFA Consulting Group. (2007). *Kingdom of Cambodia: Tonle Sap Lowland Stabilization Project TA No. 4756-CAM. Final Report to Asian Development Bank*. Hamburg. Retrieved from https://www.adb.org/sites/default/files/project-document/65843/37287-camtacr

Giraudoux, P. (2016). pgirmess: Data Analysis in Ecology. Retrieved from https://cran.r-project.org/package=pgirmess

Guimbert, S. (2010). *Cambodia 1998-2008: An Episode of Rapid Growth*. Retrieved from www.worldbank.org/kh/growth

Haggblade, S., Hazell, P., & Brown, J. (1989). Farm-nonfarm linkages in rural sub-Saharan Africa. *World Development*, *17*(8), 1173–1201.

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A Pragmatic Approach to Assessing Risks from Climate Variability and Change - A Case Study in Mozambique. *Global Environmental Change*, *19*(1), 74–88.

Hansen, M. C., Potapov, P. V, Moore, R., Hancher, M., Turubanova, S. a, Tyukavina, A., … Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, *342*(6160), 850–853.

Hap, N., & Bhattarai, M. (2006). Economic Assessment of Small-Scale Inland Fisheries and Wetland Livelihoods in Cambodia. In *International Riversymposium, Brisbane, Australia, 4-7 September, 2006* (p. 30).

Harrison, E. (1995). Fish and Feminists. *IDS Bulletin*, *26*(3), 39–47.

Hazell, P., & Haggblade, S. (1990). *Rural - urban growth linkages in India. Policy, Research, and External Affairs working papers* (WPS 430) (Vol. 1). Retrieved from http://documents.worldbank.org/curated/en/987381468772797302/Rural-urban-growth-linkages-in-India

Hazell, P., & Roell, A. (1983). *Rural growth linkages: Household expenditure patterns in Malaysia and Nigeria* (Vol. 41). Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0020866956&partnerID=tZOtx3y1%5Cnhttp://pdf.usaid.gov/pdf_docs/PNAAN887.pdf

Heck, S., Béné, C., & Reyes-Gaskin, R. (2007). Investing in African fisheries: Building links to the Millennium Development Goals. *Fish and Fisheries*.

Heinonen, U. (2006). Environmental Impact on Migration in Cambodia: Water-

related Migration from the Tonle Sap Lake Region. *International Journal of Water Resources Development*, *22*(3), 449–462.

Hill, H., & Menon, J. (2014). Cambodia: Rapid growth in an open, post-conflict economy. *World Economy*, *37*(12), 1649–1668.

Hitayezu, P., Okello, J. J., & Obel-Gor, C. (2014). Farm households' participation in rural non-farm employment in post-war Rwanda: Drivers and policy implications. *Development Southern Africa*, *31*(3), 452–474.

Horlte, K. G., Lieng, S., & Valbo-Jorgensen, J. (2004). *An introduction to Cambodia's inland fisheries*. *Mekong Development Series No. 4*. Phnom Penh, Cambodia.

Hortle, K. G. (2007). Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. *MRC Technical Paper No. 16*, (16), 87. Retrieved from http://www.mrcmekong.org/assets/Publications/technical/tech-No16-consumption-n-yield-of-fish.pdf

Hothorn, T., & Zeileis, A. (2015). partykit: A Modular Toolkit for Recursive Partytioning in R. *Journal of Machine Learning Research*, *16*, 3905–3909. Retrieved from http://jmlr.org/papers/v16/hothorn15a.html

Human Rights Watch, & Physicians for Human Rights. (1991). *Land Mines in Cambodia: The Coward's War*. Human Rights Watch and Physicians for Human Rights.

ICLARM, & IFM. (1998). *Analysis of co-management arrangements in fisheries and related coastal resources*.

ILO. (2015, July). Growth continues for Cambodia's garment and footwear sector. *Cambodia Garment and Footwear Sector Bulletin*, (1), 8. Retrieved from http://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---sro-

bangkok/documents/publication/wcms_383562.pdf

Islam, G. M. N., Yew, T. S., Abdullah, N. M. R., & Viswanathan, K. K. (2011). Social capital, community based management, and fishers' livelihood in Bangladesh. *Ocean and Coastal Management*, *54*(2), 173–180.

Islam, M. M., Sallu, S., Hubacek, K., & Paavola, J. (2014). Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: Insights from coastal Bangladesh. *Regional Environmental Change*, *14*(1), 281–294.

Jackman, S. (2015). pscl: Classes and Methods for R Developed in the Political Science Computational Laboratory. Stanford: Stanford University. Department of Political Science. Retrieved from http://pscl.stanford.edu/

Jackson, J. B., Kirby, M. X., Berger, W. H., Bjorndal, K. a, Botsford, L. W., Bourque, B. J., … Warner, R. R. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science (New York, N.Y.)*, *293*(5530), 629–37.

Jentoft, S. (2000). The community: A missing link of fisheries management. *Marine Policy*, *24*(1), 53–59.

Jentoft, S., & McCay, B. (1995). User participation in fisheries management: lessons drawn from international experiences. *Marine Policy*, *19*(3), 227–246.

JICA. (2010). *Kingdom of Cambodia Study for Poverty Profiles in the Asian Region*. Retrieved from https://www.jica.go.jp/activities/issues/poverty/profile/pdf/cam_03_01.pdf

JICA, & MPWT. (2003). Cambodia Reconnaissance Survey Digital Data [Geospatial Data]. Ministry of Public Works and Transportation (MPWT) and Japan International Cooperation Agency (JICA).

Jogo, W., & Hassan, R. (2010). Determinants of rural household labour allocation for wetland and other livelihood activities: The case of the Limpopo wetland in

Southern Africa. *Agrekon*, *49*, 195–216.

Johnstone, G., Ranjitha, P., Fabrice, D., Mam, K., Il, O., Mak, S., … Rest, S. (2013). *Tonle Sap scoping report. CGIAR Research Program on Aquatic Agricultural Systems*. Penang, Malaysia. Retrieved from http://www.worldfishcenter.org/resource_centre/AAS-2013-28.pdf

Jones, B., & Scheiber, H. N. (2015). Fisheries Policies and the Problems of Instituing Sustainable Management: The Case of Occupied Japan. In H. Young & L. Goldman (Eds.), *Livelihoods, Natural Resources and Post-Conflict Building* (First, pp. 287–306). New York: Routledge.

Kamanga, P., Vedeld, P., & Sjaastad, E. (2009). Forest incomes and rural livelihoods in Chiradzulu District, Malawi. *Ecological Economics*, *68*(3), 613–624.

Kearney, R. E. (2002). Co-management: The resolution of conflict between commercial and recreational fishers in Victoria, Australia. *Ocean and Coastal Management*, *45*(4–5), 201–214.

Keskinen, M. (2006). The Lake with Floating Villages: Socio-economic Analysis of the Tonle Sap Lake. *International Journal of Water Resources Development*, *22*(3), 463–480.

Keskinen, M., Tola, P., & Varis, O. (2007). The Tonle Sap Lake, Cambodia: water-related conflicts with abundance of water. *The Economics of Peace and Security Journal*, *2*(2), 49–59.

Keskinen, M., & Varis, O. (2012). Institutional cooperation at a basin level: For what, by whom? Lessons learned from Cambodia's Tonle Sap Lake. *Natural Resources Forum*, *36*(1), 50–60.

Kilic, T., Palacios-López, A., & Goldstein, M. (2015). Caught in a Productivity Trap: A Distributional Perspective on Gender Differences in Malawian Agriculture.

World Development, *70*, 416–463.

Kleiber, D., Harris, L. M., & Vincent, A. C. J. (2015). Gender and small-scale fisheries: A case for counting women and beyond. *Fish and Fisheries*, *16*(4), 547–562.

Kosamu, I. B. M. (2015). Conditions for sustainability of small-scale fisheries in developing countries. *Fisheries Research*, *161*, 365–373.

Kummu, M., & Sarkkula, J. (2008). Impact of the Mekong River Flow Alteration on the Tonle Sap Flood Pulse. *AMBIO: A Journal of the Human Environment*, *37*(3), 185–192.

Kummu, M., Tes, S., Yin, S., Adamson, P., Józsa, J., Koponen, J., … Sarkkula, J. (2014). Water balance analysis for the Tonle Sap Lake-floodplain system. *Hydrological Processes*, *28*(4), 1722–1733.

Kung, J. K. S., & Lee, Y. (2001). So What If There Is Income Inequality? The Distributive Consequence of Nonfarm Employment in Rural China. *Economic Development and Cultural Change*, *50*(1), 19–46.

Kura, Y., Revenga, C., Hoshino, E., & Mock, G. (2004). *Fishing for Answers: Making Sense of the Global Fish Crisis*. Washington DC. Retrieved from http://www.wri.org/publication/fishing-answers-making-sense-global-fish-crisis

Kurien, J., Baran, E., & So, N. (2006). *Factors that drive Cambodia's inland fish catch: what role can community fisheries play?* Phnom Penh.

Lam, V. W. Y., Sumaila, U. R., Dyck, A., Pauly, D., & Watson, R. (2011). Construction and first applications of a global cost of fishing database. *ICES Journal of Marine Science*, *68*(9), 1996–2004.

Lamberts, D. (2006). The Tonle Sap Lake as a Productive Ecosystem, *22*(3), 481–495.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310

Lanjouw, J. O., & Lanjouw, P. (2001). The rural non-farm sector: Issues and evidence from developing countries. *Agricultural Economics*.

Levinson, J. (2002). *An Examination of the Community Fisheries Sub-Decree in Cambodia: Changes and Developments during the Drafting Process*. Bangkok, Thailand.

Makino, M., & Matsuda, H. (2005). Co-management in Japanese coastal fisheries: Institutional features and transaction costs. *Marine Policy*, *29*(5), 441–450.

Mansfield, C., & MacLeod, K. (2002). *Advocacy in cambodia: increasing democratic space*. Phnom Penh.

Marschke, M., & Sinclair, A. J. (2009). Learning for sustainability: Participatory resource management in Cambodian fishing villages. *Journal of Environmental Management*, *90*(1), 206–216.

McCann, K. S., Gellner, G., McMeans, B. C., Deenik, T., Holtgrieve, G., Rooney, N., … Giacomini, H. (2016). Food webs and the sustainability of indiscriminate fisheries [1]. *Canadian Journal of Fisheries and Aquatic Sciences*, *73*(4), 656–665.

McClanahan, T. R., Cinner, J. E., Graham, N. A. J., Daw, T. M., Maina, J., Stead, S. M., … Polunin, N. V. C. (2009). Identifying reefs of hope and hopeful actions: Contextualizing environmental, ecological, and social parameters to respond effectively to climate change. *Conservation Biology*, *23*(3), 662–671.

McKenney, B., & Prom, T. (2002). *Natural resources and rural livelihoods in Cambodia: a baseline assessment* (No. 23). Phnom Penh.

Meyer, D., Zeileis, A., & Hornik, K. (2006). The Strucplot Framework: Visualizing Multi-way Contingency Tables with vcd. *Journal of Statistical Software*, *17*(3),

1–48.

MoP. (2012). *Report of Cambodia Rural Urban Migration Project*. Phnom Penh.

MoP. (2013). *Integration of Demographic Perspectives in Development, Cambodia*. Phnom Penh. Retrieved from www.mop.gov.kh

MRC. (2003). *State of the Basin Report 2003*. *Mekong River Commission*.

Nadasdy, P. (2003). Reevaluating the co-managment success story. *Arctic*, *56*(4), 367–380. Retrieved from papers2://publication/uuid/64DD5754-AF63-4455-91A1-AF948030D62F

Narain, U., Gupta, S., & Veld, K. van `t. (2008). Poverty and the environment: exploring the relationship between household incomes, private assets, and natural assets. *LAND ECONOMICS*, *84*, 148–167.

Narayan, D. (1995). The contribution of people's participation : evidence from 121 rural water supply projects. *Environmentally Sustainable Development Occasional Paper Series No. 1 The World Bank, Washington, DC*, 1–122. Retrieved from http://documents.worldbank.org/curated/en/1995/07/7297293/contribution-peoples-participation-evidence-121-rural-water-supply-projects

Nasielski, J., Joffre, O., El, S., Svay, S., Cheach, M., Johnstone, G., … Tress, J. (2013). *Role and value of fish in the welfare of rural communities in Cambodia: Questionnaire development. Updated report for the project "Assessing economic and welfare values of fish in the Lower Mekong Basin."* Phnom Penh.

Nasielski, J., Tress, J., & Baran, E. (2012). *Fishing dependency in Cambodia - mapping and methodology report. Report for the project "Assessing economic and welfare values of fish in the Lower Mekong Basin."* Phnom Penh.

Neef, A., Touch, S., & Chiengthong, J. (2013). The Politics and Ethics of Land

Concessions in Rural Cambodia. *Journal of Agricultural and Environmental Ethics*, *26*(6), 1085–1103.

NGOF. (2015). *Statistical Analysis of Land Disputes in Cambodia , 2014*. Phnom Penh. Retrieved from http://www.ngoforum.org.kh/administrator/components/com_ngoforum/files/8c28b5c3c50045d8aa923b5a62247ee0-Layout-Land-dispute-report-2013-Eng.pdf

Ngor, P., Heng, K., Thor, S., & Thomson, D. (2010). *Pilot Participatory Policy Impact Assessment: Fisheries Policy Related to Community Fisheries Development in Stung Treng, Kampot/Kep, Koh Kong and Siem Reap Provinces*. Phnom Penh.

Nguyen, T. T., Do, T. L., Buhler, D., Hartje, R., & Grote, U. (2015). Rural livelihoods and environmental resource dependence in Cambodia. *Ecological Economics*, *120*, 282–295.

Nguyen, T. T. X., Bonetti, J., Rogers, K., & Woodroffe, C. D. (2016). Indicator-based assessment of climate-change impacts on coasts: A review of concepts, methodological approaches and vulnerability indices. *Ocean and Coastal Management*.

Nielsen, J. R., Degnbol, P., Viswanathan, K. K., Ahmed, M., Hara, M., & Abdullah, N. M. R. (2004). Fisheries co-management-an institutional innovation? Lessons from South East Asia and Southern Africa. *Marine Policy*, *28*(2), 151–160.

Nielsen, Ø. J., Rayamajhi, S., Uberhuaga, P., Meilby, H., & Smith-Hall, C. (2013). Quantifying rural livelihood strategies in developing countries using an activity choice approach. *Agricultural Economics*, *44*(1), 57–71.

NIS. (2016). Cambodia Socio-Economic Survey (CSES). Retrieved August 15, 2016, from https://nada-nis.gov.kh/index.php/catalog/CSES

Nuorteva, P., Keskinen, M., & Varis, O. (2010). Water, livelihoods and climate change adaptation in the tonle sap lake area, Cambodia: Learning from the past to understand the future. *Journal of Water and Climate Change*, *1*(1), 87–101.

Oglethorpe, J., Ham, R., Shambaugh, J., & van der Linde, H. (2002). Overview C: Conservations in times of war. In R. Mathew, M. Halle, & J. Switzer (Eds.), *Conserving the peace: Resources, livelihoods and security* (p. 408). Winnipeg: International Institute for Sustainable Development.

Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O'Hara, R. B., … Wagner, H. (2016). vegan: Community Ecology Package. Retrieved from https://cran.r-project.org/package=vegan

Olsson, P., Folke, C., & Berkes, F. (2004). Adaptive comanagement for building resilience in social-ecological systems. *Environmental Management*, *34*(1), 75–90.

Pauly, D. (1997). Small-Scale Fisheries in the Tropics: Marginality, Marginalization, and Some Implications for Fisheries Management. In E. K. Pikitch, D. D. Huppert, & M. P. Sissenwine (Eds.), *Global Trends: Fisheries Management* (pp. 40–49). Bethesda, Maryland, USA: American Fisheries Society Symposium 20.

Pauly, D. (1998). Fishing Down Marine Food Webs. *Science*, *279*(5352), 860–863.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., … Zeller, D. (2002). Towards sustainability in world fisheries. *Nature*, *418*, 689–695.

Pinkerton, E. W. (1992). Translating Legal Rights into Management Practice: Overcoming Barriers to the Exercise of Co-management. *Human Organization*, *51*(4), 339–334.

Pittaluga, P., Corcoran, E., & Senahoun, J. (2004). Poverty profiles of artisanal

fishers: methods based on SLA model. In A. Neiland & B. C (Eds.), *Poverty and small-scale fisheries in West Africa* (pp. 103–20). Kluwer Academic Publsihers.

Plummer, R., & Baird, J. (2013). Adaptive co-management for climate change adaptation: Considerations for the barents region. *Sustainability (Switzerland)*, *5*(2), 629–642.

Plummer, R., & FitzGibbon, J. (2006). People matter: The importance of social capital in the co-management of natural resources. *Natural Resources Forum*, *30*, 51–62.

Poffenberger, M. (2009). Cambodia's forests and climate change: Mitigating drivers of deforestation. *Natural Resources Forum*, *33*(4), 285–296.

Pomeroy, R. S. (1995). Community-based and co-management institutions for sustainable coastal fisheries management in Southeast Asia. *Ocean and Coastal Management*, *27*(3), 143–162.

Pomeroy, R. S. (2012). Managing overcapacity in small-scale fisheries in Southeast Asia. *Marine Policy*, *36*(2), 520–527.

Pomeroy, R. S., Katon, B. M., & Harkes, I. (2001). Conditions affecting the success of fisheries co-management: Lessons from Asia. *Marine Policy*, *25*(3), 197–208.

Pomeroy, R. S., & Williams, M. J. (1994). *Fisheries Co-management and Small-scale fisheries: A Policy Brief*. Manila.

Prokopy, L. S. (2004). Women's participation in rural water supply projects in India: is it moving beyond tokenism and does it matter? *Water Policy*, *6*(2), 103–116.

Quisumbing, A. R. (1996). Male-Female Productivity: Differences in Agricultural Issues and Empirical Evidence. *World Development*, *24*(10), 1579–1595.

R Core Team. (2016). R: A Language and Environment for Statistical Computing. Vienna, , Austria: R Foundation for Statistical Computing. Retrieved from

https://www.r-project.org/

Rahman, S., & Akter, S. (2014). Determinants of Livelihood Choices: An Empirical Analysis from Rural Bangladesh. *Journal of South Asian Development*, *9*(3), 287–308.

Rahut, D. B., & Micevska Scharf, M. (2012). Non-farm employment and incomes in rural Cambodia. *Asian-Pacific Economic Literature*, *26*(2), 54–71.

Ratner, B. D. (2006a). Community Management by Decree? Lessons From Cambodia's Fisheries Reform. *Society & Natural Resources*.

Ratner, B. D. (2006b). Community Management by Decree? Lessons From Cambodia's Fisheries Reform. *Society & Natural Resources*, *19*(1), 79–86.

Reardon, T., Berdegué, J., Barrett, C. B., & Stamoulis, K. (2007). Household income diversification into rural nonfarm activities. In S. Haggblade, P. B. R. Hazell, & T. Reardon (Eds.), *Transforming the rural nonfarm economy. Opportunities and threads in the developing world* (pp. 115–140). Baltimore: The Johns Hopkins University Press.

Resurreccion, B. P. (2006). Rules, Roles and Rights: Gender, Participation and Community Fisheries Management in Cambodia's Tonle Sap Region. *International Journal of Water Resources Development*.

Ricciardi, A., & Rasmussen, J. B. (1999). Extinction rates of North American freshwater fauna. *Conservation Biology*, *13*(5), 1220–1222.

Salayo, N., Garces, L., Pido, M., Viswanathan, K., Pomeroy, R., Ahmed, M., … Masae, A. (2008). Managing excess capacity in small-scale fisheries: Perspectives from stakeholders in three Southeast Asian countries. *Marine Policy*, *32*(4), 692–700.

Salmivaara, A., Kummu, M., Varis, O., & Keskinen, M. (2016). Socio-Economic

Changes in Cambodia's Unique Tonle Sap Lake Area: A Spatial Approach. *Applied Spatial Analysis and Policy*, *9*(3), 413–432.

Samkol, P., Sath, K., Patel, M., Windsor, P. A., & Holtenius, K. (2015). Survey of smallholder beef cattle production systems in different agro-ecological zones of Cambodia. *Tropical Animal Health and Production*, (JUNE), 1299–1306.

Sarkkula, J., & Koponen, J. (2010). *DMS - Detailed Modelling Support Project, Final Report*.

Schuhbauer, A., & Sumaila, U. R. (2016). Economic viability and small-scale fisheries - A review. *Ecological Economics*, *124*, 69–75.

Scoones, I. (1998). *Sustainable Rural Livelihoods: A Framework for Analysis*. *IDS Working Paper* (Vol. 72).

Sen, A. (1993). Capability and Well-being. In M. Nussbaum & A. Sen (Eds.), *The Qulity of Life*. New York: Oxford University Press, Inc.

Shi, X., Heerink, N., & Qu, F. (2007). Choices between different off-farm employment sub-categories: An empirical analysis for Jiangxi Province, China. *China Economic Review*, *18*(4), 438–455.

Sinh, L. X., Hap, N., & Pomeroy, R. S. (2014). Value Chain of Snakehead Fish in the Lower Mekong Basin of Cambodia and Vietnam. *Aquaculture Economics & Management*, *18*(1), 76–96.

Sithirith, M. (2014). The Patron-Client System and Its Effect on Resources Management in Cambodia: A Case in the Tonle Sap Lake. *Asian Politics and Policy*, *6*(4), 595–609.

Smith, D. R., Gordon, A., Meadows, K., & Zwick, K. (2001). Livelihood diversification in Uganda: Patterns and determinants of change across two rural districts. *Food Policy*, *26*(4), 421–435.

So, N., & Song, S. L. (2011). Fisheries management and development in Tonle Sap Great Lake, Cambodia. In *Consultation on Development Trends in Fisheries and Aquaculture in Asian Lakes and Reservoirs, 20–23 September 2011, Wuhan, China*.

Sodhi, N. S., Posa, M. R. C., Lee, T. M., Bickford, D., Koh, L. P., & Brook, B. W. (2010). The state and conservation of Southeast Asian biodiversity. *Biodiversity and Conservation*, *19*(2), 317–328.

Sokhem, P., & Sunada, K. (2006). The Governance of the Tonle Sap Lake, Cambodia: Integration of Local, National and International Levels. *International Journal of Water Resources Development*, *22*(3), 399–416.

Solesbury, W. (2003). *Sustainable Livelihoods : A Case Study of the Evolution of DFID Policy*. *Development*.

Soltani, A., Angelsen, A., Eid, T., Naieni, M. S. N., & Shamekhi, T. (2012). Poverty, sustainability, and household livelihood strategies in Zagros, Iran. *Ecological Economics*, *79*, 60–70.

Strange, N., Theilade, I., Thea, S., Sloth, A., & Helles, F. (2007). Integration of species persistence, costs and conflicts: An evaluation of tree conservation strategies in Cambodia. *Biological Conservation*, *137*(2), 223–236.

Sumaila, U. R., & Walters, C. (2005). Intergenerational discounting: A new intuitive approach. *Ecological Economics*, *52*(2), 135–142.

Sunil, T. S., & Sagna, M. (2015). Decomposition of childhood malnutrition in Cambodia. *Maternal and Child Nutrition*, *11*(4), 973–986.

Swift, J. (1989). Why Are Rural People Vulnerable To Famine. *IDS Bulletin*, *20*(2), 8–15.

Sze Choo, P., Nowak, B. S., Kusakabe, K., & Williams, M. J. (2008). Guest Editorial:

Gender and Fisheries. *Development*, *51*(2), 176–179.

Taylor, J. E., Rozelle, S., & de Brauw, A. (2003). Migration and Incomes in Source Communities: A New Economics of Migration Perspective from China. *Economic Development and Cultural Change*, *52*(1), 75–101.

Teh, L. S. L., Teh, L. C. L., & Rashid Sumaila, U. (2014). Time preference of small-scale fishers in open access and traditionally managed reef fisheries. *Marine Policy*, *44*, 222–231.

Tep, C., Meng, K., Tith, P., Deap, P., Chap, S., Sim, B., & Rivera-Guieb, R. (2007). *Cambodia: Asserting rights, defining responsibilities*. Chennai, India.

Tesfaye, Y., Roos, A., Campbell, B. M., & Bohlin, F. (2011). Livelihood strategies and the role of forest income in participatory-managed forests of Dodola area in the bale highlands, southern Ethiopia. *Forest Policy and Economics*, *13*(4), 258–265.

Thay, S. (2002). *Fisheries Policy Reforms and the Current Perceptions about Community Fisheries and Co-management of Fisheries: A Case Study from Selected Fishing Lot Areas of Siem Reap and Battambang Provinces Kingdom of Cambodia*. Phnom Penh: PNMR.

Thys, E., Oueadraogo, M., Speybroeck, N., & Geerts, S. (2005). Socio-economic determinants of urban household livestock keeping in semi-arid Western Africa. *Journal of Arid Environments*, *63*, 475–496.

Tilley, A., & Lopez-Angarita, J. (2016). Predicting vulnerability to management changes in data-limited, small-scale fisheries. *Marine Policy*, *72*, 211–218.

Timmer, C. P. (1988). Chapter 8: The agricultural transformation. In *Handbook of Development Economics* (Vol. 1, pp. 275–331).

Townsley, P. (1998). Livelihoods and aquatic resource management. In D. Carney

(Ed.), *Sustainable rural livelihoods: what contribution can we make?* (pp. 139–154). London: Department for International Development.

Travers, H., Clements, T., Keane, A., & Milner-Gulland, E. J. (2011). Incentives for cooperation: The effects of institutional controls on common pool resource extraction in Cambodia. *Ecological Economics*, *71*(1), 151–161.

UNCDF. (2010). *Local development outlook Cambodia: Trends, policies, governance*. Phnom Penh.

van Brakel, M. L., & Ross, L. G. (2011). Aquaculture development and scenarios of change in fish trade and market access for the poor in Cambodia. *Aquaculture Research*, *42*(7), 931–942.

Van Zalinge, N., Nao, T., Touch, S. T., & Deap, L. (2000). Where there is water, there is fish? Cambodian fi sheries issues in a Mekong River Basin perspective. In M. Ahmed & P. Hirsch (Eds.), *Common property in the Mekong: issues of sustainability and subsistence* (pp. 37–48). Manila: ICLARM Studies and Reviews 26.

Varis, O. (2008). Poverty, economic growth, deprivation, and water: the cases of Cambodia and Vietnam. *Ambio*, *37*(3), 225–231.

Vixathep, S., & Matsunaga, N. (2012). Firm Efficiency in Cambodia's Garment Industry on the Eve of the Multi-Fiber Arrangement Termination. *Asian Economic Journal*, *26*(4), 359–380.

Vrieze, P., & Naren, K. (2012, March). Carving Up Cambodia: One concession at a time. *Cambodia Daily, Weekend, Issue 730*, pp. 4–11. Phnom Penh.

Webb, P., Richardson, E., Seyoum, S., & Yohannes, Y. (1994). *Vulnerability mapping and geographical targeting an exploratory methodology applied to ethiopia*. Washington D.C.

White, A. T., Hale, L. Z., Renard, Y., & Cortesi, L. (1994). *Collaborative and community-based management of coral reefs.* West Hartford: Kumarian Press.

World Bank. (2006). *Cambodia Halving Poverty by 2015 ? Poverty Assessment 2006*. Retrieved from http://documents.worldbank.org/curated/en/154931468214795356/pdf/352130KHMER0Bo0overty0by020150Khmer.pdf

World Bank. (2014). *Where Have All The Poor Gone ? Cambodia Poverty Assessment 2013*. Washington D.C. Retrieved from http://documents.worldbank.org/curated/en/824341468017405577/pdf/ACS45450REVISE00English0260May02014.pdf

World Bank. (2015a). *Cambodian Agriculture in Transition: Opportunities and Risks*. Washington D.C. https://doi.org/10.1017/CBO9781107415324.004

World Bank. (2015b). Official exchange rate (LCU per US$, period average). Retrieved August 23, 2015, from http://data.worldbank.org/indicator/PA.NUS.FCRF

World Bank. (2016). World Development Indicators. Retrieved June 1, 2016, from http://data.worldbank.org/country/cambodia#cp_wdi

WorldFish Center. (2007). *Study of the Influence of Built Structures on the Fisheries of the Tonle Sap: Technical Assistance Consultant's Report*. Phnom Penh, Cambodia.

Yandle, T. (2006). Sharing natural resource management responsibility: Examining the New Zealand rock lobster co-management experience. *Policy Sciences*, *39*(3), 249–278.

Yohannes, Y., & Webb, P. (1999). *Classification and Regression Trees, CART: A User Manual for Identifying Indicators of Vulnerability to Famine and Chronic*

Food Insecurity. Washington DC: International Food Policy Research Institute.

Yoshimura, C., Omura, T., Furumai, H., & Tockner, K. (2005). Present state of rivers and streams in Japan. *River Res. Applic*, *21*(2–3), 93–112.

Yu, B., & Diao, X. (2011). *Cambodia's Agricultural Strategy: Future Development Options for the Rice Sector - A Policy Discussion Paper*. Phnom Penh. Retrieved from http://www.cdri.org.kh/webdata/download/sr/agriStrategy9e.pdf

Yu, B., & Fan, S. (2011). Rice production response in Cambodia. *Agricultural Economics*, *42*(3), 437–450.

Ziv, G., Baran, E., Nam, S., Rodriguez-Iturbe, I., & Levin, S. A. (2012). Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proceedings of the National Academy of Sciences*, *109*(15), 5609–5614.

APPENDIX A: QUESTIONNAIRE

Household Survey

Maintaining productivity and income in Tonle Sap fisheries in the Face of climate change

This survey looks at the livelihood strategies of fishing dependent household in and around Tonle Sap Lake. We want to understand the household assets and how they make decisions in allocating their family resources. The goal is to identify ways in which the inhabitants in and around Tonle Sap Lake may be affected due to the changing fishery resources and also identify the voices of residents in managing fishery resources. We are very interested in your opinions, concerns, and ideas. To accomplish this, we need your help in completing this questionnaire. All households were randomly selected – all responses will be confidential. You are able to withdraw at any point during interview. If you choose to withdraw, your information will not be used. Your assistance is greatly appreciated.

Do you have any questions about the survey? Do we have your agreement to proceed?

Participant understands role and has given verbal consent (please check) ☐

Questionnaire for Household Survey

Part A. This first part of the questionnaire we would like to ask you about yourself, your family and your local residency.

1. Identification

1.1	Date of Interview			
1.2	Village			
1.3	Commune			
1.4	District			
1.5	Province			
1.6	Name of Interviewer			
1.7	GPS Coordinate	X:	Y:	Z:

2. History

2.1	How long has your family been living in this village? Years_____
2.2	Did your family migrate from another place? YES_____NO_____ If **YES**, where did you live before? Name of the Village:_____ Commune: _____ District_____ Province: _____

3. Household composition

3.1	How many people live in your house?	Number of people .....
3.2	What is your household ethnicity? _____ 1= Khmer, 2= Vietnamese, 3= Cham 4= Mix, 5=Others (specify……)	

3.3	Details of each individuals						
S.N	**Gender** (1= M, 0=F)	**Age** (Enter "NA" if don't know)	**Marital Status (code)**	**Relat'ship to HH head (code)**	**Education (code)**	**1st Occup. (code)**	**2nd Occup. (code)**
1*							
2							
3							
4							
5							
6							
7							
8							
9							
10							

***Household head**

4. Training

4.1	Have you or any household members received any trainings over the past years?	YES_____NO_____
4.2	If answer YES, details of training	
	Types of Trainings	
1		
2		
3		
4		
5		
4.3	Please list the FIVE most important skills or training programs for the improvement of your household socioeconomic conditions and we would like you to indicate the competence of your household in general to perform the skill. ***Competence to Perform the Skill*** 1 = Not at all Competent, 2 = Little Competence, 3 = Moderately Competent, 4 = Fairly Competent 5 = Very Competent Skills/Trainings Scale (1 to 5) a. _____: ____ b. _____: ____ c. _____: ____ d. _____: ____ e. _____: ____	

5. Resources and ownership

5.1	Which of the following best describes your situation: a. We rely on fishing only b. Our livelihood is based on both farming and fishing c. Our livelihood is based on a combination of fishing, farming and off farm jobs d. We rely on farming only e. Our livelihood is based on farming and income from off farm jobs f. Our livelihood is based on fishing and off farm jobs
5.2	What is the percentage of time you spend in each activity? Agriculture:_____% Fishing:_____% Aquaculture:_____% Off-Farm Jobs (Specify_____):_____% Other (Specify_____):_____%
5.3	Was the situation always like this? YES_____NO_____ If YES, please go to 6 If NO, which of the following best describes your situation? a. We changed from fishing to farming b. We changed from fishing to a combination of fishing and farming c. We changed from fishing to a combination of fishing, farming and off farm jobs d. We changed from farming to a combination of farming and off farm jobs **e.** We changed from farming to a combination of farming fishing and off farm jobs
5.4	When did you change? Year:_____
5.5	Reason for changing: a. Fishing is not enough to meet the families need b. Farming is not enough to meet the families need c. Both fishing and farming is not enough d. Both farming and off farm jobs is not enough e. For an extra income f. Others(Please specify):_____

6. Housing

6.1	Is the house owned by one of the household members? YES_____NO_____
6.2	Can you describe the conditions of your house? _____ (1 = thatch house, 2 = wooden house roofed with tin sheets, 3 = Wooden house roofed with tiles and fibrous cement, 4 = concrete/brick house, 5 = others (specify): .....)
6.3	What is the area of the house? _____m2
6.4	When did you build or rebuild the house? Year_____
6.5	What is the toilet facility of the house? _____ (1 = toilet inside the house, 2 = toilet is outside the house, 3 = household doesn't own a toilet)

7. Household assets

7.1	Do you own any of the following? How many or how much? Can you please estimate the approximate worth?		
Assets		Number	Worth (total value)

Car/truck/van		
Motorbike		
Bicycle		
TV/Radio/Other electronics		
Sewing machine		
Electric fan		
Big pieces of furniture (i.e sofa, valuable bed, etc)		
Generator for electricity		
Solar panel		
Other assets.....		
Other assets.....		
Total		

Part B. This part of the questionnaire we would like to ask you about the management of your resources (farming, fishing, family labor etc.)

8. Farming activities

8.1	Do you do farming? YES_____NO_____
8.2	When did you start doing farming? YEAR_____
8.3	What is the reason you started farming? _____
8.4	What are you plating/growing in your farm? _____

8.5	Descriptions of the land property rights and land use			
Plot Number	Size of plot in sq.m	Property rights/land title a. Permanent right with certificate b. Permanent right without certificate c. Rented in d. Rented out e. Public land f. Others	Crop grown	
			Annual	Perennial
			a. Wet season Rice b. Dry season Rice c. Maize d. Cassava e. Beans f. Other vegetables	a. Litchi b. Mango c. Orange d. Others
Plot 1				
Plot 2				
Plot 3				
Plot4				
Plot 5				

8.6	Do you own any of the following farming equipment? How many or how much? Can you please estimate the approximate worth?		
Farming Equipment		Number	Worth (total value)
Cart (pulled by animal)			
Tractor			
Bulldozer			
Plough			
Threshing machine			

Harrow/rake/hoe/spade/axe…		
Insecticide sprayer		
Semi-tractor (Kou Yon)		
Rice mill		
Water pump		
Other (specify)		
Other (specify)		
Total		

8.7 Crop production volume and associated cost

	Wet season Rice	Dry season Rice	Maize	Cassava	Beans	Other vegetables	Other: _____
Size (m2)							
Production (kg)							
Total value of crops (Riel)							
Production cost							
Consumption amount (kg)							
Barter/given away (kg)							
Sell amount (kg)							
Sell price ( )							

9. Livestock

9.1	Do you do livestock production? YES_____NO_____
9.2	When did you start? _____
9.3	What is the reason you started livestock production? _____
9.4	What type of animals are you raising? _____
9.5	Livestock production and associated cost

	Cows/ Buffaloes	Pigs	Chickens	Ducks	Other (specify) .....
Herd size (no.)					
Total quantity (Kg)					
Total value (Riel)					
Production cost (Riel)					
Consumption amount (number/kg)					
Barter/given away (kg)					
Sell price (Riel/kg)					

10. Aquaculture

10.1	Do you do aquaculture? YES_____NO_____

10.2	When did you start? _____
10.3	What is the reason you started to do aquaculture activities? _____
10.4	What are you raising? _____
10.5	**Production and associated cost ($/pond or farm)**

	Fish	Crocodiles	Other: _____	Other: _____
Amount/Size/Number				
Total amount (Kg)				
Total value (Riel)				
Production cost (Riel)				
Consumption amount (number/kg)				
Barter/given away (Kg)				
Sell price (Riel per kg)				

11. Fishing

11.1	When did you start fishing? How long have you been fishing? since_____
11.2	What is the reason you started fishing? a. Farming was not enough b. Better livelihood compared to farming c. Easy to catch fish d. Good fish market e. Others (Please specify):_____
11.3	How many members of your family are engaged in fishing? _____persons full time _____persons part time
11.4	Do you own any of the following fishing equipment? How many or how much? Can you please estimate the approximate worth?

Fishing Equipment	Number	Worth (total value)
Boat		
Outboard motor for boat		
Harpoon/spear		
Gillnet (morng) <2.5 cm (1 finger)		
Gillnet (morng) 3-4 cm (2 fingers)		
Gillnet (morng) 5-7 cm (3 fingers)		
Gillnet (morng) 8-11 cm (4 fingers)		
Gillnet (morng) >12cm		
Seine/drag net (uorn/neam/anhchourn)		
Castnet (samnanh)		
Liftnet		
River trawl (magn)		
Hooked line (santouch)		
Funnel trap		
Brush Park		
Electric fishing gear		

Shrimp trap		
Plunge basket		
Trap		
Scoop		
Long hook line		
Small Trap		
Push net		
Fyke net made of mosquitoes net		
Other (specify)		
Total		

11.5	How much was your average catch per day? Wet season _____kg/day. Dry season _____ kg/day
11.6	What other products you catch/collect besides fish? _____
11.7	Has the trend of your fish catch been in decreasing in the last five years? YES_____NO_____ Why if YES or NO_____
11.8	If answer to the earlier question is fish catch decreased, then could you please tell us how you coped with the reducing fishing resources? (Note: answer choices focus on the livelihood decision to cope with change) a. Increase farming activities b. Started to farming on rented farm c. Started upland cultivation d. Bought farmland e. Economic migration of some members (in country or abroad) f. Other (Please specify):_____
11.9	Is income from fishing enough to support your family? YES_____NO_____ If NOT, what did you do to support your family? a. Increase farming activities b. Started to farming on a rented farm c. Started upland cultivation d. Bought farmland e. Some members of the family went to Phnom Penh/Bangkok/other provinces/abroad for a job f. Others (Please specify):_____
11.10	Do you expect that the fishery will maintain its current level of productivity over the next 10 years? YES_____NO_____ If NOT, what do you see as possible livelihood options for you a. Start farming activities b. Increase farming activities c. Changing to farming only d. Start off-farm activities e. Increase off-farm activities f. Moving to off farm jobs only g. Others (Please specify):_____
11.11	Did you ever think to stop fishing? YES_____NO_____ If YES, why_____

11.12	Do you think your children will also be in fishing business? YES_____NO_____ If NOT, why_____
11.13	**Production and associated cost**

	Fish		Aquatic animals		Other products	
	Wet	Dry	Wet	Dry	Wet	Dry
Amount caught/collected (kg)						
Total value of catch (riel)						
Operational/maintenance cost (i.e gear, boat) (Riel)						
Consumption amount (kg)						
Barter/given away (kg)						
Sell amount (kg)						
Sell price (Riel)						

12. Access to common property resources

12.1	Do you have access to common property resources located within/outside your commune? YES_____NO_____
12.2	If YES, what type of common property resources? a. inundated forest b. big river/lakes c. flooded rice field d. bank/bed of river/lake e. irrigation canals/dike/small river f. others (Please specify):_____
12.3	What kind of product and benefits do you get from these common property resources?

	Inundated forest	River/ lake	Flooded ricefield	River bank	Irrigation/canal/dike	Others
a) Firewood						
b) Feed (animal, livestock, aquaculture etc)						
c) Bamboo/canes						
d) Fish						
e) Wild animals/birds						
f) Irrigation water						
g) Transportation facilities						
h) Fruits/vegetables collection						
i) Snails/crab collection						
j) Fish-cage culture facilities						
k) Others						

12.4	How large is the area of common property resources within your commune in which you or your family go for above products and benefits?

	a. inundated forest: _____h.a b. big river/lakes: _____h.a c. flooded rice field: _____h.a d. bank/bed of river/lake: _____h.a e. irrigation canals/dike/small river: _____h.a f. others (please specify):_____h.a
12.5	What portion (%) of the families in your commune depend on these common property resources like you? _____
12.6	If access to the above common property resources became restricted, how will it affect your livelihood opportunities? a. ''No effect,'' because current benefits are very small b. Will affect only little, but can easily manage without these c. Will significantly affect the livelihood, because alternatives are limited d. Others (please specify):_____
12.7	What has been the trend of availability of products and benefits from the common property resources in recent years (last 10 years)? (1 = Increased, 2 = Decreased, 3 = Didn't change) a. inundated forest: _____ b. big river/lakes: _____ c. flooded rice field: _____ d. bank/bed of river/lake: _____ e. irrigation canals/dike/small river: _____ f. others (please specify): _____
12.8	If the availability of products and benefits from common property resources for your family are decreasing over time, what are the main reasons? (Rank in order of importance, if applicable; put zero otherwise) a. Overexploitation: _____ b. Change of environment: _____ c. Destruction of habitat (e.g... Loss of inundated forest): _____ d. Increasing pressure of population in the commune: _____ e. Use of pesticides/poisons in ricefields: _____ f. Conversion of common land/water into crop lands for private use: _____ g. Others (specify: _____): _____
12.9	What kind of regulation or restrictions do you need to follow to access and use the common property resource (mentioned in question 12.2 above) for non-fishery purposes? (if applicable put 1; zero otherwise) a. Need to buy licenses for cutting wood and bamboo: _____ b. Need permission from head of commune: _____ c. Pay lease for seasonal use of land and water: _____ d. Free and unlimited access: _____ e. Others (specify: _____): _____
12.10	What are the rules in the village governing access to fish resources (who, where and how can access)? a. community areas: _____ b. public areas: _____ c. conservation areas: _____ d. other areas: _____
12.11	In your opinion, what are the main threats to rights in the fisheries? _____ _____

13. Off-farm activities, income, migration

13.1	Of your family members, who are permanently and temporarily absent?				
S.N.	Name	Causes of absence (code)	Occupation (code)	Since when the job was started?	Money sent per month (Riel)
1					
2					
3					
4					
5					

14. Borrowing and lending activities

14.1	Does your household have outstanding loans or debts to other households or institutions? YES_____NO_____

14.2	Details of loan					
LN	How old is the debt? (Month, put "0"if <1 month)	From whom did you obtain the loan? (Enter code)	What was the primary purpose for which your household borrowed the money? (Enter code)	What was the total amount borrowed? (Riels)	How much is the outstanding loan now (this month)? (Riels)	If interest is charged, what is the monthly rate of interest? (% or write "0" if no interest is charged)
1						
2						
3						
4						
5						

14.3	**If you borrowed money**, you are obliged to sell fish to your money lender? YES_____NO_____
14.4	If yes, do you get the market price for your fish from fish trader? YES_____NO_____
14.5	If no, how much less per kg in %? _____
14.6	Over the past 12 months?), has your household lent money (or rice) to someone? YES_____NO_____
14.7	If yes, how much? _____Riels
14.8	Do you have any cash deposits in a banking institution, community saving group or micro-finance scheme? YES_____NO_____
14.9	If yes, how much? _____Riels

15. Social network

15.1	Do you or any of your household members belong to any groups or associations involved with any of the following? If so, what is the group? Why did you join the group ?		
Group/ associations		Name/Type	Why?
related to main economic activity (fishing, farming, trade, manufacturing, etc)			

related to health or education			
Religious groups			
other groups			
15.2	Do you think being a member of a group help you to socially and economically perform better than being alone? YES_____NO_____		
15.3	How do you describe your interactions with other members within the group/ association/network in which you belong to? a. positive b. negative c. normal		
15.4	How do you describe your interactions with others in the community? a. positive b. negative c. normal		
15.5	Have you or your household members excluded from any social events? YES_____NO_____ If YES, When_____ Why_____		
15.6	In your village, do you or any of your household members help each other with fishing, farming and/or other work? YES_____NO_____		
15.7	Do you or any household members give or receive food to/from other neighbors or villagers? YES_____NO_____		
15.8	Do you or any household members lend or borrow from other villagers fishing gear, agricultural equipment or other household assets? YES_____NO_____		
15.9	Have these forms of mutual aid increased, decreased or stayed the same over time? a. increased b. decreased c. the same		
15.10	In your opinion, how do you compare your community with others in terms of social relation and mutual aid? a. better b. worse c. the same d. don't know		
15.11	How do you usually receive information relating social and economic activities? (Rank in order of frequency: 1 to 9) a. Word of mouth (friends and neighbors) b. Groups, association, network (CF, CBO, and other groups) c. Village and commune chiefs/officials d. Village/commune police e. Provincial and district government departments f. NGOs g. Television/Radio h. Business people and money lenders i. Other, specify.....		

Part C. This part will ask you about your response to hypothetical change in Tonle Sap fishery.

16. Views/perceptions under possible policy/future conditions

Some studies show that because of the ongoing development of dam construction in the Upper Mekong Basin, climate change and urbanization, there will be four possible situations in the future:

(a) 50% reduction of fish production in Tonle Sap Lake,
(b) Increased agricultural land due to changes in flood plain habitats,
(c) Creation of more jobs due to the urbanization and increased economic activities in urban centers or,
(d) Stagnation (more or less the same situation as today).

Assuming one or more of these conditions arise in the future, then how would your livelihood be affected and how would you allocate and manage your resources.

16.1	Those who are currently only fishing
A	50% reduction of fish production in Tonle Sap Lake and everything else remains same **Would you still be fishing only?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Start farming activities b. Start off-farm activities c. Changing to farming only d. Moving to off farm jobs only **e.** Others (Please specify):_____ **Compared to your current situation of 100% family resources in fishing, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% sending for off farm job c. _____% will go for upland cultivation d. _____% will rent the neighbouring farm land e. _____% Others (Please specify):_____
B	50% reduction of fish production in Tonle Sap Lake and increased agricultural land due to decrease flood plain **Would you still be fishing only?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Start farming activities b. Start off-farm activities c. Changing to farming only d. Moving to off farm jobs only **e.** Others (Please specify):_____ **Compared to your current situation of 100% family resources in fishing, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% sending for off farm job c. _____% will go to newly available agricultural land d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land **f.** _____% Others (Please specify):_____

C	50% reduction of fish production in Tonle Sap Lake and increased agricultural land due to decrease flood plain and increased jobs in cities **Would you still be fishing only?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Start farming activities b. Start off-farm activities c. Changing to farming only d. Moving to off farm jobs only e. Others (Please specify):_____ **Compared to your current situation of 100% family resources in fishing, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% sending for off farm job c. _____% will go to newly available agricultural land d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land f. _____% Others (Please specify):_____
D	Stagnation (more or less same situation as today) **Would you still be fishing only?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Start farming activities b. Start off-farm activities c. Changing to farming only d. Moving to off farm jobs only e. Others (Please specify):_____ **Compared to your current situation of 100% family resources in fishing, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% sending for off farm job c. _____% will go for upland cultivation d. _____% will rent the neighbouring farm land **e.** _____% Others (Please specify):_____
	If respondent's views do not match any options above, then please use the space below to note down the response: _____ _____ _____ _____ _____ _____

6.2	**Those who are currently fishing and farming (_____% fishing _____% farming)**
A	50% reduction of fish production in Tonle Sap lake and everything else remains same **Would you still continue with the same proportion of fishing and farming?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Increase farming activities b. Start off-farm activities c. Change to farming only d. Moving to off farm jobs only e. Others (Please specify):_____ **Compared to your current situation of_____% fishing _____%farming, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% for current farming activities c. _____% sending for off farm job d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land **f.** _____% Others (Please specify):_____
B	50% reduction of fish production in Tonle Sap Lake and increased agricultural land due to decrease in flood plain **Would you be interested to do farming activities in newly available agricultural land?** YES_____NO_____ **If YES, Compared to your current situation of _____% fishing _____% farming, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% for current farming activities c. _____% will go to newly available agricultural land d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land **f.** _____% Others (Please specify):_____

C	50% reduction of fish production in Tonle Sap lake and increased agricultural land due to decrease in flood plain and increased jobs in cities **Would you be interested in diversifying your livelihood options and reallocating your family resources?** YES_____NO_____ **If YES, what do you see as possible options?** a. Increase farming activities b. Start off-farm activities c. Change to farming only d. Moving to off farm jobs only e. Others (Please specify):_____ **Compared to your current situation of _____% fishing _____% farming, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% for current farming activities c. _____% sending for off farm job d. _____% will go to newly available agricultural land e. _____% will go for upland cultivation f. _____% will rent the neighbouring farm land **g.** _____% Others (Please specify):_____
D	Stagnation (more or less same situation as today) **Would you be interested to diversify your livelihood option and reallocate your family resources?** YES_____NO_____ **If YES, Compared to your current situation of _____% fishing _____% farming, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% sending for off farm job c. _____% for current farming activities d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land f. _____% Others (Please specify):_____
	In the future, how do you think you will you manage your land? Same as today:_____ Differently:_____
	How would you manage your land resources? _____ _____ _____ _____ _____ _____ _____ _____

	If respondent's views does not match any options above then please use the space below to note down the response: _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

16.3	**Those who are currently doing a combination of fishing and off farm activities (_____% fishing and_____% off farm jobs)**
A	50% reduction of fish production in Tonle Sap lake and everything else remains same **Would you still continue with the same proportion of fishing and off farm jobs?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Changing the proportion of fishing and off farm activities b. Start farming activities c. Moving to off farm jobs only **d.** Others (Please specify):_____ **Compared to your current situation of _____% fishing _____% off farm jobs, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% sending for off farm job c. _____% will go for upland cultivation d. _____% will rent the neighbouring farm land e. _____% Others (Please specify):_____
B	50% reduction of fish production in Tonle Sap Lake and increased agricultural land due to decrease in flood plain **Would you be interested to do farming activities in newly available agricultural land?** YES_____NO_____ **If Yes, compared to your current situation of _____% fishing_____% off farm jobs, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% sending for off farm job c. _____% will go to newly available agricultural land c. _____% will go for upland cultivation d. _____% will rent the neighbouring farm land e. _____% Others (Please specify):_____
C	50% reduction of fish production in Tonle Sap lake and increased agricultural land due to changes in flood plain habitats and increased jobs in Phnom Penh **Would you be interested to diversify your livelihood option and reallocate your family resources?** YES_____NO_____ **If YES, what do you see as possible options?** a. Increase off-farm activities b. Start farming activities c. Moving to off farm jobs only d. Changing to farming only e. Others (Please specify):_____

	Compared to your current situation of _____% fishing _____% off farm jobs, how would you manage your family labor resources? a. _____% for fishing activities b. _____% sending for off farm job c. _____% will go to newly available agricultural land d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land f. _____% Others (Please specify):_____
D	Stagnation (more or less same situation as today) **Would you still continue with the same proportion of fishing and off farm jobs? YES_____NO_____** **If NOT, what do you see as possible options?** a. Start farming activities b. Increase farming activities c. Increase off-farm activities d. Change to farming only e. Moving to off farm jobs only f. Others (Please specify):_____ **Compared to your current situation of _____% fishing and_____% off farm jobs, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% for farming activities c. _____% sending for off farm job d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land f. _____% Others (Please specify):_____
	If respondent's views does not match any options above then please use the space below to note down the response: _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

16.4	**Those who are currently doing a combination of fishing, farming and off farm activities (_____% fishing _____%farming and_____% off farm jobs)**
A	50% reduction of fish production in Tonle Sap lake and everything else remains same **Would you still continue with the same proportion of fishing, farming and off farm jobs?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Changing the proportion of fishing, farming and off farm activities b. Moving to farming activities c. Moving to off farm jobs only **d.** Others (Please specify):_____ **Compared to your current situation of _____% fishing _____% farming _____% off farm jobs, how would you manage your family labor resources?** a._____% for fishing activities b._____% for current farming activities b._____% sending for off farm job c._____% will go for upland cultivation d._____% will rent the neighbouring farm land e._____% Others (Please specify):_____
B	50% reduction of fish production in Tonle Sap Lake and increased agricultural land due to decrease in flood plain **Would you be interested to do farming activities in newly available agricultural land?** YES_____NO_____ **If Yes, compared to your current situation of _____% fishing_____% farming _____% off farm jobs, how would you manage your family labor resources?** a._____% for fishing activities b. _____% for current farming activities c._____% sending for off farm job d. _____% will go to newly available agricultural land e._____% will go for upland cultivation f._____% will rent the neighbouring farm land g._____% Others (Please specify):_____
C	50% reduction of fish production in Tonle Sap lake and increased agricultural land due to changes in flood plain habitats and increased jobs in Phnom Penh **Would you be interested to diversify your livelihood option and reallocate your family resources?** YES_____NO_____ **If YES, what do you see as possible options?** a. Increase off-farm activities b. Start farming activities c. Moving to off farm jobs only d. Changing to farming only e. Others (Please specify):_____

	Compared to your current situation of _____% fishing _____farming _____% off farm jobs, how would you manage your family labor resources? a._____% for fishing activities b._____% for current farming activities c._____% sending for off farm job d_____% will go to newly available agricultural land e_____% will go for upland cultivation f_____% will rent the neighbouring farm land g_____% Others (Please specify):_____
D	Stagnation (more or less same situation as today) **Would you still continue with the same proportion of fishing, farming and off farm jobs?** YES_____NO_____ **If NOT, what do you see as possible options?** a. Start farming activities b. Increase farming activities c. Increase off-farm activities d. Change to farming only e. Moving to off farm jobs only f. Others (Please specify):_____ **Compared to your current situation of _____% fishing _____% farming and_____% off farm jobs, how would you manage your family labor resources?** a. _____% for fishing activities b. _____% for current farming activities c. _____% sending for off farm job d. _____% will go for upland cultivation e. _____% will rent the neighbouring farm land f. _____% Others (Please specify):_____
	If respondent's views does not match any options above then please use the space below to note down the response: _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

Community Fishery Survey

The survey looks at the ways members of the community fishery groups participate in managing fishery resources and decision-making. We want to understand the perceptions of operation, impact, successes and challenges of community fishery. The goal is to assess the performance of community fishery in managing fishery resources in Tonle Sap lake. We are very interested in your opinions, concerns, and ideas. To accomplish this, we need your help in completing this questionnaire. You were randomly selected – all responses will be confidential. You are able to withdraw at any point during the interview. If you choose to withdraw, your information will not be used. Your assistance is greatly appreciated.

Do you have any questions about the survey? Do we have your agreement to proceed?

Participant understands role and has given verbal consent (please check) ☐

A	**Description of CF**	
1	What is the name of the CF?	
2	Where is it located?	Village_____Commune_____ District_____ Province_____
3	Established Date:	
4	Area:	
5	Number of Households:	
6	Population:	
7	Committee Members	Male:_____ Female:_____

B	**Management/operation of CF**	
1	Has some organization or government supported the establishment of community fishery?	YES_____NO_____
2	If yes, name of organization	
3	Is there a Community Fishery Area Agreement?	YES_____NO_____
4	Is there a Community Fishery Area Management Plan?	YES_____NO_____
5	Are there rules and regulations for fisheries management?	YES_____NO_____
6	Does the CF have an activity plan for the next six months?	YES_____NO_____
7	Does your CF have a conservation area?	YES_____NO_____
8	What is the purpose of the conservation area?	
9	Does the CF help to resolve conflict in the fisheries?	YES_____NO_____
10	Is illegal fishing a problem?	YES_____NO_____
11	Who conducts the illegal fishing?	

12	What type of illegal fishing occurs?	
13	Is there any enforcement of rules against illegal fishing?	
14	How many are outsiders coming into your fishing area?	
15	Only small fishing gear should be allowed on the lake?	Agree_____ Disagree_____
16	Is the government taking effective action to reduce illegal fishing?	YES_____NO_____
17	Does the Community Fisheries Committee work to reduce illegal fishing?	YES_____NO_____
18	Does the CF do regular patrolling?	YES_____NO_____
19	Have illegal activities	Increase_____ same_____ or decreased_____ compared to last year?
20	Have illegal activities	Increase_____ same_____ or decreased_____compared to five years ago?

C	**Community Fishery Committee (CFC)**	
1	Are you a member of the Community Fishery Committee?	YES_____NO_____
2	If yes, what is your position?	
3	Does the CFC engage in the following duties: Draft by-laws and management plans Represent CF in conflict management Manage finances Participate in consultations Report violations Manage fisheries Coordinate with commune council Develop networks with other CFs and organizations Engage with women in the community Training and capacity building of members Engage in community development projects	 YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____ YES_____NO_____
4	Were elections for the CFC open to everyone and transparent?	YES_____NO_____
5	Do you feel that the CFC operates in transparent manner in fisheries management?	YES_____NO_____
6	If NOT, do you feel that the CFC represents your interests in fisheries management?	YES_____NO_____
7	Is the CFC open, clear and transparent in the way it makes decisions?	YES_____NO_____

8	Does the CFC represent all affected groups in management decision-making?	YES_____NO_____
9	Is the CFC accountable for the decisions that they make?	YES_____NO_____
10	Do women participate in the CFC?	YES_____NO_____
11	Does the CFC meet regularly?	YES_____NO_____
12	How often does the CFC meet with members?	
13	Women participate actively in Community Fisheries activities?	YES_____NO_____
14	Community fishery members are consulted on important decisions made by the CFC?	YES_____NO_____
15	Are community members informed of all important decisions made by the CFC?	YES_____NO_____
16	Did you support the banning of fishing lots?	YES_____NO_____
17	Is there any other associations/organizations/group in your community?	YES_____NO_____
18	If YES, What are these?	
19	Where does the CF get finances/income?	
20	Are the finances (income and expenditures) of the CF available for all members to examine?	YES_____NO_____

E	**Impact of CF**	
1	Before the community fisheries did you have access to fish on lake?	YES_____NO_____
2	How has CF affected your management? Fishing ground (area): Before_____ Now_____ Equipment/Gear: Before:_____ Now_____	
3	Has the overall livelihood getting better or worse since the CF**?**	Better off _____ Worse off _____
4	Have you benefited from Community Fisheries?	YES_____NO_____
5	If yes, How? More fish catch_____ More income_____ more markets for fish_____Alternative livelihood_____	
6	Did receiving these benefits influence your decision to be involved in community fisheries?	YES_____NO_____
7	Do you feel that benefits are shared by all of the people in the community fisheries?	YES_____NO_____
8	What are the changes that happened to your community after the establishment of CF?	
9	Has access to the fisheries improved?	YES_____NO_____

10	How would you describe the condition of the fisheries five years ago?	Very bad_____ bad _____ neither good nor bad_____ good _____ very good_____
11	How would you describe the condition of the fisheries today?	Very bad_____ bad _____ neither good nor bad_____ good _____ very good_____
12	Have changes in your income been the result of community fisheries?	YES_____NO_____
13	Do you feel that community fisheries have had an impact on your standard of living?	YES_____NO_____
14	If YES, Please explain	

F	**Community Fisheries Sustainability** (Please rate on a scale 1 to 3 based on your situation five years ago and today?
1	**Participation in community affairs in general** 1- Cannot participate in any meeting on community affairs in general (e.g. political, social, etc.) 2 - Participated in some meetings 3 - Participated in all meetings Five years ago_____ Today _____
2	**Participation in community fisheries management** 1 - Cannot join any meeting on community fisheries 2 - Can join some meetings 3 - Can join all meetings Five years ago_____ Today _____
3	**Influence over community fisheries management** 1 -Nothing you say or do makes a difference with respect to community fisheries management 2 - Some of what you say makes a difference 3 - Your opinion is important Five years ago_____ Today _____
4	**Control over fisheries** 1 - No control over who, where and how fisheries are to be harvested 2 - Some control 3 - Control over who, where and how fisheries are to be harvested Five years ago_____ Today _____
5	**Fair allocation of access rights to fisheries** 1 - Unfair allocation of access rights to fisheries (certain persons are allowed to harvest anywhere while others are not allowed to harvest fish at all) 2 - Some unfairness in allocation of access rights 3 - Completely fair (same rights are given to everyone) Five years ago_____ Today _____
6	**Overall quality of life of the household** 1 - Worst possible existence for your household (i.e. little food, inadequate shelter, and sickness) 2 - Just enough resources 3 - More than enough food for your household, best possible house, and healthy household members Five years ago_____ Today _____
7	**Household income**

	1 - No income at all for your household 2 - Some income 3 - Best possible income you can imagine for your household Five years ago_____ Today _____
8	**Income from fisheries** 1 - No income from fishing 2 - Some income from fishing 3 - Best possible income you can imagine from fishing Five years ago_____ Today _____
9	**Employment** 1 - No alternative employment opportunities available in your community 2 - Some alternative employment opportunities 3 - Several alternative employment opportunities available in your community (e.g. agriculture, tourism, etc.) Five years ago_____ Today _____
10	**Overall quality of fish** 1 -An area with no fish, where the water is so foul that nothing can live 2 - Some fish and the water is adequate 3 - Fish are abundant and the water is clean and productive Five years ago_____ Today _____
11	**Compliance with fisheries rules** 1 - No one obeys the fisheries rules 2 - Some people obey the rules 3 - Everyone obeys fisheries rules Five years ago_____ Today _____
12	**Ease of collective decision making on community problems** 1 - Very difficult for your community to decide on solutions to community problems (illegal fishing, peace and order) 2 - Some decisions are made 3 - Very easy for your community to decide on solution to community problems Five years ago_____ Today _____
13	**Knowledge of fisheries management** 1 - Fishers in your community have very little knowledge of fisheries management 2 - Fishers have some knowledge 3 - Fishers have adequate knowledge of fisheries management Five years ago_____ Today _____
14	**Quickness of resolving community conflicts on fisheries related issues** 1 - Your community takes a very long time to resolve fisheries related conflict 2 - Your community takes some time to resolve fisheries related conflict 3 - Your community resolves fisheries conflicts very quickly Five years ago_____ Today _____