A SYSTEM DYNAMICS APPROACH TO SUSTAINING FISHERIES RESOURCES AND ENHANCING BENEFITS FOR THE POOR: CASE STUDY OF TRAPEANG RUNG COMMUNE, CAMBODIA

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MASTER OF SCIENCE

PROGRAM IN NATURAL RESOURCES AND ENVIRONMENTAL MANAGEMENT

MAE FAH LUANG UNIVERSITY

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ABSTRACT

In recent years, fishermen in Trapeang Rung commune have noticed that their annual catch has been reduced by about one-half as compared to what they were able to achieve in earlier years. This decline has resulted from several different causes, including the emergence of additional households who depend on fishing for their livelihood, use of more-destructive fishing gear, and disturbance of a growing number of fishery-supporting habitats. In addition, a survey of fish-catch distribution reveals that the benefits from fishery resources accruing to poor fishing families are now much less than those being received by the non-poor. This is due mainly to the fact that the poor fishermen have much less ability to invest in ways to increase their capacity to conduct efficient fishing activities. This research addressed both of these policy issues -- how to sustain the area's total fishery stock, and how to allow poor fishermen to obtain more benefits from this resource. System dynamics modeling techniques have been used in this study to model interactions between fishermen and their shared fisheries resources. The objective was to project potential future fish production and identify and test potential management options to solve the dual problems of declining fisheries resources and providing greater benefits to poor fishermen. Extensive experiments with the system dynamics models explored the implications of various management options, including reducing the number of new fishermen entrants, restricting the fishing gear allowed to be used, establishing a community fish hatchery and nursing program, and establishing a local saving group. This research found that certain combination options offered the best way to deal simultaneously with the two key problem areas.

Keywords: system dynamics modeling / catch per capita / fisheries resources management options.

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
BCI	Biodiversity Conservation Corridors Initiative
CEP	Core Environment Program
CFi	Community Fisheries
CBNRM	Community Based Natural Resource Management
CFDO	Community Fisheries Development Office
CFDD	Community Fisheries Development Division
DoF	Department of Fisheries
EOC	Environment Operations Center
EPAs	Environmental Performance Assessments
FAO	Food and Agricultural Organization
FGD	Focus Group Discussions
FA	Forestry Administration
FiA	Fisheries Administration
GMS	Greater Mekong Sub-region
HHs	Households
ITQ	Individual Transferable Quota
Lao PDR	Lao People's Democratic Republic
NTFPs	Non Timber Forest Products
NPF	Non-poor Fishermen
NRs	Natural Resources
NZ	New Zealand
PFO	Provincial Fisheries Office
PF	Poor Fishermen

LIST OF ABBREVIATIONS (continued)

PRSPs	Poverty Reduction Strategy Papers
SD	System Dynamics
SEAs	Strategic Environmental Assessments
VSG	Village Support Group

CHAPTER 1

INTRODUCTION

This chapter includes various introductory sections: research background, problem statement, research questions and objectives, justification of research, scope and limitations, and expected outcomes.

1.1 Background of research

The Asian Development Bank (ADB) has facilitated the Greater Mekong Sub-region (GMS) Core Environment Program (CEP), which includes a Biodiversity Conservation Corridors Initiative (BCI). In Cambodia, two BCI sites were identified, one of which runs from the Cardamom and Elephant Mountains landscape down to the coast (Figure 1.1). Each BCI site has associated with it one or more remote target communes in which the incidence of poverty is sufficiently high that it needs to be reduced, potentially through achieving added value from locally-available natural resources or other relevant alternative livelihood options that can contribute to maintaining the area's rich biodiversity as well (Asian Development Bank, 2009).

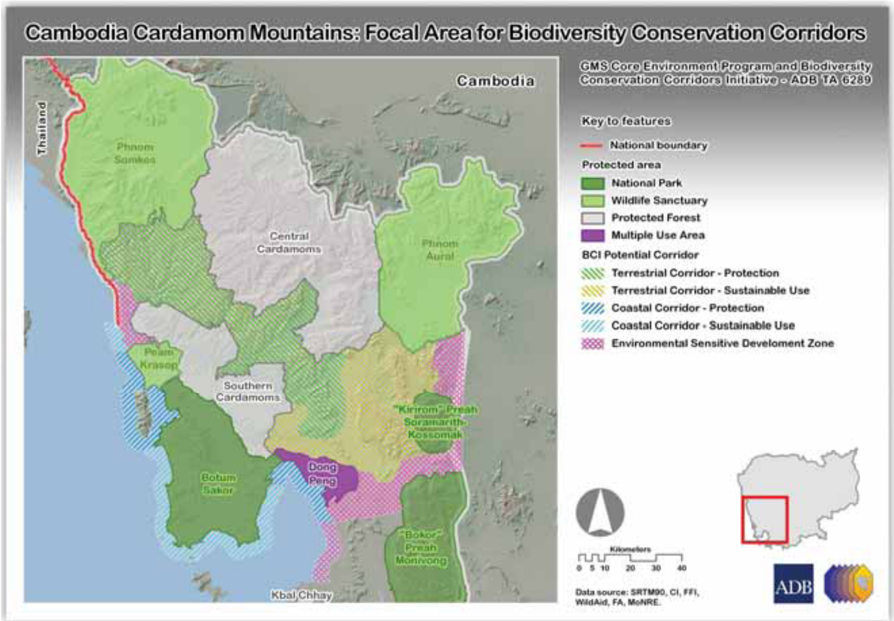

Figure 1. 1 Biodiversity Conservation Corridor (BCI) Focal Areas of Cambodia (Asian Devlopment Bank, 2007)

Mae Fah Luang University's (MFU) project on Capacity Building for Natural Resources Management and Socio-Economic Benchmarking in the GMS, initially funded by ADB, selected Trapeang Rung Commune, located in Koh Kong Province within the Coastal Cardamoms Protected Forest and Botum-Sakor National Park area[1], as its target area. Trapeang Rung covers an area of 90,653 hectares (ha). It consists of five villages with a total 2008 population of 2,023 people. Poverty incidence in the commune is very high, accounting for 94% of the entire population[2].

Typically, villagers in Trapeang Rung meet most of their livelihood needs through natural resources (NRs) utilization, which accounts for 60% of their income (the other 40%[3]comes from other activities not related to natural resources). Since 2002 the local forested area has been under the protection of the Wildlife Alliance (WA), a conservation organization. The WA has enforced rules and regulations on access to the forest and limits on taking forest

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[1] ADB-CEP RETA 6289, Cambodia, BCI Site Benchmarking Report, 2008

[2] ADB-CEP RETA 6289, Cambodia, BCI Site Benchmarking Report, 2008

[3] ADB-CEP RETA 6289, Cambodia, BCI Site Benchmarking Report, 2008

resources such as NTFPs. Their goal is to manage the forest ecosystem's goods and services sustainably.

Currently the majority of the local population relies heavily on fisheries as the main contributor to their livelihood. Besides supplying food, fisheries resources provide employment opportunity for a large group of mainly poor people. Fishing is often the most significant way for villagers in this area to earn some income and ensure their employment almost year round.

The Trapeang Rung Channel and its tributaries are the main water bodies and fishing areas in this commune. The channel leads to the Gulf of Thailand. It is filled with fresh water only during the rainy season, when runoff enters the waterway. During the dry season, sea water backflows into the channel, resulting in it becoming saline (salty) and thus unfit for either irrigation and water supply for domestic consumption. Since water is abundant year round, the channel provides a favorable habitat for various types of fish, both freshwater (snakehead fish, catfish, prawns, and others) and marine (especially mud crabs). Fishermen in this area target different fisheries resources according to the season. During the dry season most fishermen concentrate on mud crabs, while in the early of months of the rainy season they look for prawns and other freshwater fish.

In this area, while natural resources can be accessed relatively freely, in practical terms accessibility varies greatly among commune fishermen, whose available assets differ greatly. Access to fishing boats and fishing gear vary according to different wealth groups. Since they own only tiny assets, poor residents of the commune are unable to go fishing as much as can the non-poor. Some of the poor cannot afford a fishing boat (one rowboat costs about $50). Sometimes they have to rent a boat, paying its owner back in cash or in kind. While this may be a good option to share the commune's available tools among the villagers, during fishing peak times boat owners hesitate to lend their boat to the poor since they need to use it themselves. At such times the poor villagers cannot go fishing even though opportunities to catch fish are at a peak.

Because the fishing grounds are available for open access, everyone can potentially use fishery resources; they all do so as much as they can without facing any externally-imposed limits. No formal management system exists to assure optimal utilization of the area's fisheries resources. Throughout the world, such "common pool" resources lacking clear ownership have a tendency to witness resource depletion as indicated by Ostrom, Burger, Field, Norgaard, & Policansky (1999), especially in the long-term.

1.2 Problem statement

Fishermen in Trapeang Rung Commune in recent years have observed major declines in fish stock, similar to trends seen globally (Food and Agriculture Organization, 2005). They report that current catch rates have dropped by almost a half in comparison with those a few years earlier. This situation is widely reported in this locality. Fishermen in Trapeang Rung said that they were now catching fewer amounts of fish than before. Sometimes they catch not even 1 kg of fish per fishing trip (usually one night).

Facing this challenge, some local fishermen have tried to explore new fishing grounds and use new and more effective fishing techniques/gear. In discussions, fishermen pointed to two primary causes of these fishery declines: (i) a significant increase in the number of people who now depend on fishing for an important part of their livelihood; and (ii) the absence of fishery management at the fishing ground. Fishermen try to catch as many fishers as possible to maximize their income.

The growing dependence on fishing as the source of local livelihoods has been driven by many factors. These include the regulatory limits on access to NTFPs in protected forest areas, the growing need for cash in order to sustain basic family needs, and the limited employment opportunities in and around the community. Regarding the absence of fisheries management, over the years this common pool resource has been freely accessible by all users without considering the availability of fish stocks, the negative impact on non-target species of using certain fishing gear, and the lack of controls on the size of fish being caught. (A fisherman in Dei Tumniep Village, Trapeang Rung Commune, reported that some fish species were being caught at an immature size.)

As the availability of fish in the local channel decreases, reduction in fish catch is becoming the main challenge for everyone in Trapeang Rung, both for the poor group and the well-off group. However, the well-off group has much better ability to cope with this challenge through investment in better means to access fish at the good catch locations (using modern fishing gear and larger motorboats). In contrast, the poor group is restricted to fish. Generally, by employing this traditional fishing equipment, the poor get fewer amounts of fish. Moreover, with few alternative livelihood options the poor are least able to cope with diminishing sources of protein. Overall, the potential for fisheries to contribute to poverty reduction is becoming more limited in the absence of any effective intervention that both helps the poor gain better access to fisheries resources and sustains those resources for long-term utilization.

In summary, local fishermen encounter the following fisheries resources problems:

1. Declining resources (due to over-harvesting and the lack of a management scheme to help maintain and protect fisheries resources)

2. Limited access to the fisheries resources for poor fishermen (who thus get fewer fish to consume and sell to make income)

1.3 Research questions

After seeing the dual problems facing Trapeang Rung Commune in terms of fish stock declines as the result of over-harvesting and diminishing benefit to poor fishermen from fisheries resources, many questions are waiting for answers. To bring these complex and interrelated issues under a specific scope a set of focused questions have to be raised. This research study aims to find the answers to the following two main research questions

1. What would be the acceptable management options to maintain/increase fisheries resources available for long-term harvesting?

2. What would be the practical ways to help the poor get more benefits from fisheries resources?

The specific research questions focus on

1.3.1 Assessment (on stock, current catch, and effort devoted to fishing)

1.3.1.1 What are the main fish species currently being harvested by local people, along with rates of catch per capita by poor and well-off groups?

1.3.1.2 How much access to fishery resources do poor and well-off households currently have, and what means do they each have available to catch fish?

1.3.1.3 What are the ways to provide poor households with more effective catching means, and to increase their access to the fisheries?

1.3.2 Development of a System Dynamics (SD) model to capture the system in order to illustrate the base line behavior and predict the future of fisheries resources trend

Given different policy options, what trends are likely to be seen in terms of fish stock, fishermen populations, and catch per capita of poor and non-poor fishermen?

1.3.3 Exploration of the SD model to test various options and identify acceptable solutions

What appropriate community-based fisheries management options can address the dual problems of over-harvesting and improved access to fisheries by the poor?

1.4 Research objectives

1.4.1 General objective

To determine management options to sustain fisheries resources better and thus contribute to poverty reduction in the commune.

1.4.2 Specific objectives

1.4.2.1 To investigate the contribution of fisheries resources to overall income generation and to local diets (as a protein source)

1.4.2.2 To investigate current rates of catch per capita between poor and non-poor fishing households

1.4.2.3 To explore possible community-based fisheries resources management options to sustain fisheries resources in the commune (using SD modeling to select appropriate management options). These options would aim at helping the poor gain more benefit from fisheries resources through enhancement of their accessibility to these resources.

1.5 Justifications and benefits of research

The reasons for conducting this research are as follows:

1.5.1 Within the context of a biodiversity conservation corridor, diversification of alternative options for livelihood improvement of the poor has been emphasized. Management of local fisheries resources provides the opportunity to diversify employment in the commune since the resources are now being utilized but are not (at this time) receiving any attention in terms of management.

1.5.2 Since the fisheries stock has declined gradually with negative impact on the livelihoods of the poor, it is important to find options that can maintain and improve the fisheries as well as to provide better access to these resources by the poor.

Certain specific benefits can be obtained by this research:

1.5.3 Insight into appropriate management options for fisheries and poverty reduction through adapting system dynamics modeling, thereby illustrating the ways that this tool can potentially be used in other academic fields.

1.5.4 Integrated approach to policy development for both natural resources and human systems at the local level, providing techniques that can be used in other similar situations.

1.6 Scope and limitations of the research

1.6.1 Scope

The research was carried by fixing its boundary as the whole Trapeang Rung Channel (including its attributes) in the Trapeang Rung commune. In addition, the study focuses on the main current fisheries captured by local fishermen (for both consumption and commercial purpose). The current species that the fishermen catch are fish, crab and lobster. With this regard, the research considered only the species that are mostly caught, their availability and their economic value as well as nutrition value desired by the local fishermen (especially the poor). The research also tried to look at the biological aspect of fisheries in terms of the aging structure (young fish, maturing, and adult fish). In addition, the catch per fishermen of poor fishermen and non-poor fishermen was included in the model and some impacts of fishing gears/methods, inappropriate caught size, over-harvesting on the fisheries stock as well.

1.6.2 Limitations

Primary limitations on this research effort exist in the ever-present time constraints and the inadequacy of predicting the future correctly. The research looks at current fisheries population status, related management schemes, and the accessibility to key resources by different groups in the area. Uncertainty exists when trying to improve or develop comprehensive management options for fisheries and access of the poor to the resources.

A few limitations of the system dynamics modeling used in this study are important to consider before giving a more thorough discussion of its implications. First, the model was constrained by a limited understanding of the nature of the fisheries dynamics, especially its scientific underpinnings in terms of biomass. Hence, the research did not focus directly on fish population dynamics, but instead focused on growth from young to adult fish through applying available growth rate data. Similarly, the researcher explains a problem of intervening on challenges at the intersection of fishermen population and their resources utilization as well as fish population as it persists in a specific socio-geographic context. Some variables and feedback structures in the models are based on data collected from structured interviews, which reflect respondents' perceptions plus some actual data recorded. As a result, the system behavior identified might not represent actual behavior of particular fisheries resources. Finally, the precision that would come with quantitative modeling is not realized in our model. It is not certain to what extent the dynamics between variables are influencing one another. Hence, certain assumed non-linear relationships were proposed and included in the model. For instance, the study could not figure out the actual fish stock production and some of non-linear relationships were assumed from other relevant studies.

1.7 Expected outcomes

The expected outcomes from this research may be summarized as follows

1.7.1 An initial assessment of the fisheries resources currently available in the study area, and of users' interactions with these resources

1.7.2 A model developed to assess management options that could better sustain the fisheries resources and improve access of the poor to these resources

1.7.3 An identification of practical options that can be reviewed, studied and tested with a model such that recommendations emerge to improve access to fisheries resources and to use these resources more effectively to increase income and diversify livelihood options

1.7.4 A guideline and framework for more sustainable fisheries resource management (improved fish stocks and yields) that can be used practically at community level

Thesis outline

The complete thesis consists of five chapters. Chapter 1 is the introduction, giving the focus of the research, its aims, objectives, scope and limitations. Chapter 2 reviews relevant literature about fisheries management options of other countries; Cambodia's legal and institutional framework for fisheries management; and concepts of community-based natural resources management. It also covers lessons learned through in-depth analysis of the community fisheries management case study that existed in Cambodia and linkages between fisheries resources management and poverty reduction. The study's research design and methods are also described in Chapter 3. This chapter covers the study area justification, sample design, explanation of information-gathering techniques used, and overall research framework.

Research results and data analysis are presented in Chapter 4. This chapter sets out available information about the socio-economic characteristics of small-scale fishermen in Trapeang Rung commune. Variations in catch per unit effort among fishermen with different economic profiles provide critical information for subsequent analysis. This chapter reveals the significant scenarios to ensure better access of the poor under the various management approaches based on the case study and data analysis. Moreover this chapter draws out possible management options for fisheries management at the local level in order to enhance accessibility of the poor to these resources. Chapter 4 also covers the limitations and difficulties of fisheries management at the local level to ensure effectiveness of practice under the current management system.

The author's primary recommendations and conclusions are presented in Chapter 5. Recommendations mainly cover possible alternative approaches to meet the needs and requirements of local communities -- especially the poor -- to ensure their greater benefit. The conclusion section summarizes the overall findings of the research and what could be done as a further study on this particular issue to meet the challenges of sustainable resources management.

CHAPTER 2

LITERATURE REVIEW

In Chapter 2 we examine fisheries-related management options seen in other countries as well as within Cambodia, and review previous applications of system dynamics modeling to fisheries management as well as other natural resources management challenges.

2.1 Overview of management options

2.1.1 Fisheries management measures

Measures to manage fisheries resources can be categorized in different ways:

1. technology-based controls,
2. accessibility-based controls, and
3. input- and output-based controls (Food and Agricuture Organization, 2002).

Technology-based controls focus on fishing gear, area restrictions, and time restrictions.

Gear restrictions: These controls are used to manage both freshwater and marine fisheries resources. This type of measurement regulates the type, characteristics, and operation of fishing gear. Gear restriction measures are aimed to (i) reduce catch efficiency so that fishing capacity cannot be increased, (ii) mitigate negative impacts on non-commercial sizes, species or habitats of fish, and (iii) avoid introduction of a new technology that may increase significantly the existing distribution of exploitation rights (particularly when these involve new participants).

It is important to consider the impacts of gear restrictions on smaller fish (for example, juveniles) of the target species and on fish in by-catch species. For example, Article 20 of the Law on Fisheries of Cambodia (2006) prohibits using some specific fishing gear. This includes (in all areas) electrocuting devices, explosives, all kinds of poisons, pair trawler or encircling nets with attractive illuminated lamps to attract concentrations of fish, and (in inland fishing areas) nets or seines with mesh size of less than 1.5 centimeters and fishing gear made of mosquito nets (more detail written in the Cambodian Fisheries Law, 2006).

Area-based and time-based restrictions: These measures allow the fishermen to fish only at a particular time within the season or in a specific area. Area and time restrictions are based on conservation as a goal. It is crucial to understand the biology of the fisheries lifecycle in order to set up reasonable time and area restrictions. In some countries, the date for opening of the fishing season can be set based on the expected high economic value of certain commercial fish species. For example, opening of the season for the Bering Sea pollock fishery is delayed until late January when the pollock roe commands the highest market price (Food and Agricuture Organization, 2002).

In Cambodia, time and area restrictions are intended to leave enough time for fish breeding. In addition, time and area restrictions here do not apply to fishing operations below a certain size. The Law of Fisheries exempts family or subsistence scale fishing activities, while mid-sized and large-scale fishing operations have to comply with this regulation.

Access Limitations: This type of control takes users' property right types into consideration (see Food and Agricuture Organization, 2002). In the absence of such limits, everyone can exploit open access fishing grounds according to their own capacity and economic orientation. This may lead to over-fishing and thence to natural fish stock collapses. Hence, access needs to be limited in some way. Giving the right to access fisheries resources to particular users can be done by government through an auction process (or in other ways). As one example, Cambodia's Law of Fisheries uses auctions to allocate private sector entities' fishing access (this is called the "fishing lot" system).

Input (effort) controls: These controls use licenses or permits to restrict the number or size of fishing boats or nets in an area or the number of fishing days allowed. These restrictions are known as individual effort quotas (Food and Agricuture Organization, 2002). To work properly, this measure requires that the regulatory agency have sufficient reliable data for making decisions on the right size or amount of effort to be allowed. The fisheries officers have to be able to generate the data and capture the dynamic of the factors that influence data.

Output controls: These catch control measures are particularly designed for large-scale fisheries. This measure sets out a total allowable catch along with individual transferable quotas (ITQs). This does not require as much information as input control; however, regular assessment is needed in order to gain understanding on the impact of the change of technology improvement on the catch. On top of that, the fishery officers have to monitor often in order to enforce the law and avoid violations (Food and Agricuture Organization, 2002).

Experience from New Zealand Fisheries Management: This country has adopted various management regimes in order to address over-fishing in its fishing grounds. In 1983, NZ applied the limited individual transferable quota (ITQ) system, in which the total allowable catch specifically for seven species is divided with fishing rights issued for a 10-year period. In 1985, the government changed this management system to quotas in perpetuity. From 1996 until recently, NZ continued to us the ITQ system, which is known to be a successful measure in managing the fisheries resources in New Zealand's inshore fishing grounds.

The factors behind New Zealand's success were analyzed by Meister (2009). Under ITQ, the fishermen who had been hunting for fish in the open access fishif\ng grounds became "owners" of the fisheries resources, with shared responsibility to prevent possible fisheries decline. They were incorporated into the decision-making process for designFing the management options. Anton points out that while introduction of fisheries management encountered many challenges, some principles helped to assure achievement of the goals in New Zealand. These management principles include: (i) Total catch must be controlled, because sustainability can only be achieved if total fish take is controlled in accordance with the fishery's fluctuating sustainable yield. (ii) Access to the fishery should be controlled because catch control without access control leads to an inefficient situation with too much effort being applied to catch fish. (iii) Decision-making should be participatory (bottom-up), as without support from the stakeholders any scheme will fail. If stakeholders participate in making decisions and see that all interests are considered, they more likely to accept the outcome, even if it is not in their direct favor. (iv) Research and monitoring are essential. Without sufficient knowledge of the fisheries, management is like "flying by the seat of one's pants." (v) Development of a management system should take place in an integrated fashion considering all factors associated with or affected by the system.

Conclusion: All of the management measures noted above have been introduced in one or more countries around the world in their attempts to solve the problem of fisheries decline. Typically, mid-sized and large fishing regulatory bodies are involved. Moreover, some of these measures (input and output control) require a strong and workable institutional system to monitor and enforce the regulations. Such institutional capabilities are unlikely to exist in a developing country such as Cambodia. However, the lessons learned from fisheries management in New Zealand emphasize the importance of ownership and responsibility of fishermen toward the resources on which they depend for their livelihoods, combined with assistance from the government in terms of technical issues (introduction of ITQ). Clearly, community users' participation is critical to make a management scheme at the ground level achieve its goals.

2.1.2 Community based fisheries management of selected countries in the Gulf of Thailand

This section provides an overview of existing community-based fisheries management practices in the coastal areas of Malaysia, Thailand, and Vietnam, as documented by Nopparat & Charles (2009). Conclusions from each country's case study were depicted with the aim of enriching knowledge and understanding of diverse community-based fisheries resources management practices in order to apply the utmost community-based resource management (CBRM) approach in fisheries management to the particular community in Cambodia covered by this thesis research.

2.1.2.1 Malaysia

Malaysia established community-based fisheries management in its current ninth National Plan. The following information was drawn from one example of community-based fisheries management in Malaysia, with specific focus on community law enforcement. The lead government agency worked in partnership with the Southeast Asian Fisheries Development Center (SEAFDEC) to provide technical assistance to the Langkawi community to develop and carry out community-based regulations. The agency worked closely with community members and established a four-person Local Enforcement Unit: two regulatory agency officers plus two community volunteers. The team patrolled the demarcated area to investigate local fishing practices.

In order to implement law enforcement effectively, the officers tried to incorporate community religious practices and beliefs into the management scheme. For instance, according to the religious belief, fishing is prohibited on Fridays or when there is a death in the community. Any fisherman who breaks this rule will be punished with a fine of one dozen plates to be given to the mosque. A strong social network exists in this community, as local people help each other. This allowed the officers to initiate an effective surveillance and monitoring program.

The principal lessons from this case study of community-based fisheries management in Malaysia are associated with the cooperation between the fisheries officers and fisheries users in order to achieve fisheries management. A strong chance exists for this particular community to become self-governing with respect to fisheries management since it possesses the strong unity of social network and beliefs.

2.1.2.2 Vietnam

Vietnam has a long history of managing natural resources at the local level. Small-scale fishermen living in an area where traditional fishing rules are in place (Van Son Hai, near the city of Danang) have had experience with conflict resolution over natural resources. They have traditionally played a role in fisheries management on issues concerning residential proximity rights, primary rights, and the right to sell, transfer or lease and share these rights.

According to these rules and practices, the right to fish at the certain fishing ground will be allocated to a person. Once that person has set up his or her operations by locating his gear at a given fishing spot, others cannot fish in this area until the previous “owner” has dismantled the equipment. Fishermen in are permitted to loan or share their access rights. These rights are reallocated annually among other fishermen in their village. Usually the son inherits from his father the right to fish in the village’s marine territory. But if a family does not have any sons, then a daughter is allowed to inherit this right. Outsiders must wait for a minimum of 10 years before being granted fishing rights.

The fishermen formed the regulatory scheme and enforced the rules by themselves in this community. Community residents, supported by the local government authority, formed a Fisheries Protection Group to patrol and detect any use of illegal fishing gear. This group has been strong and stable in terms of enforcement of the regulation towards both local community members and outsiders. As the result, the number of fishermen using electric gear reportedly declined in the village.

This case study demonstrates how traditional practices of utilizing the natural resources can support sustainability in management of fisheries resources. Although the community has a strong history of cooperation and responsibility for their resources, significant government support is still necessary in order to strengthen this type of management system.

2.1.2.3 Community-based fisheries management practice in Thailand

Community-based fisheries management was established here in 1995, with the Thai Department of Fisheries (DOF) responsible for facilitating the process. Successful initiatives were implemented through local Tambon Administrative Organizations (TAO). These local government bodies play an important role as organizations operated with funds from both local taxes and provincial government agencies. These local organizations can respond to people's needs faster than can the central government; with TAO council agreement they can move budgets to new projects.

Nasuchon assessed the practices of two community-based fisheries management projects. The first case focused on a project in Bang Saphan Bay that was established to solve fishing conflicts between small-scale fishermen and an illegal fishing trawler operation. This community, which covers an area of 240 km^2 in the coastal waters of Gulf of Thailand, established nine fishermen's groups. They established regulations imposing a ban on trawlers and prohibiting use of specified fishing gear, such as push nets, cockle cast nets, and purse seines (apart from anchovy-surrounding nets operating during daylight hours). Some of the rules and regulations on the fishing grounds access area were derived from a legal framework issued by DOF. This community and its TAO are able to take strong action in public consultation in order to solve certain problems. Local residents also carry out such tasks as monitoring the fishing practices of the other community members in order to ensure their compliance with applicable rules and regulations.

In the second Thai case, the writer examined crab conservation efforts carried out cooperatively by a local community, DOF, and the Southeast Asia Fisheries Development Centre (SEAFDEC). DOF and SEAFDEC jointly established an integrated coastal fisheries management project in Pathew district (ICFM-PD). The aim is to address over-harvesting of the blue swimming crab. A protected area was created in 2002. In order to solve the problem of over-harvesting, the project and the community established a set of restrictions on allowable fishing gear (the mesh size of a crab trap).They also built a net cage in which to keep gravid crabs until they spawn. They established a Crab Bank Fishermen's Group of 15 members who were empowered to enforce compliance with community rules.

Based on these two case studies, in order to solve local fisheries problems fishermen have united themselves to establish a cooperation groups that have power to enforce the local regulations. However, the support from local government administrative agencies has played a very significant role in producing the good results in these two communities. Meanwhile, support from other non-government organizations in terms of technical aspects was also very important to facilitate the community process.

2.1.3 Fisheries management practices in Cambodia

This section summarizes existing legislation and other institutional frameworks relevant to fisheries management in Cambodia and presents their evolution. This information helps one understand the existing fisheries management system, especially its emphasis on the community management efforts that are currently being promoted throughout the country.

The Fisheries Law enacted in 2006 is the main legal instrument for fisheries management, development and conservation of fisheries resources in Cambodia. This law sets out different categories that define the fisheries management system being used in the country.

CATEGORY OF FISHERIES SYSTEM IN CAMBODIA

In Cambodia, fishing activities are classified into two main categories for inland and marine fisheries, respectively. The classifications are defined based on fishery law and specific proclamations. For instance, inland fisheries are classified into large-, middle-, and small-scale fishing, according to types of fishing gear and the difference in fishing ground.

In large-scale fishing, large fishing gear such as set nets and weirs are used in the licensed fishing area called a 'Fishing Lot'. Lot owners who conduct fishing in a Fishing Lot zone purchase exclusive fishing rights every two years from the government (Fisheries Administration - FiA). In middle-scale fishing, gill nets, round nets and seine nets are operated in open access fishing areas. In small-scale fishing, spears, hooks with lines, and traps are usually used in rice fields, small lakes, and rivers near villages.

Small-scale fishing can be conducted inside the Fishing Lot during the closed season (1 June to 30 September north of Chaktomuk, and 1 July to 31 October south of that point). Large- and middle-scale fishing is conducted for commercial purposes, and small-scale fishing is recognized as a subsistence activity.

Marine fisheries are classified into middle-scale fisheries and small-scale or artisanal fisheries. Within this classification, the middle-scale fisheries employ relatively efficient fishing gear that has the capacity to fish offshore and the participants in these fisheries are required to pay a fishing tax to the government. On the other hand, the small-scale or artisanal fisheries use traditional gear or gear of relatively low efficiency and non-motorized or motorized boats of less than five horsepower. Those who fish at this scale are not required to pay a fishing tax (Adapted from Nam et al., 2005).

The government has also created fish sanctuaries intended to provide refuges from intensive fishing mortality for fish breeding stock during the dry season and thereby improve replenishment of the fish stocks during the breeding season. The serious decline in some fish stocks and the threatened status of some fish species makes protection of breeding stock a high priority. In this regard, in 2008, the Fisheries Administration also established legal instruments that cover ways to define and establish a fish conservation area within a defined community fisheries area. This is an important element in the community fishing area management plan.

2.1.4 Legal requirements and legislation related to fisheries resources management in Cambodia

Cambodia's oldest law on Fisheries Management and Administration was enacted in 1987. This Law provided the legal framework for use and management of fishery resources. However, following revision of national fisheries policy in 2000/01, a new series of legal instruments has been developed and management structures have been revised. The Fisheries Administration issued a series of sub-decrees to formalize release of fishing lots via auctions. In addition, in May 2005 a Royal Decree on establishment of CFi was proclaimed; and in the following month the Sub-Decree on Community Fisheries Management was approved by the

Prime Minister. In March 2006, this Sub-Decree was given more solid legal standing when the National Assembly approved the new Fisheries Law, promulgated by the King on 21 May 2006. Several articles in the new law recognize the significant role of local people and local authorities in managing fisheries resources.

2.1.5 Community-Based Natural Resources Management (CBNRM) Concept and Practice in Cambodia

Fishery policy reform in 2000 extended to small-scale fishers the ability to fish in open access areas. However, the larger number of people engaged in fishing activities placed increasing pressure on fisheries resources (Nam & Roitana, 2005). Consequently, in 2001, the Department of Fisheries (DoF) formed a new Community Fisheries Development Office (CFDO) to deal with this issue; CFDO later became the Community Fisheries Development Division (CFDD). This new unit was designed to assist the fisheries community implement community-based fisheries management.

The trend to expand the role of local people in development through decentralization formally began in February 2002 when Cambodia first elected decentralized government bodies, the commune councils (PACT, 2004). However, in 2001, 165 formulated Community Fisheries already existed throughout the country (Department of Fisheries, 2006). In this sense, awareness of the need to empower local people to manage their own natural resources is not a new issue in Cambodia. However, in reality most community development tended to treat the community as a beneficiary group, reducing the extent to which power really has been empowered to localities (Noy, Oeur, Sochanny & McAndrew, 2009). Transfer of power was primarily designed to match a political agenda, helping establish a legitimate profile for the state at local levels through democratic election of local councils. Commune councilors are empowered to represent the interests of their citizens through legislative and executive authority written in the law on commune administration enacted in 2001. In spite of its political focus, many of these councils developed commune development plans that encompassed natural resources and environmental management besides such broad aspects as economy, social, administration, security and gender.

In Cambodia, community-based fisheries (CFi) are one of several natural resources management strategies based on the concept of community-based natural resources management

(CBNRM) (Toby, Kalyan & Marona, 2005). CBNRM efforts in Cambodia have emphasized conservation, poverty reduction, and improvement of rural livelihoods through empowerment of the local people. Community fisheries' goals have reflected this approach, allowing groups of local people to manage, conserve, develop and utilize their fisheries resources in a sustainable manner as mentioned by Gun (2002) and cited by Toby et al. (2005).

2.1.5.1 Lessons Learned from Community Fisheries in Cambodia -- Case study of Bak Amraek-Doun Ent Community Fishery

This brief case study was chosen to include in the literature review part of this thesis because of way its local authority applied powerful management options so that its residents could successfully sustain local fisheries resources in response to a decline in fish resources. The villagers together with their local authority and the Provincial Fishery Officer (PFO) formed a community fisheries management system to stop illegal activities and thereby sustain and manage their fisheries resources. An effective management plan helped the community strengthen its resources management capacity. On top of that, the community realized the importance of implementing a comprehensive enrichment program to generate more fish in their community fishing grounds.

2.1.5.2 Reflections on use of CBNRM in Cambodia

This section will give an idea of the fisheries management system that is currently being promoted throughout the country, with an emphasis on community fisheries management.

1. A few CFi systems provide for regeneration to sustain fish stock in recognition of the lack of technical support on how to do nursing in the sustainable way. However, some CFi approaches apply a protected zone method to reserve the breeding zone in order to supply enough stock for the fishing ground.

2. Job alternatives besides fishing are usually seen as the best option that has been introduced to reduce dependency on fisheries resources and improve fishermen's livelihoods.

3. Generally, a variety of small loan schemes have been implemented through self-help groups or women's group with the specific goal of assisting in job diversification or lessening reliance on fishing. However, there are no specific measures to provide special treatment for the poorer group of the fishermen.

2.1.6 Accessibility to fisheries resources

Fisheries management often involves controlling access to the resource and limiting the fishing effort in order to reduce pressure on available resources. Limits control exploitation in two ways: (i) regulating the permeability of the resource area's boundaries through such controls as boat registration, licensing, and seasonal and area closures; and (ii) regulating gear types and specifications. However, Fiona (2006) suggested that while there is a legitimate concern for fisheries' sustainability, the need also exists to improve access to the resource by more marginalized members of society (the poor group) who now lack such access, and to ensure security of access to those in this group who already have access. According to this author, such steps will lead to improved natural resources management since improving access to, and benefits from, natural resources is a key to reducing poverty.

However, the Cambodian fishery policy reform can teach us some important lessons about ways to pursue this goal successfully. The country reduced the total fishery concession area (fishing lots) by more than half (about 56%), with these areas being transferred to local communities that were expected to regulate access to fisheries resources therein (Evans, 2002). Somony (2002) claimed that the immediate impacts of this policy reform were to increase villagers' access to fishing areas and decrease their costs to obtain fish. However, these benefits were enjoyed mainly by medium-scale fishers. In contrast, the poorer fishers or those using small-scale gear do not appear to have benefited as much from the fisheries reform. Kurien et al. (2006) later wrote that since the fisheries resources are state property, leasing access rights to lot owners with clearly defined demarcating community fishery boundaries in coastal areas can bring about significant change for all (national economy and local livelihoods).

Sultana & Thompson (2007) stated that community-based fisheries management systems are expected to achieve many desired results; these include greater security of access to fisheries and cooperation, leading to enhanced sustainability of the resources, more equitable distribution of benefits, improved conflict resolution among fishers, enhancement of fishers' status in relation to other stakeholders, sharing of information between co-managers, and higher levels of voluntary compliance. However, Parvin et al. observed that non-governmental organizations (NGOs) have a vital role to play if these management innovations are really to succeed. Actions are required to strengthen and mobilize the local people as they gather together as well as to create support systems (such as making credit available at lower interest rates than informal sources) and provide training in skills needed to take up additional income generating activities. Moreover, their study indicated that significant improvements can be made in fishery management, access, benefits and regulation compliance at the community level as the result of using community-based institutions. The role of supporting agencies to facilitate community-based management by local people is significant as pointed out by Fiona (2006). Local groups must have access to adequate funds and skills if they are to implement the rules they create; ideally, these funds should be raised locally.

2.1.7 Linkages between local fisheries management and poverty reduction

In a Uganda case, poverty in the fishery sector was proposed to be solved through empowering local people to govern the fisheries by themselves (Fiona, 2006). The poor fishermen have been recognized in terms of their limited access to and control over resources. The Uganda government realized that improving access can be promoted by fisheries co-management through participatory, poverty-focused licensing procedures, opening up access for women and boat crew members. As a part of the co-management, the government delegated power to issue boat licenses to local governments. While women and boat crew members were the main targets, due to their lack of access to credit to buy a boat and equipment and lack of understanding and awareness of the new procedures and opportunities, only some of them could actually obtain a license.

Béné (2003) termed fishermen ‘‘the poorest of the poor.’’ Focusing on fisheries as a commodity to which all have open access, Béné pointed out the conclusion that “the open-access nature of the fisheries allows more and more people to enter the fishing sector, which leads to the economic (and possibly biological) overexploitation of the resources, thus the Malthusian dimension of poverty, dilapidation of the economic rent, and finally impoverishment of the fishing community.” This quote has been emphasized more by Kurien (1993) who wrote about the overexploitation of common resources by outsiders using modern trawlers to catch fish off the coast in Kerala (South India), leading to overexploitation of the local stocks that negatively affected the livelihoods of local population -- both their incomes and their food supply. Clearly, overexploitation of natural fisheries is the major cause of dissipation of the livelihoods of many fisheries-dependent households.

Other than overexploitation of fisheries that induces poverty, the economic capacity to employ the fishing activities is one of the constraints that limit the access to profitable location faced by the poor (Béné, 2003). A study by Kremer (1994) in Bangladesh, examined the economic exclusion encountered by the poor. He observed that the poorest households do not have access to fishing during the driest season when the entry premiums, which mirror the expected yields, are at their highest values. He also pointed out that the equipment that can generate a higher surplus (e.g., brush pile and pump embankment) require the most capital (including bribes and tolls); such equipment is usually available only to well-off households. There is consequently a tendency for poorer households to be excluded from more profitable areas in which specific fishing techniques or gears (that the poor could not afford) are required.

With respect to access limitations faced by the poor households, Kremer (1994) cited by Béné (2003) conducted a comparative study of households' access to water bodies in several villages along the western shore of Lake Chad (Nigeria). This study showed that while the richest and medium strata of the population have access to the same types of water bodies, the poorest households only have access to a marginal part of the water bodies exploited by the community. These differences in access indicated that the constraints faced by the poor can be known as ''direct'' (financial) and ''indirect'' (technical). The direct restrictions result from the various legal and/or illegal taxes that are imposed for access to the water bodies, while indirect (or technical) restrictions of access resulting from their lack of adequate fishing equipment and boats necessary to fish in particular water bodies (such as the open waters of the lake).

Regarding this problem, in the same article, Béné wrote that improved access to finances and credit is the central element to poverty alleviation in the fisheries he was studying. However, he figured out that even this does not ensure access to the fisheries by the poor. Other socio-institutional aspects such as socio-marginalization, class exploitation and political disempowerment need to be addressed.

The key lay in empowerment of local people for access to and control over their local fisheries. In this regard, Béné observed that socio-marginalization may impoverish the poor through their ethic status and/or gender. Class exploitation referred to individual patron–client relationships through which the poor work extensively to serve higher class individuals (the "big man"). Moreover, this class exploitation happened at national level where the water body had been leased to the care of a private party. This action prevents the poor from having access to the resources since the fishery location is exclusively controlled by the private individual who has full power to set the rules to protect the location. Due to political disempowerment the voice and concerns of the poor have not been heard in political discussions.

These socio-institutional constraints suggest a solution that can be tackled. Specifically, in the past national authorities allocated particular parts of water bodies to be controlled by powerful individuals from outside the area. The local people lived with poverty and tension. If the "big man" were instead the community itself (specifically the poor fishermen group) this may help them improve both access to and control over the fisheries resources and their livelihoods as well.

2.1.8 Poverty reduction in relation to the fishery sector

Thorpe, Ried, Anrooy, Brugere, & Becker (2005) examined 50 national Poverty Reduction Strategy Papers (PRSPs) across Asian and African countries in order to assess whether the fisheries sector has been included. They observed that incorporation of the fishery sector in these PRSPs varied among those nations. For instance, some countries' PRSPs acknowledged fisheries-related issues, elaborated the linkage between fisheries and poverty, set up a responding program to solve the fisheries decline, and indicated the extent to which stakeholders participated toward the management process. Other PRSPs did not have such information. Andy et al. also showed that only about 36 PRSPs mentioned a program to respond to fisheries declines. However, he pointed out that most emphasis was placed on the macro (or national) level. However, these mentioned activities have not given any hint in terms of their impacts on poverty reduction at the commune level (the micro level).

The Greater Mekong Sub-region (GMS) countries, specifically Cambodia, Lao PDR and Vietnam, who are each struggling with attempts to reduce poverty in their country, have included the fishery sector in their PRSPs since this sector plays an important role in the GDP and livelihoods of local people. Details from an IMF document are presented in Table 2.1.

Table 2.1 Programs toRespond to Fishery Declines in Three GMS Countries' National PRSPs (2004- 2006)

Responding program mentioned in the PRSPs	Countries
- Enable and strengthen community-based development of fisheries sector by empowering local communities - Improve livelihood of poor people by enhancing their capacity to more effectively use fish (post-harvesting improvement/ value addition) - Transform fishing lots whose concession contracts have expired into fish sanctuaries, thereby increasing natural fish stocks and conserving endangered species. - Protect freshwater fisheries by sustaining the bodies of water, in terms of both quality and quantity, on which they depend.	Cambodia
- Encourage and promote private sector aquaculture to respond to the needs for fish, at the same time decreasing pressure on natural fisheries - Protect access to those critical resources to which the poor already have access (e.g. entitlements to land, water, trees, pastures and fishing grounds); - Promote fish production - The production of aquatic animals of high commercial value should be increased, especially fish raising in the Mekong and its tributaries. - Promote (improve and expand) the fish processing industry to increase the value-added in this sector.	Lao PDR
- In 2005, ensure that the area for aquaculture production is about 1.2 million hectares, with total production volume of approximately 2.6 million tons, of which shrimp production amounts to about 300,000 tons. - Ensure the sustainability of the growth of aquaculture production. - Improve the access of poor fishery households to production inputs, information, extension services, credit and markets.	Vietnam

Source. IMF, 2004; 2006; 2008

According to the activities noted in these three countries' PRSPs, the fishery sector can best contribute to poverty reduction through local empowerment, promoting accessibility (credits, fish area extension, information) and value addition/marketing.

In 2001, Daniels studied poverty alleviation in the subsistence fisheries sector in South Africa, focused on a micro-econometric analysis. He used the Foster Greer and Thorbecke (FGT) (1984) index, a static poverty measure that allows us to identify the required public expenditure necessary to lift a population of individuals out of poverty. He found that poverty can be entirely eradicated (relative to a R1000 per month poverty line) by allocating to these poor communities access rights to fish for higher market value species or to add value in wholesale of known subsistence fisheries (lower market value fish species). Though this study focused specifically on the role of fisheries in poverty reduction for local households, the work gives little precise information on ways to promote poor households' access to higher market value fish species or participate more fully in wholesale valued-addition processes.

2.1.9 Summary of fisheries management measures

Table 2.2 below summarizes the fisheries management measures that have been implemented in other areas in the world as well as in Cambodia. The measures and their description were taken from the literature presented in this section.

Table 2.2 Summary of Fisheries Management Options

Management Measure		Short Description		Ways to Add to System dynamics Model
Gear restrictions	-	Ban use of some fishing equipment	-	Quantifying measurements into the model.
Area and time-based restrictions				
Closed fishing season	-	Closing access to fishing during certain periods of the year	-	Add more details to accommodate in the simulation.
Marine Protected Areas	-	According to IUCN (1999), an MPA can be defined as "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or the entire enclosed environment".	-	Interpret this approach into additional regeneration of the resources (e.g. nursing) aimed at accelerating the process of recovery of the resources.
Access Limitations	-	Issue a license to a particular group or individual to operate exclusively in the fishing grounds	-	Devise a more detailed model in order to accommodate the simulation.

Table 2.2 (continued)

Management Measure	Short Description	Ways to Add to System dynamics Model
Input (effort) controls	- Restrictions on the number of fishing units and amount of fishing days through issuance of licenses or permits stipulating such unit efforts - Limiting number of new entrants into fishing	- Interpret each measure into the simpler form to Apply two variables to simulation in the model: (1) Reducing fishing effort unit will decrease the normal catch per trip or person; (2) Limit new entrants to fishing will decrease fractional new entry rate of fishermen.
Output controls	- Catch control measures (limits on total catch) -- also known as Individual Transferable Quotas (ITQs)	- Add sufficient data in order to set the quota and monitor performance, and design the SDM in more detail.

Table 2.2 (continued)

Management Measure	Short Description	Ways to Add to System dynamics Model
Sustainable alternative livelihoods	- Alternative and supplemental livelihoods allow certain fishers to exit from the occupation. Supplemental livelihoods may be related to the fisheries sector or rest outside it; alternative livelihoods reflect a non-fishing livelihood, such that the individual would no longer derive the majority of his/her income from capture of fish. The livelihood options require potential skills or knowledge by local people. For instance, most supplemental livelihoods are related to agriculture (livestock raising or wage laborer) plus some construction work.	- Translate this option into a form that can be simulated in the model. For instance, providing alternative jobs besides fishing can reduce the number of existing fishermen as well as the number of new entrants.

2.2 System dynamics approach

2.2.1 Definition of system dynamics

System dynamics is a tool to understanding the behaviour of complex systems over time. It deals with internal feedback loops and time delays that affect the behaviour of the entire system. Various definitions exist for system dynamics (SD), which can be viewed from different perspectives. For instance, from the engineering viewpoint SD is defined as a combination of two words: systems and dynamics. A system refers to a grouping of parts that operate together for a common purpose (Forrester, 1990). Andrew (1999) defined "dynamics" to refer to fundamental patterns such as growth, decay and oscillation. This definition was considered to apply in environmental modeling. Coyle (1977) wrote: "System dynamics is a method of analyzing problems in which time is an important factor, and which involve the study of how a system can be defended against, or made to benefit from the shocks which fall upon it from the outside world." This indicates that the process is concerned with creating a model or representation of real world systems of all kinds, then using the model to study the systems actions under varying circumstances (and assumptions).

2.2.2 Causal Loop Diagrams

A causal loop diagram is a visual representation of the feedback loops in a system. Causal loop diagrams are an important tool to represent a system's feedback structure. Causal loop diagrams are excellent for:

2.2.2.1 Quickly capturing hypotheses about the causes of dynamics;

2.2.2.2 Eliciting and capturing the mental models of individuals or teams;

2.2.2.3 Communicating the important feedbacks one believes are responsible for a problem.

A causal loop diagram consists of variables connected by arrows denoting the causal influences among the variables.

2.2.3 Diagramming Notation for Stocks and Flows

A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change in a stock.

System dynamics uses particular diagramming notations for stocks and flows.

2.2.3.1 Stocks are represented by rectangles (suggesting a container holding the contents of the stock).

2.2.3.2 Inflows are represented by pipes (arrow) pointing into (adding to) the stock. Outflows are represented by pipes pointing out of (subtracting from) the stock.

2.2.3.3 Valves control the flows.

Clouds represent the sources and sinks for the flows. A source represents the stock from which a flow originating outside the boundary of the model arises. Sinks represent the stocks into which a flow leaving the model boundary drains. In a model (though not in the real world) sources and sinks are assumed to have infinite capacity and can never constrain the flows that they support.

2.2.4 System dynamics in fisheries management

Many existing models have been developed to simulate fisheries and construct general management frameworks to address important fishery issues. These models apply mathematics, statistics, and computer simulations and are based on original formulations and use system dynamics modeling (SDM) techniques. Original formulations require sufficient data to conduct the model. Often, in order to run a mathematical model, complete equations are developed; the result of the simulation reflects that particular set of inputs.

This study emphasized SDM in which systems were constructed by visualizing each model component separately to define an overall structure linking components that are able to capture expected changes over time. The design generates the relevant dynamics endogenously, allowing a data-less approach in which the model structure can be modified to examine increasingly dynamic and complex situations. Sushil (1993) argues that it is worthwhile to apply SDM techniques to unearth the feedback structure in situations in which data is not available to use strict quantitative analytical modeling based upon open loop systems.

The Schaefer biomass dynamic model and its modifications have been recognized as a fundamental simulation model for use in fisheries management cases; it can easily be put into a system dynamics format (Dudley, 2008). Schaefer (1954) developed the classic dynamic (differential equation) model for fish biomass as a function of pristine (unfished) biomass, intrinsic rates of increase, fishing effectiveness, and fishing effort. A general fishery model using system dynamics was used as a tool to study fishery management policy by Dudley and Soderquist (1999). Andrew (1999) created a fish harvesting model ("Tucannon") through application of SDM. Van den Belt et al. (1988) developed the "Patagonia Coastal Zone Management Model" in which an elaborate simulator using system dynamics takes into account the interplay between ecosystems and economic systems. Somewhat later, another detailed cohort-based simulator for exploring fish harvesting policies was devised by Sampson (2001). A high-level model produced by Dudley (2003) adds additional feedback loops to the Schaefer biomass dynamic model.

SDM has been recognized as the primary tool to display all the causes and effects of a particular problem through feedback dynamics. For instance, laboratory experiments with policy decision makers in a renewable resource context (setting reindeer quotas to avoid overgrazing) revealed that simplistic mental models prevented subjects from making the appropriate decisions, even though they had sufficient information to correct their flawed mental models (Moxnes, 1998, 2001, and 2004). Here the focus was on the role of simple versus complex fishery models in the context of policy sensitivity analysis. While policies proved relatively insensitive to the complexity of the underlying biological situation, they were highly sensitive to assumptions about non-linear economic relationships that are in fact highly uncertain (Moxnes, 2005).

2.2.5 System dynamics modeling specifically related to fisheries resources management

As shown, system dynamics modeling to analyze environmental resources and commodities is not something new; indeed, a number of studies have been conducted to understand and improve decision-making efficiency for utilization of natural resources. Andrew (1999) documented some examples related to application of modeling in complex natural resources systems such as the salmon smolts' spring migration, life cycle of salmon born in the Tucannon River in eastern Washington, and the study of deer herds on the Kaibab Plateau in northern Arizona. These studies aimed to provide insight via adoption of system dynamics into environmental management approaches in order to tackle the problems' critical root causes as well forecast problems emerging in the future.

In 2004, Bead, J. and B. Sara jointly produced a system that modeled the interactions among Colombian indigenous communities and their ecosystem. Their objective was to predict the stability of regulatory enforcement, identify potential failure modes, and guide investment of scarce resources into community fisheries resources management. Their modeling goal was to improve the probability of actually achieving fair, sustainable and community-managed subsistence fishing in the region. Their model focused on common-pool resource non-cooperative games using self-organizing commons management principles that allow agents to affect the existence of game rules as well as choosing weather to act within the bounds of those rules. From their field work results, they also pointed out that their model covered the whole range of species commonly caught by the fishermen. They were able to incorporate the biomass of catchable fish into the model rather than model the underlying fish population. Even though they were able to produce only preliminary results from their model, they claimed that their model represented the real fisheries management system in the Colombian community.

Some points can be derived from the Bead, J. and B. Sara (2004) case study in order to develop a model to replicate real world problems. For instance, they constructed their model with available data obtained from the field, producing commensurate results. Their model seemed to be a step forward towards solving core fisheries problems, since community fisheries management existed already in the area studied, unlike some areas where the villagers still do not know which management option should be adopted to recover or sustain their fisheries resources.

Two other case studies illustrate the diversity of system dynamics applications to fisheries resources management around the world. In the first such case, a system dynamics model was applied to management of fisheries resources (particularly sardine populations) in the Eastern Adriatic. Here, system dynamics was used to link the interactions in a complex fishery system. Sliskovic, Munitic, & Jelic-Mrcelic (2008) used Schaefer production models to apply the system dynamics approach to fisheries management, claiming that their model can be used in the face of insufficient biological data. In this study, Sliskovic, Munitic, & Jelic-Mrcelic took fishing effort as testable parameter in order to find the optimal catch rate under sustainable utilization of the sardine population. Their results indicated that fishing effort can be defined in terms of fishing days. They found that under the sustainable sardine catching goal, utilization falls between 4,115 and 5,292 effective fishing days per year. At this fishing level the sardine population is running under its equilibrium state and its population behavior is far below its carrying capacity.

Regarding this study, the writer appreciated the system dynamics modeling effort for its flexibility and testability in order to generate recommended fishery management options without endangering real populations. In sum, the case study confirms the usefulness of system dynamics modeling in fisheries management. However, the study did not point out how to come up with a definition of effective fishing days nor what should be each fisher's level of fishing per year in order to understand the allocation of resources among user groups.

The second case involves use of a model to manage the gooseneck barnacle (Pollicipes pollicipes) in the Gaztelugatxe Marine Reserve in northern Spain. In this study, Juan et al. (2005)

used system dynamics modeling as the tool to construct population dynamics of the gooseneck barnacle and assess the management decision to maintain a moratorium (a spawning pool of larvae) while allowing commercial exploitation of the gooseneck. Their model was able to simulate stocks (juveniles, non-exploited adults and exploited adults), capture rates, duration, and location in order to decide which types can be caught in what amounts. Simulating eight approaches in order to identify the best management decision for conservation, they concluded that the gooseneck barnacle can be conserved through maintaining a fishing moratorium alternated annually between two different locations.

In conclusion, this case study - which includes simulation of population dynamics - provides insight into growth behaviors as well as the biological limitations of fisheries at different growth stages. It is important to understand this dynamic since in practice fishers may use all kinds of different equipment to catch the fish without being concerned about the impact on the internal dynamics of potentially exploiting the overall stock. However, this study did not include the population of fishers into the system. In other words, they did not mention what would happen to the resources if fishers increased their fishing capacity by employing better fishing efforts.

2.3 Understandings and gaps

Review of the above articles revealed the close link between fisheries declines and poverty. Moreover, some papers claimed that local fisheries management approaches can improve accessibility of the poor to fisheries resources (especially to some high market-value fish species). However, it is still an open question when it comes to how to help the poor have access to the resources effectively, since there is no homogeneous economic condition within the community. As in Uganda’s case, Cambodia’s central government transferred the right to issue fish catch licenses to local governments in order to favor the poor group. However, since that group has insufficient financial capital to buy the appropriate fishing inputs needed, they still cannot effectively gain access to the fisheries.

Some case studies of fisheries management already conducted at community level have highlighted the management options intended to be carried out by the full complement of local villagers (fishers). However, none to date have taken into account the real economic situation of different categories of fishers (that is, poor fishers vs non-poor fishers). The absence of any awareness of incorporating into these conceptual models the economic profile of those fishers who are supposed to enforce the regulations in order to sustain the fisheries resources may discourage some groups of fishers from participating actively in effective community management processes. If some groups (especially poor fishers) feel excluded from joining the community and remain isolated from the decision-making process, this might exclude them from ownership of the fisheries resources and make them feel that problems of sustainable fisheries resources are not their problems.

CHAPTER 3

RESEARCH METHODOLOGIES

This chapter presents information on the study site and on the two main research methodologies used in this thesis, summarizing data collection tools and techniques used and system dynamics modeling approaches applied. In addition, information is given on fishing households.

3.1 Study site

The research focuses on a case study of Trapeang Rung commune, situated in Koh Kong district, Koh Kong province in western Cambodia. This commune is one of the pilot sites of the Asian Development Bank's (ADB) Biodiversity Conservation Corridor Initiative (BCI). The Cardamom mountain range has been identified by a group of experts from the Cambodian Ministry of Environment as one of the important BCI landscapes requiring priority conservation efforts to counteract regional economic development pressures. Its landscape is dominated by forest cover; extensive water supplies are present. The area produces several important commercial non-timber forest products (NTFPs) and fisheries used for both subsistence and income generation (Asian Development Bank, 2008).

Trapeang Rung commune, covering an area of 90,653 ha, consists of five villages: Dei Tumniep, Koh Kong Knong, Prak Angkoinh, Trapeang Rung, and Veal Taphou, However, Trapeang Rung village was excluded from the study because only a small proportion of its households are involved in fishing. This is because the village is situated along National road 48, allowing the villagers to sell their agricultural products easily. Some residents are food vendors, while others depend more on collection of NTFPs such as rattan for income generation than on fishing.

The commune's major water feature, the Areng catchment, also locally called the Trapeang Rung Channel, serves as the watershed providing water for much of the commune area. This channel is an important local fishing ground.

In general, villagers fish throughout the year, with seasonal changes in their target species. The channel hosts a range of fisheries resources including crab and lobster as well as fin fish. These different marine resources are caught seasonally. Crab harvesting season runs from February until May; the rainy season is the time to harvest lobster and fish. Besides the Trapeang Rung Channel, villagers fish in several local ponds that contain water year round. These ponds, however, are not as good a habitat for production of fish stocks as is the main channel.

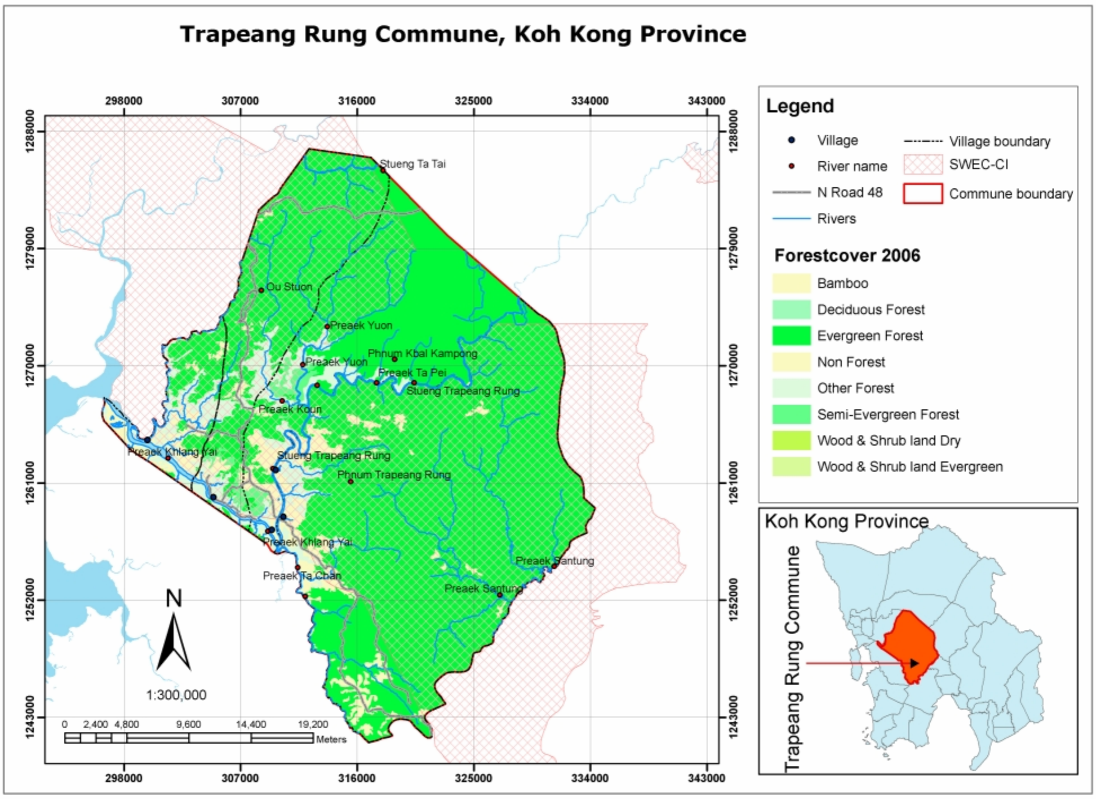

Figure 3.1 Research Location -- Trapeang Rung commune, Koh Kong province, Cambodia (GIS from the Ministry of Rural Development, 2008)

3.1.1 Hydrology

All 5 villages of Trapeang Rung commune lie along the banks of the Trapeang Rung Channel, which has a total surface area of over 10 million square meters (GIS from the Ministry of Rural Development, 2008). While this channel leads to the sea, ironically it is only filled with fresh water during the rainy season, reflecting the large volume of rainwater run off. During the dry season, sea water back flows into the channel, resulting in its becoming salty and thus unfit for irrigation of nearby fields. The high content of brackish water in the channel during the dry months also affects the groundwater in wells near the channel, making them unfit for human consumption. During the rainy season, several fresh water channels in addition to the main Trapeang Rung Channel flow through the area (see Figure 3.2). This area's rather unique hydrological features greatly influence the biology and ecology of fish here. Hence knowledge about its features and characteristics is essential to the study of species behavior of the local fisheries and related livelihoods of local villagers.

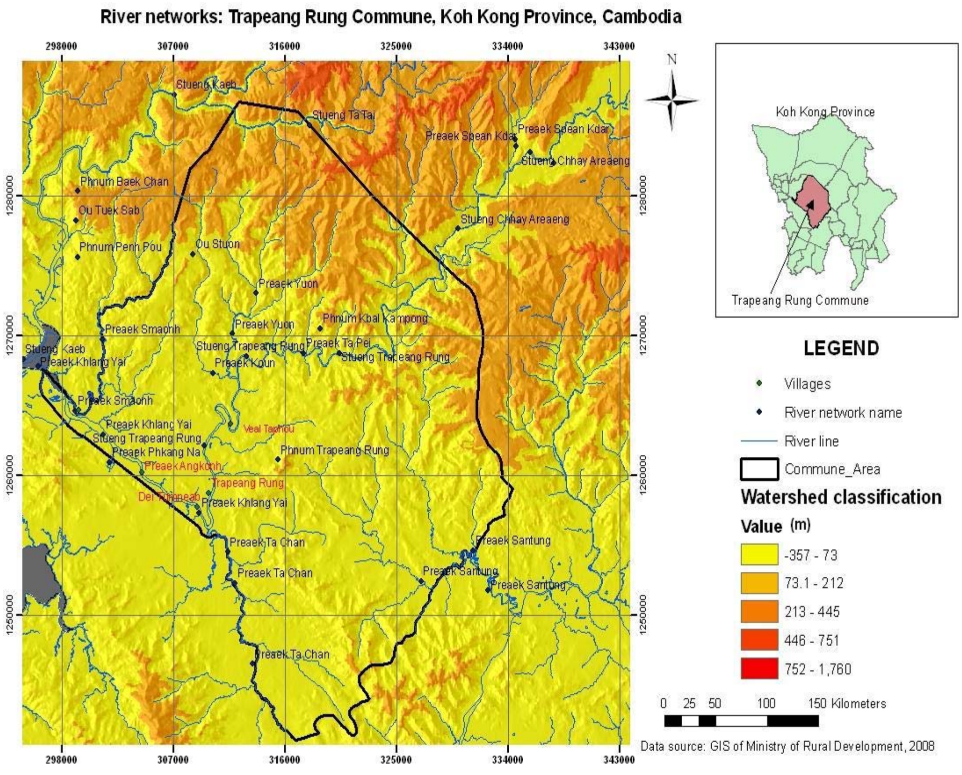

Figure 3.2 Local River Networks (GIS from the Ministry of Rural Development, 2008)

3.1.2 Climatic conditions

Since no climatic data are available specifically for Trapeang Rung commune, the study has assembled data from the nearest meteorological station, in downtown Koh Kong Province. According to the data obtained from this station (Forestry Administration, 2007), mean annual temperature from 2001 to 2005 was 28^0C, while mean annual rainfall was 710 mm (shown in Figure 3.3). The availability of water in the commune throughout the year, and its huge variability, provide a very good habitat for fish to live and breed in the area.

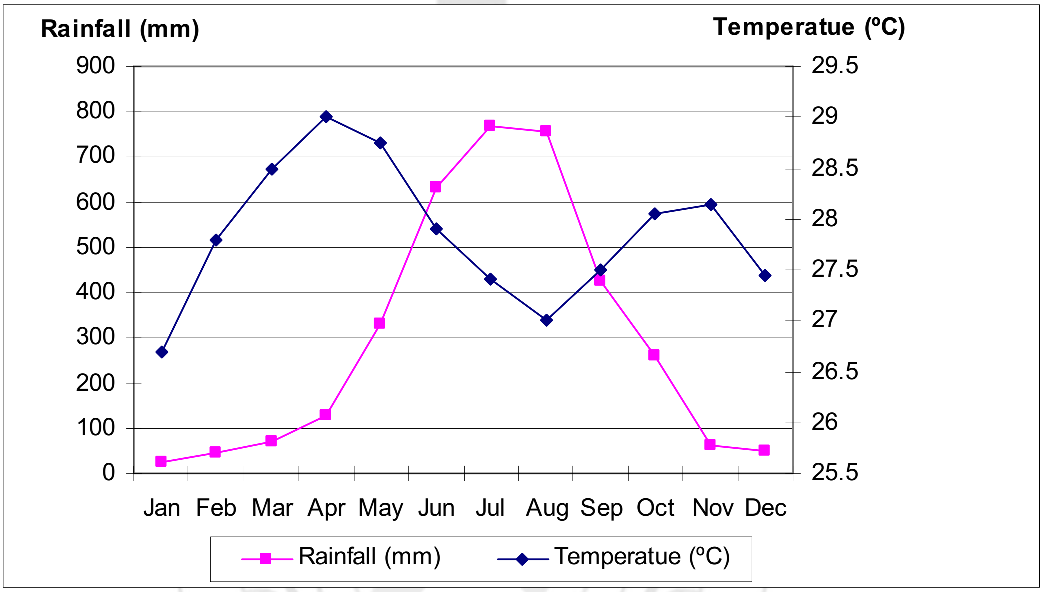

Figure 3.3 Average Monthly Rainfall and Temperature in Koh Kong province, Cambodia 2001-2005 (FA, 2007)

3.2 Fishing households' sample design

Due to time and resource constraints, the research was restricted to 67 fishing households within the study area (out of 293 fishing households in total). This is a sample proportion of about 23% overall. However, the percentage of households sampled was not identical in each village; the sampling proportion was smaller in villages with a larger number of total households. For instance, the more-populated villages of Dei Tumniep and Veal Taphou have 125 and 76 total households, respectively. Here sample proportions were only 15%. In the less populated villages of Koh Kong Knong and Praik Angkoinh, with 52 and 40 total fishing households respectively, the sample reached 30% (see details in Table 3.1).

Table 3.1 Fishing Households Sampled in Each Village

Village	Total HHs	HHs sampled	
Dei Tumniep	125	24	15% of total households
Koh Kong Khnong	52	17	30% of total households
Praik Angkoinh	40	13	30% of total households
Veal Taphou	76	13	15% of total households

The 67 households sampled were classified in terms of their economic status: well-off, marginal poor, moderate poor, and very poor. As the results show in Table 3.2, only 3 well-off households were available to be interviewed during the fieldwork. This reflects the fact that most of the well-off households in the commune are not involved in fishing. In contrast, households in all three other income groups -- marginal poor (26 HHs), moderate poor (25 HHs) and very poor (13 HHs) -- are heavily engaged in fishing. Based on the information gleaned from the field study, in developing research results we combined data from the well-off and marginal poor groups because they both have similar fishing capacity in terms of better tools, motorboats, and finance. In sharp contrast, the moderate poor and very poor groups possess limited fishing gear and boats (most of them use rowboats for fishing). Therefore, these two groups have been combined into a poor group in this study (more details about the fishing households sampled are provided in Table B2 in Appendix B).

3.3 Empirical data collection tools

3.3.1 Primary data

The modeling effort is based on the knowledge obtained from field observation and data collected at the study site. The models were used to get a better understanding of behavior over time and to construct appropriate hypotheses. Field data collection included questionnaire interviews, focus group discussions, and semi-structured interviews.

3.3.1.1 Questionnaire interviews: A detailed questionnaire was completed for 67 fishing households. In most cases, responses were provided by 2 or 3 household members who were actually involved in fishing. The questionnaire sought information about the household's socio-economic status and its members' involvement in and views about their fishing activities (fishing days per year, start and ending months for fishing during rainy and dry seasons, type of boat owned, fishing gear employed, costs per fishing trip, number of days spent per trip, catch per trip, distance to the fishing used, perceptions of changes in fish availability, causes of such changes, and motivational factors assessment on fisheries management).

3.3.1.2 Focus group discussions: The research used 8 focus groups (2 groups in each of the 4 villages) to discuss a range of fishery management options as well as to verify some information related to catch per trip and fish species caught.

3.3.1.3 Semi-structured interviews: A total of five semi-structured interviews were conducted during the field study: with representatives of the local governing authority in Trapaeng Rung commune, two local fisheries-related non-governmental organizations, NGOs (the World Fish Center and Community-Based Natural Resources Management Learning Institute), and two central government officers -- the top Koh Kong province fisheries official and the lead local officer of the Community Development Division of the national Fisheries Administration.

Some important data which were collected during the filed trip are provided in Table B1 of Appendix B.

3.3.2 Secondary data

During fieldwork, information that has been documented by various institutions related to fishery biology as well as the management plan and conservation were collected in order to assist in the research. Those reports and data were very important in allowing the researcher to confirm, clarify, or dismiss certain findings from the research, and to give quantitative and qualitative information from various dimensions to enrich the complete comprehensive study.

3.4 Research steps and framework

To understand some of the basic interactions of the fishing community with their fisheries resources, this research relied on the findings of relevant social science research. Such research is based on observations and descriptions of behavior in everyday situations (Punch 1998) that enable the researcher to employ a combination of qualitative and quantitative research approaches to obtain information that helps explain the situation and its ongoing processes. For instance, one typically starts with a description of the residents' livelihoods and the current situation of available fisheries resources and their use. However, there is a need to explain the ongoing processes in more depth. This calls for going at least one step beyond such description, into what is commonly known as "underneath problem analysis."

The research for this thesis proceeded through four main steps: literature review, field data collection, data analysis, and conclusions and recommendations in order to obtain both primary and secondary data (Figure 3.4). The first step, literature review, gave an opportunity to develop an overview on the topic and better understand the core issues. This was an essential element of the research, which gave good background knowledge about those issues that relate to options for management of fisheries resources. The literature review continued throughout the research effort, from its beginnings until the analysis of results, as insights from certain previous studies helped to refine and support this study's arguments.

After generating ideas about the subject, field data was collected in the local villages to assess how things appear in a real life situation. The aim was to understand as fully as possible the current situation of fisheries resources, the fishing community, and the realistic management options that are appropriate for this locale and set of demanding environmental management challenges.

Thereafter, the researcher proceeded to analyse the collected data. At this point, the knowledge gained from the literature review was related to the new understanding of the real-life situation. A coding method was used to analyze the interviews with different stakeholders and the field notes of the observations. To support this analysis, a system dynamics approach was constructed in which models simulated the potential management approaches that were generated from the literature and the field findings. These tests helped winnow the results. Finally, the key findings were reviewed and presented. The research aimed to generate policy recommendations to overcome over-harvesting of fisheries resources and improve the access of poor fishers to those resources.

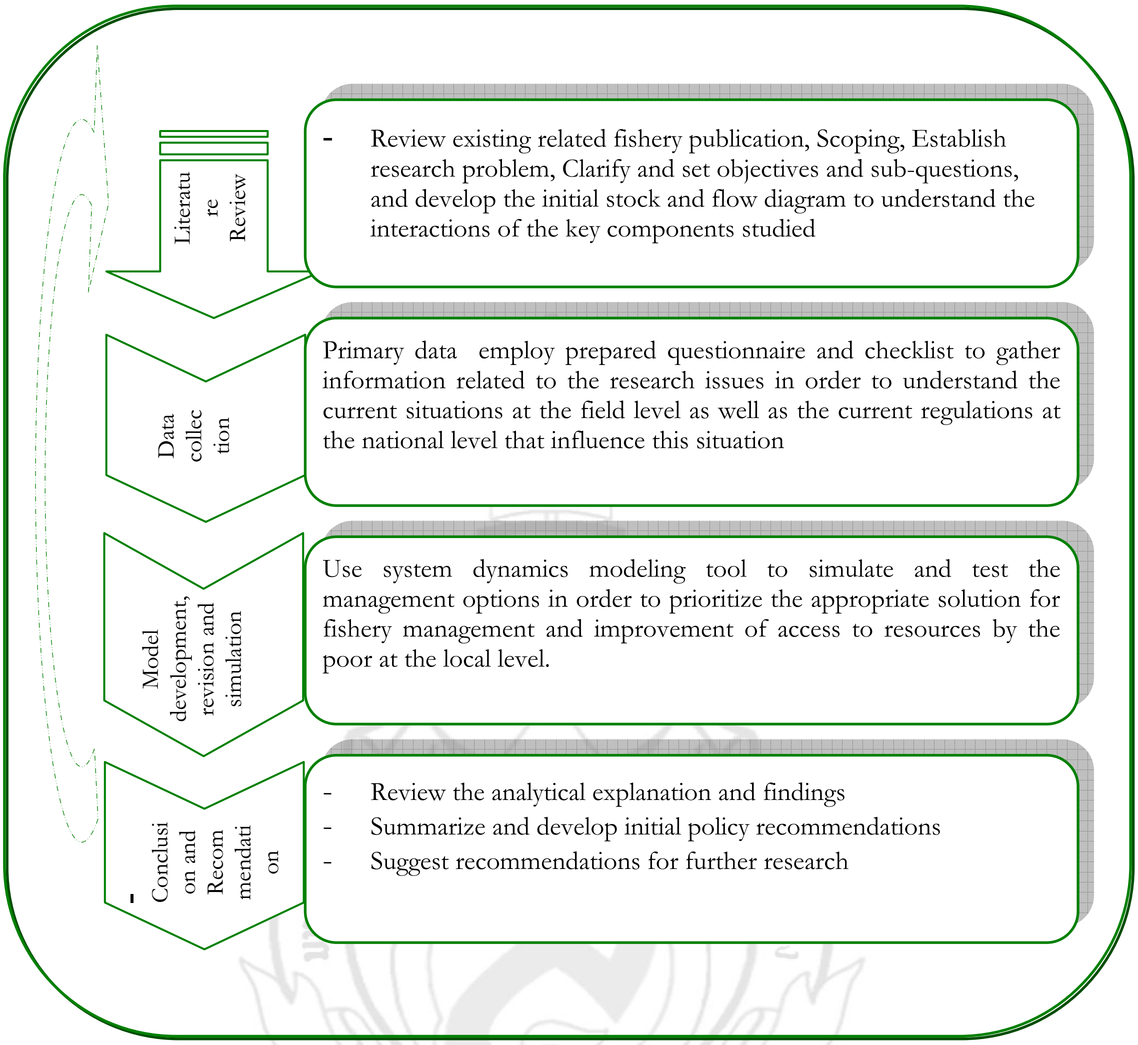

Figure 3.4 Major Steps in the Research

The diagram presented in Figure 3.5 shows the steps in system dynamics modeling that were carried out for this thesis research. This research framework was intended to portray the main concerns and scope of the research.

Each step in the modeling required various inputs, including actual data gathered from the fieldwork as well as the perceptions of relevant stakeholders. Of course, different outputs were produced from each step of the modeling and some of those outputs were used as inputs for the next step of modeling.

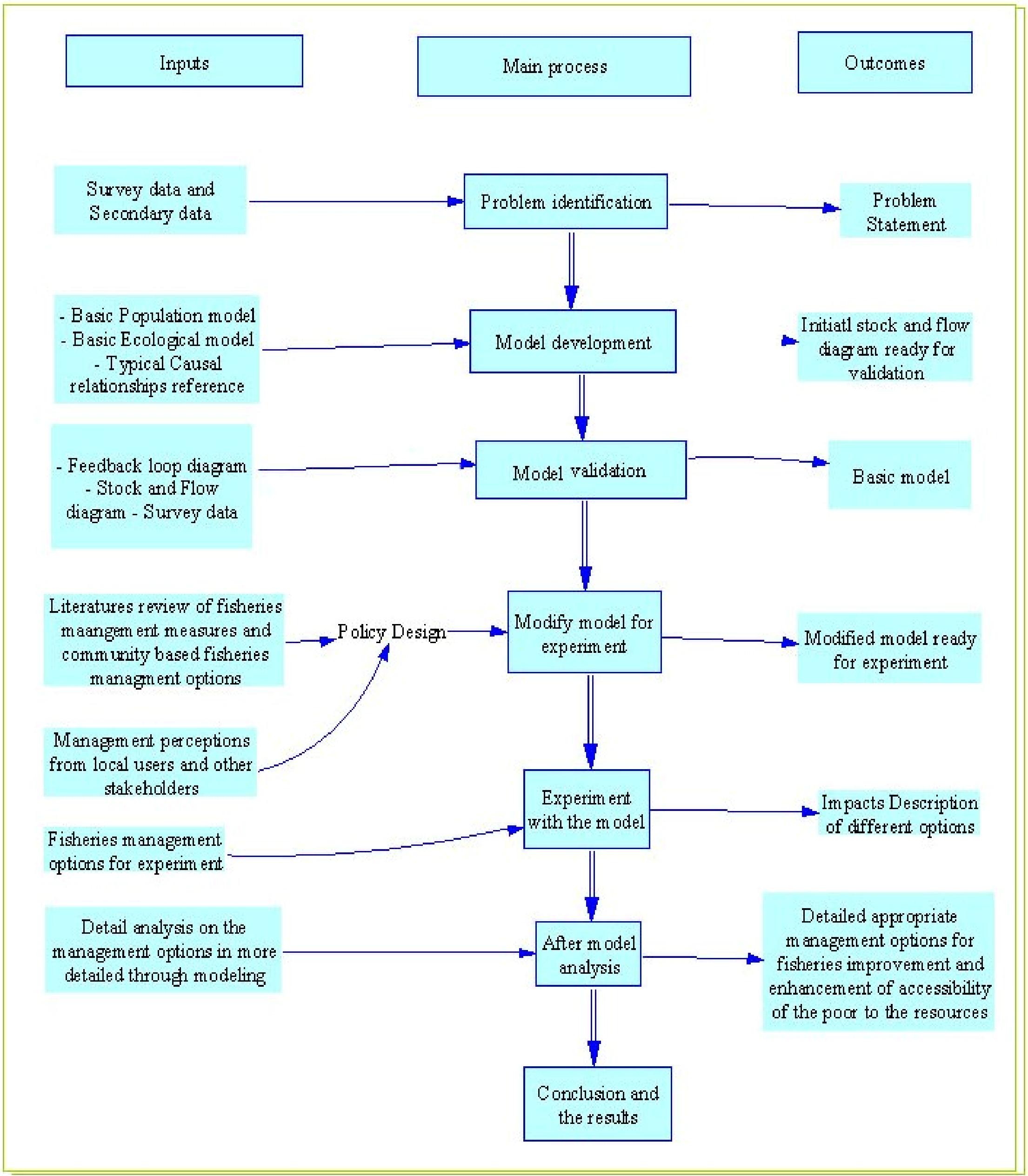

Figure 3.5 Overall Research Framework System Dynamic Model Based

3.5 Empirical modeling approaches

3.5.1 System dynamics approach

System dynamics (SD) is an approach to understanding the behavior of a set of interconnected parts of a system over time. Wolstenholme (1994) wrote "SD is a rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies, which facilitates quantitative simulation modeling and analysis for the design of system structure and control." He pointed especially to two characteristics of SD that arise from its holistic view. The first is its ability to generate structures that can be transferred to create insights into other systems; the second is its ability to help identify the counter-intuitive behavior of certain systems. Often unintentional consequences result from implementation of new policies; SD provides a way to help determine what these might be (Wolstenholme, 1994). Sushil (1993) termed SD a data-less approach. Thus, in problem situations where not enough data is available to go for strict quantitative analytical modeling based on open loop approaches, one can apply SD modeling to unearth key feedback structures and generate systems behavior.

Since this research attempts to suggest appropriate management options for dealing with overfishing and poverty reduction through improved access to the resources in order to use them sustainably, the SD approach was used as a key tool to understand the key interactions as well as test the validity of various options. This model used the criterion of catch-per-person as the dependent variable for assessing the impacts of each management option and benefit sharing to the poor.

3.5.2 Some basic models

In this study, the methodology has stressed use of Vensim system dynamics modeling software and two existing models: one for generic population dynamics (Andrew, 1999), the other an ecosystem population modeling approach called Predator-Prey Population (Deaton and James 2000). These two models are both based on the basic concept of natural dynamics of development of a population (generic population dynamics). In addition, they illustrate the nature of ecosystems function that uses density as a crucial regulating factor.

3.5.2.1 Generic population dynamics modeling

Generic population dynamics modeling studies the growth of animal populations through three age groups. As shown in Figure 3.6, total births depend on such variables as the number of mature females and births per mature female per year. The maturation flow rate transforms a young population of animals into a mature population, while the aging flow transfers a mature population into an elderly population. The final category, deaths, reflects the size of the elderly population and the death rate.

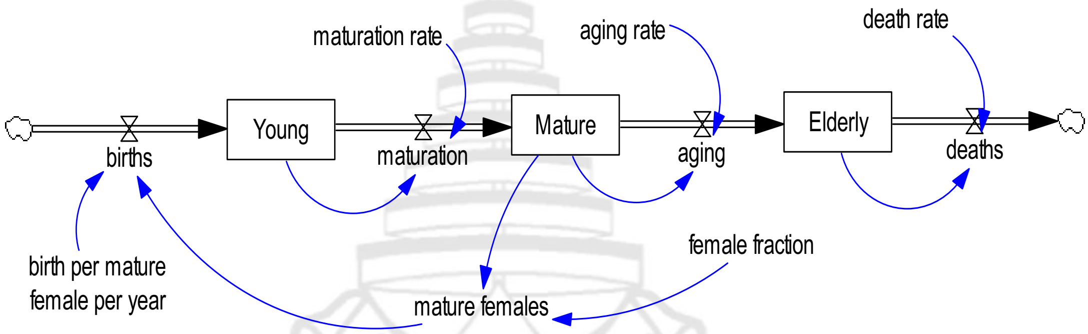

Figure 3.6 Generic Population Model (Andrew, 1999)

This dynamic population model constructs a system of physical evolution from youth to old age. This structure, modified appropriately, is well suited as a model of fisheries resources in the study site, allowing us to understand the internal dynamics of fisheries and to identify the impacts of fishing activities on different components of the fish life cycle.

3.5.2.2 Predator-prey population modeling

Predator-prey studies have focused on interactions of deer and wolf populations. The emphasize the factors that limit the growth of either prey or predator populations. The limited variable here, density dependence, plays a very important role in regulating the growth of population without destroying the carrying capacity (Figure 3.7) and lets the system function well with diversified species.

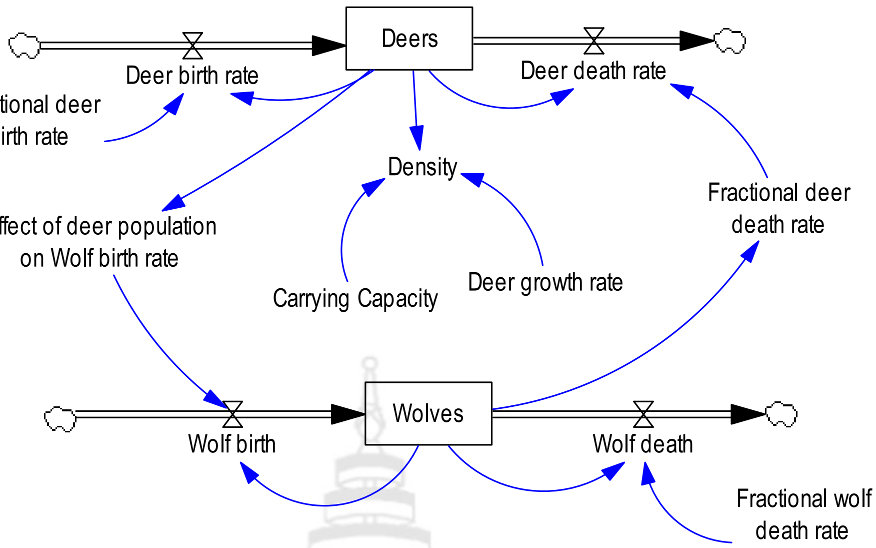

Figure 3.7 Density Dependent Deer and Wolf Populations (Deaton and James, 2000)

3.6 Conceptual framework for the research

The research is focused on two key interrelated concerns: fisheries resources management and poverty reduction through improved accessibility of the poor to local fisheries resources. The research intends to discover the appropriate management options suitable to the local context by focusing on relevant socio-economic and social structures as well as the indigenous knowledge of local villagers. Through the appropriate fisheries management scheme, the research will suggest the options that favor improved accessibility of the poor to fisheries resources.

The research perceives that appropriate management options and poverty reduction reinforce each other. Introduction of effective management options will increase catch per capita of the poor, allowing these fishers to gain more benefit. Furthermore, over the long term benefit positive interactions can assist biodiversity conservation for the upland forest resources since people have better options to improve their livelihoods. The diagram in Figure 3.8 indicates the interactions of those two aspects, which can be tested through system dynamics modeling.

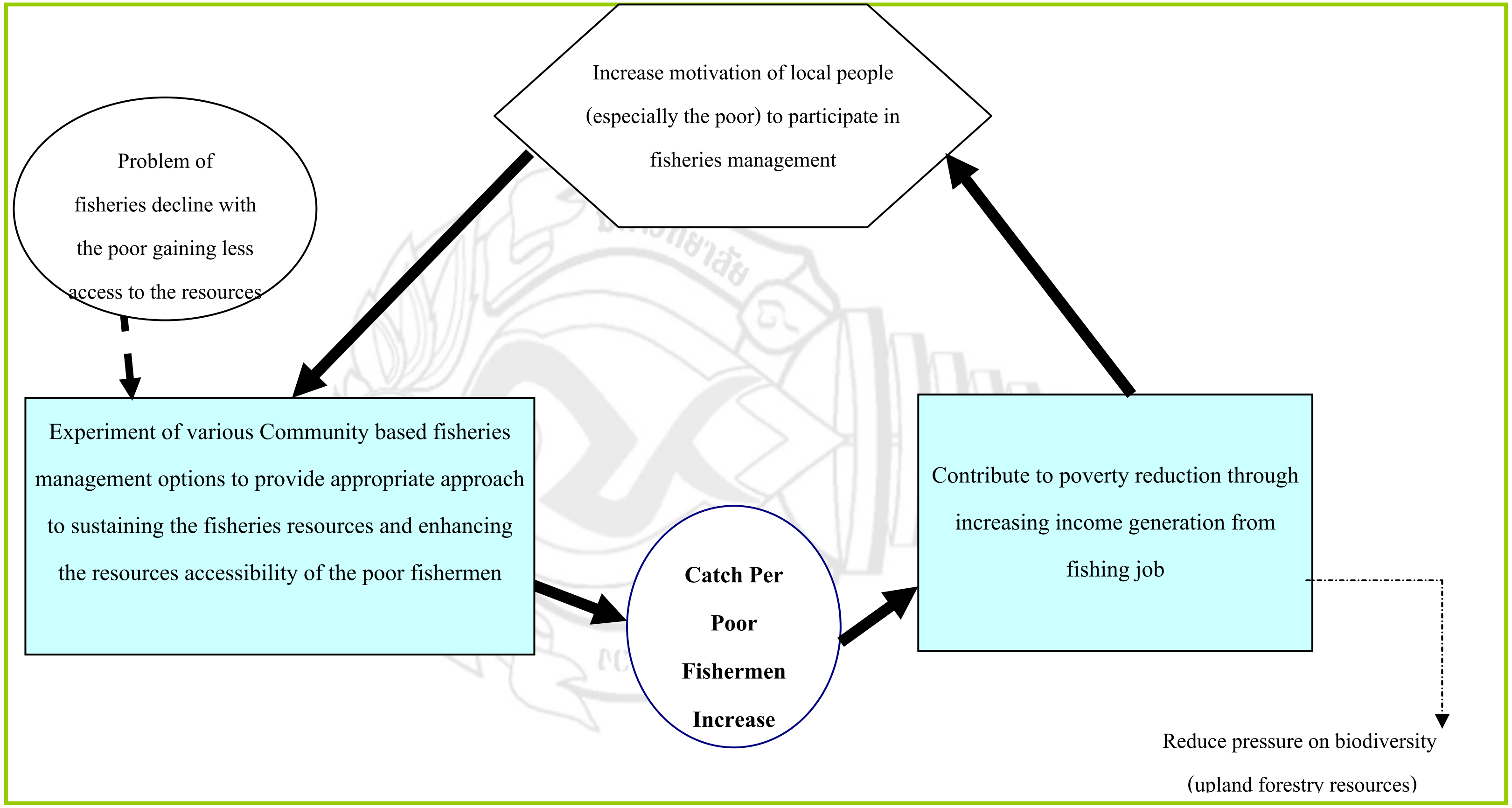

Figure 3.8 Research Conceptual Framework

CHAPTER 4

DATA RESULTS AND SYSTEM DYNAMICS MODELING DEVELOPMENT

This chapter presents information on the current situation of fisheries resources in Trapeang Rung commune based on the principal results of the research conducted in Trapeang Rung commune. We investigated and analyzed the current situation of those local households that use fisheries resources to sustain their economic situation. We also assess here the catch per capita of poor and non-poor fishing households, and the consequences of excessive catching on current fish production. Fishermen’s perspectives on fisheries management options are also presented.

Some essential background information is given about the commune, Trapeang Rung. These facts and figures allow the reader to get familiar with the local context and learn about who these local people are and how they live in this area on a daily basis. This gives a better understanding of the issues discovered during the case study research. This information allows a subsequent multiple stakeholder analysis to illustrate what is happening in the commune today related to fishing practices. On top of that, this section provides insights into the opinions of people about community-based fisheries management practices and about what they see as barriers and challenges to using this approach.

Moreover, this chapter presents an assessment of fisheries management options through application of system dynamics modeling. This part will emphasize the analysis of impacts of each management approach for sustaining fisheries resources as well as to improve access to fisheries resources for the commune’s poor group of fishermen.

4.1 Socio-economic status of local fishermen

4.1.1 General demographic characteristics

A total of 67 fishing households were interviewed over during the study. On average, these households have 4.8 members each. Approximately 81 people answered study questions, with men accounting for nearly 60% of total respondents.

As shown in Table 4.1, most respondents were 21 to 50 years old. Most such individuals engage in fishing activities or were household heads. Some local fishers were quite young (between 10-20 years old). The group aged 51 or older mostly fish for their own household's subsistence, rather than for cash income. Overall, in this locality most fishers can keep fishing for much longer (often for 30 to 40 years) than in many other occupations.

Table 4.1 Ages of Respondents

Age	Number	(%)
10-20	10	12.35
21-30	19	23.46
31-40	19	23.46
41-50	23	28.40
51-60	6	07.41
>60	4	04.94

Source. Calculated from fieldwork data, 2009

4.1.2 Income-generating activities

It is common for rural Cambodian people to have a combination of income sources. Since they only make a small amount of money from each source, they cannot rely on only one activity. This research divided respondents' livelihood options into major and secondary income generation sources.

Without doubt, members of this fishing-dependent community derive a high proportion of their income from fisheries resources. Field observations showed that fishing is by far the most important source of income earning in this community, accounting for 87%. Other sources of income such as agriculture (fruit tree plantations), middle person/trader, and wage labor account for very small proportions. For the fishers' secondary sources of income, agriculture accounts for the highest proportion -- 29%. Wage labor and collection of NTFPs share the same percentage -- 11% each. Selling fish and running business (grocery shop/cake vendor) are 10% and 5%, accordingly (as shown in Table B4 in Appendix B).

4.1.3 Economic situation of fishermen

These village respondents possess striking differences in wealth, and can be divided into four identifiable categories: well-off, marginal poor, moderate poor, and very poor. The well-off group accounts for only 4% of total household respondents, while the marginal poor contribute another 39%. The moderate poor group makes up of 37% and the very poor group is about 19% (see Table 4.2).

Table 4.2 Village Fishers' Different Income Levels

HH income levels	Number of HHs	%
Well-off	3	4
Marginal poor	26	39
Moderate Poor	25	37
Very poor	13	19
Total	**67**	**100**

Source. Calculations from fieldwork data, 2009

Overall characteristics of each income group in the study site are as follows:

4.1.3.1 The well-off households own significant local assets, run a business such as a grocery shop, or act as middlemen/traders. In these roles they are able to earn income daily. In addition, well-off households here own one or two motorboats each, with 5- to 8-horsepower engines; and they have several sets of fishing gill nets and long line hooks.

4.1.3.2 The characteristics of the marginal poor group are not too different from the well-off group, though of course at somewhat lower levels. They also own some properties, run small businesses, and access the market easily. Most of them seem to be somewhat more involved more in agricultural activities than are the well-off households. Most of them have a motorboat for traveling as well as fishing; they also have a good set of fishing equipment, similar to that of the well-off fishermen.

4.1.3.3 Households in the moderate poor group own a small plot of land, just enough on which to build a house. Some of these households also own a parcel of farmland, from 0.5 up to 3 ha, but with poor quality and hence low outputs received from their agricultural production activities. They also each have a rowboat; some of them have a motorboat as well. However, they typically own only limited sets of gill nets and long-line hooks.

4.1.3.4 Households in the very poor group are not so difficult to recognize by outsiders who simply look at their house appearance, although they might have some limited (minimum) personal assets. In addition, some of them do not have a boat for fishing, having to borrow one from their relatives or neighbors. With regard to fishing gear, they own few sets of gill nets and most of them do not have long-line hooks. They have one or two fishing forks for hunting prawns or other fish species.

4.1.4 Differing income and expenditure patterns

4.1.4.1 Household income

Different groups have differing monthly income levels, which (of course) can also vary considerably from one household to another within the same wealth group. Monthly incomes of household respondents range from a low of US$12.16 (equivalent) to a high of $121.65. One-third of households in the very poor group earn $36.49 to $48.66 monthly. A few households in both the moderate poor and marginal poor groups can make more than $121.65 per month (see Table B5 in Appendix B).

4.1.4.2 Household expenditures

Across the studied village, rice is a crucial item for all of the villagers. Most have to spend cash money to get rice every day, since they do not have enough rice field areas to cultivate to meet their family's demand. Other expenses that most villagers incur include food (sources of protein beside fish and some vegetables), fishing gear, fuel, and educational fees for their children. Some of the poorer households can only afford to meet their limited basic needs. Daily expenditures of most household respondents range from \$1.21 to \$2.43. Over half of the very poor households (53%) spend money at this level. Households in both the well-off and marginal poor groups spend on average more than \$2.43 daily. Details are illustrated in Table B6 in Appendix B.

4.1.5 Characteristics of small-scale fishing in the study site

In Cambodia overall, small-scale fishing activities are carried out using traditional gear or with equipment of relatively low efficiency. These fishers normally use non-motorized boats or those with motors of less than five horsepower. People who fish at this scale are not required to pay a fishing tax and can fish all year round.

While small-scale fishing in Trapeang Rung commune is generally consistent with the national situation, fishing here shows some particular local characteristics. For instance, most fishing households use motorized boats (with 5 horsepower) and a set of common fishing gear like gill nets, long-line hooks and fish forks. Also, each person fishing typically spends 1 to 3 nights out on each trip (as shown in Table B7 in Appendix B). Currently, only a few households here have individuals who would fall into the category of small-scale commercial fishing. Most of the villagers have other jobs and cannot spend a lot of time fishing because the profits made from this work are not enough for them to survive.

4.1.6 Income gained and expenses incurred per fishing trip

The amount of money made per trip depends not only on the number of fish caught but also on their types. Fish prices range considerably, from 4,000 Riel (97 cents US) to 9,000 Riel (\$2.18) per kg for both marine and freshwater varieties. Other aquaculture products such as prawns have a value ranging from 7,000 Riel ($1.70) to 12,000 Riel ($2.91) per kg. Prawn prices vary depending on size; the smaller in size, the lower the price.

The amount of income that can be derived from fisheries resources per fishing trip varies considerably for individuals in the four income categories. Interestingly, both very poor fishermen (54%) and moderate poor fishermen (56%) can earn from $2.43 to $4.86 per fishing trip. Fishermen in both the well-off and marginal poor groups earn much more, over $9.73 per trip (as seen in Table B8 in Appendix B).

Typically, main items of expense include gasoline, rice and other food, and ice. Expenses per trip in the different income groups vary not only in total scale but also in proportions spent for different items. Most members of the very poor fishing group spend very little, less than $1.21 per trip. This reflects the fact that most of them do not use a motorboat that requires buying gasoline. About 35% of marginal poor and 48% of moderate poor fishermen spend more than $4.86 per fishing trip. This may be because they usually go fishing at some distance from their village and stay longer at the fishing grounds once they get there. Some of the marginal poor fishing households (27%) and moderate poor group (24%) spend about $2.43-$3.64 per trip (as can be seen in Table B9 in the Appendix B).

Consistency is apparent between gross income earned per trip and expenditures paid per trip. The very poor fishermen can afford less expenditure and get less return. The better-off fishermen are able to spend more per trip; hence, they get more return than do the poor ones.

4.1.7 Fishing gear used and effort devoted to fishing

The study was conducted during the rainy season, when the Trapeang Rung channel contains fresh water. Thus most fishermen employed only a few types of fishing gear: gill nets, long-line hooks and fish forks. Most fishermen here use gill nets sized from 4 to 7 cm, depending on the type of fish being sought. On lines they attach from 30 to 125 long-line hooks. Fish forks are used to catch both prawns and fish.

Figure 4.1 shows that gill nets are the most common equipment used (about 39%), with long-line hooks and fish forks following closely behind at 32% and 29%, respectively. It is noted that All the reported fishing gear is legal for use in this area, and can be used freely in family-scale fishing under the Fisheries Law of Cambodia ratified in 2006.

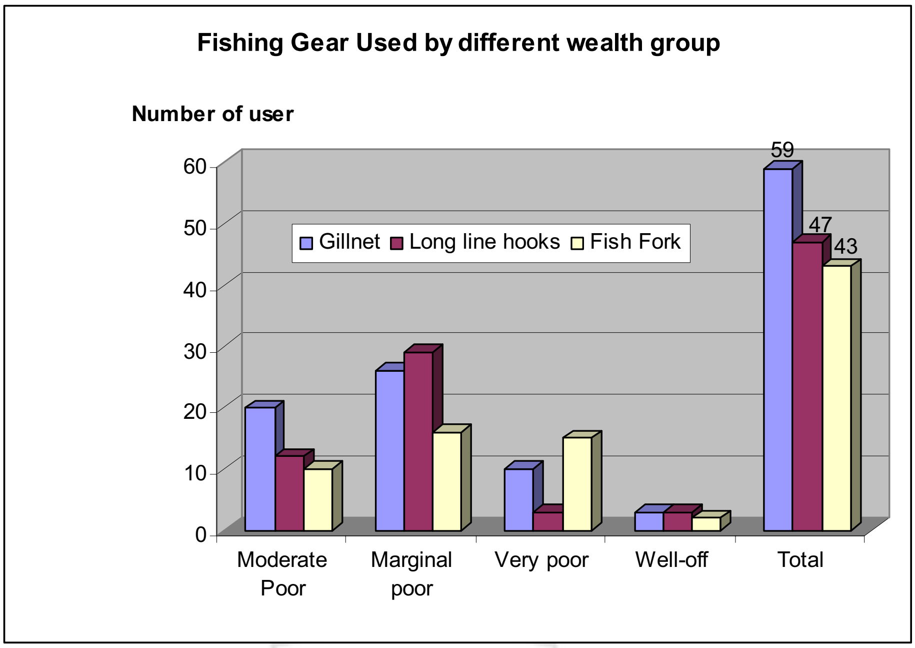

Figure 4.1 Fishing Gear Used by Different Income Groups

However, use of different types of fishing gear varies among households in the different income groups. The poorer households (not surprisingly) have less or more limited fishing equipment in comparison to non-poor households. For example, some non-poor fishermen own more than 10 sets of gill nets and a large number of hooks (as shown in Appendix B, Tables B10, B11, and B12). On top of that, the non-poor fishermen own and use fishing gear that is better and more effective than that of the poor group. They have specific fishing gear designed to catch different fish species (some types of gill nets are designed to catch specific high-commercial-value fish). Therefore, they can catch larger amounts of target species than can the poor fishermen.

Even though, in general, the types of fishing gear currently being employed seem to be in compliance with the law, there are some reports of illegal fishing gear being used for fishing in this area, especially during the dry season when the density of the fish is higher than in the rainy season. Within the commune, the fishermen acknowledge having encountered others using illegal fishing gear: explosive substances, electronic devices, and fine ring mesh net (less than 6 cm) in crap traps. Some fishermen who have been recognized as using illegal gear are known to and under observation by the commune authority. While the authority has paid attention to illegal fishing activities, there are still gaps associated with weak enforcement and irregular observation since the fishing grounds are spread across the entire commune.

Recently, the commune local authority group was asked by the provincial level to carry out enforcement of the Fishery Law of Cambodia to combat illegal fishing in their territory in order to protect the remaining fisheries resources. Through enforcement of these rules, some fishermen have been recognized as using illegal gear. However, the investigation has not been carried out regularly because the commune level lacks sufficient human and financial resources. Mostly, local authority representatives are able to observe events at the fishing grounds when conducting their other governance missions; they do not have an actual law enforcement team in each village. Therefore, there is still a gap in law enforcement (prohibition of using illegal fishing gear to catch fish that was declared in the Fisheries Law of Cambodia) within the area.

There is no big difference of fishing time choices in this area. For instance, about 30% of household respondents reported that, most often, they fish in the afternoons; this was followed by night time (26%), evening time (23%), and in the morning (about 21%). Details are illustrated in Appendix B, Figure B1. It seems that the fishing time that the fishermen go to fish does not have any influence on the catch. On the other hand, it indeed shows that even though the fishermen try hard to go fishing throughout the day, they can catch only a smaller amount of fish.

In contrast, the length of time spent fishing is a major factor affecting the catch. Generally, respondents report that the longer they stay at the fishing location, the greater amount of fish they will catch. However, fishermen from poor households are not able to spend as much time fishing as do the non-poor fishermen; therefore, generally, the poor fishermen get fewer fish per trip compared to the non-poor fishermen. Most fishermen (66%) spend only one night fishing; another 30% spend 2 to 4 nights out there. Only a very few fishermen (less than 5%) have stayed from 3 to 5 nights at the fishing grounds. Details are presented in Table C1 of Appendix B. This result indicates that most fishermen are subsistence fishing folks who go fishing just to supply food for their own household and perhaps earn little extra money.

4.1.8 Fish catches related to fishermen's economic profiles

The household respondents reported about their different yields per trip. Sometimes, some of them cannot catch enough fish for even one meal. They claimed that when they were able to catch only such a small amount of fish they were usually trying to catch fish in the channel near their houses using traditional fishing gear like gill nets or fish forks. Most of them said that if they can go to their preferred fishing locations (which are quite far from their houses, about 7 km) they can catch more fish; but to do so they will incur more expense since they have to use more gasoline and stay there a few days.

Overall, it is quite hard to estimate average catch per trip because many fisherman experience great variations in their yields (sometimes, they cannot catch even a kilogram of fish; at other times they can catch around 10 kg of fish in one trip). Therefore, estimates of catch amounts were based on the most frequent amount of catch per trip, varying from 3 kg to more than 10 kg per fishing event.

As shown in Table 4.3, most very poor households (69%) can only catch less than 3 kg per time. These households have only 1 or 2 sets of less-effective fishing gear; and some of them do not even have a boat to use for fishing.

Table 4.3 Different Groups' Yield per Fishing Trip

	Catch per trip (%)			
Household Status	**Less than 3 kg**	**3-5 kg**	**5-10 kg**	**More than 10 kg**
Moderate Poor	40	20	24	16
Marginal poor	35	19	31	15
Very poor	69	31	0	0
Well-off	0	0	0	100

Source. Calculated from fieldwork data, 2009

Moderate poor and marginal poor households have results similar to one another; over half catch less than 5 kg/trip. The well-off households, in contrast, catch much more in each fishing attempt: more than 10kg.

Respondents reported that they sold almost all of their catch (around 90%-95% of total catch per fishing trip) in order to acquire money. According to this result, the average yield per fishing trip per capita ranges from 3 to 6 kg across the groups. In addition, most fishermen go fishing about 8 months per year -- 4 months during the rainy season and 4 months during the dry season.

Using these data, fish consumption per capita is 15 to 30 kg annually (for the 4.8 members of an average household). This rate of consumption is a bit lower than the rate in Cambodia nationally, which is about 32.3 kg for inland fish (Mekong River Commission, 2007). This result shows that the Trapeang Rung fishermen have not yet met the standard level, especially at the lower ends of the average consumption range. The reasons for this result may be either the shortage of fishermen employing effective tools, or the extent to which the number of local fishermen over time has caused available fish stocks to decline. The first reason is consistent with the fact that most local fishermen are poor, while the second reason is based on the current decreased degree perceived by fishermen that showed fish stocks declining about 40%-50% over the past 5-10 years.

4.1.9 Types of fish caught

Through field observation, gill nets mostly catch species that have commercial value; these include *mugil cephalus* (a marine fish species) and such freshwater fish as Asian redtail catfish, Striped bony lip carp, and Eyespot spinnyell. However, the size and type of gill net can have an affect on the species caught. For instance, while an 8 cm mesh size gill net can catch *mugil cephalus*, fishermen have to use gillnets with 4.5 to 6.5 cm mesh size to catch Asian redtial catfish or Striped bony lip carp.

During the rainy season, fishermen catch mostly freshwater fish species. At that time the Trapaeang Rung channel is full of fresh water, which allows some freshwater species to migrate from the upper part (Areng catchment watershed area) to the channel in order to feed themselves. In that season fishermen can catch those fish species easily (as shown in Figure B2 in Appendix

B). Asia redtail catfish comprises more than half (56%) of all the fish species caught at that time. This common freshwater fish species can be found everywhere within Cambodia.

As mentioned earlier, different types of fish species are caught by different kinds of fishing gear. However, since the various households (by wealth) seem to own slightly different fishing gear, those fishermen also catch different types of fish species according to the capacity of their tools. In addition, data on individual group catch rates shows that some households simply do not catch some types of species. For instance, fishermen from the moderate and very poor households do not catch Brownstripe snapper, the fish species with the highest commercial value in the commune (1 kg of Brownstripe snapper sells for $2.19, while some species like Asian redtail catfish sell in the markets for only 50 cents (US) per kg (see Figure B3 in Appendix B). This suggests that the absence of ability to possess better equipment is a crucial constraint to access key fishing resources. Therefore this factor is important for design and implementation of a policy intervention to enhance or improve the accessibility of those disadvantaged groups to better fishing gear.

4.1.10 Declines in catch rates (as perceived by local fishermen)

Fishermen interviewed from both poor and non-poor households agree that fisheries resources have declined as compared to the preceding few years. Basing this conclusion on the fact that they have personally experienced a noticeable drop in their fishery catches. However, they view the degree of decline differently among different fish species. Nearly all of them said that their catches of the most valuable market fish species (such as mud crab, giant freshwater prawn, and brownstripe snapper) had decreased by 40%-60% per season in recent years (as seen in Table 4.4). In addition, they also pointed out that fish catches have declined about 10%-20% for all fish species, with the most notable declines seen in the freshwater fish that are commonly caught only during the rainy season. Even though there is no scientific evidence to prove that fish stocks in the Trapeang Rung channel and its tributaries have declined at a particular rate, it seems reasonable to take the perceptions of local fishermen into account because they are able to derive their conclusions based on their extensive local ecological knowledge.

As stated by Baird & Mean (2005) in their study of fisheries in the Sesan River, “local ecological knowledge is based on the individual and collective real-life experiences of fishermen and is accumulated from generation to generation. It is not a stagnant form of knowledge based only on the passing on of ancient practices, but is highly adaptable, dynamic and very practical. It is the basis for local livelihoods and is in a constant state of change. Like all forms of knowledge, it can be developed and changed to meet new circumstances." Following this insight, it seems reasonable to incorporate into this study of fisheries in Trapeang Rung commune the villagers' knowledge of fish stock declines and its different causes.

Table 4.4 Perceived Degree to which Valuable Fisheries Catches have Declined

Extent to which fisheries resources have declined	**HH responses**
Decline of 30-40%	1%
Decline of 40-50%	48%
Decline of 50-60%	48%
Decline of 60-70%	3%

Source. Calculated from fieldwork data, 2009

Local insights into the causes of these fisheries declines are shown in Table 4.5. Nearly half of all fishermen (48%) believe that the increasing number of fishermen in their area in recent years is the main factor causing the decline. These increased numbers, in turn, result from the fact that most of these people do not have alternative jobs that they can rely on for sufficient income. Respondents said that in the past they had been able to rely more on forestry products for some income. However, since 2002 when their commune was designated as a protected forest area, they no longer have free access to the forest. Meanwhile their agricultural fields are also not producing good yields for them. Some other fishermen (about 28%) reported that not only do more people now go fishing, but that some of them use illegal fishing gear that harm fisheries resources. Loss of fisheries habitat, sand drainage and changes in seasonal rains also contributed to fisheries decline in the area (though at relatively low proportions).

Table 4.5 Perceived Causes of Fisheries Decline

Perceived reasons behind the decline in fisheries resources	Pecentage
Increased numbers of fishermen in the fishing grounds	48%
Some fishermen using illegal fishing equipment (poison, electrical gear)	28%
Impacts from sand drainage	12%
Loss of fisheries habitat such as the Smach bust (*Meleleuca leucadendra*)	9%
Change in seasonal rains (rain comes earlier than usual, impacting water quality)	3%

Source. Calculated from fieldwork data, 2009

Some fishermen, especially elders, pointed out to some changes that they felt would help manage their local fisheries resources better. Community-based management was noted, since the villagers assumed that this would give some power to local fishermen to protecting the resources. They mentioned their concern that reliance on the fishermen alone would not be sufficient. Instead, they wanted to involve others, especially local government authorities and the technical officer from the Provincial Fisheries Administration. They also wanted to involve another key organization -- the Wildlife Alliance organization that is running an eco-tourism project in the commune. Moreover, the villagers believe that engaging these other stakeholders to support organizing and developing clear rules and regulations is imperative. The local villagers by themselves would find the work loads beyond their capacity; they feel powerless to solve the problem on their own.

4.2 System dynamics modeling development

This chapter also presents an assessment of fisheries management options through application of system dynamics modeling. We analyze the impacts of each potential management approach in terms of sustaining fisheries resources as well as improving access to such resources for the commune's poor group of fishing households. Drawing on the facts and figures that were obtained from the fieldwork, models simulated changes in fisheries stock in order to test the viability of various community-based fisheries management options.

Specifically, the modeling focused on the impacts of the two most-significant causes of the declining fish population: increased numbers of fishermen, and illegal fishing activities. Explanations of the impact of these two factors on the fish population are as follows

1. In recent years, more fishermen have come to Trapeang Rung Channel to go fishing. As a result, more fish have been removed from the channel. In turn, fewer fish are available to spawn and thereby regenerate the young fish that would grow and refill the fish population for the next year's catch.

2. Use of illegal fishing gear has a crucial impact on both capability of fishermen to catch fish and on the fish population. On the one hand, this activity increases catch per fisherman, each of whom gains increased income from their illegal activity. However, the overall result impacts negatively the fish population. As mentioned above, more fish being caught means fewer fish are available for breeding. However, the impact of illegal equipment use may be even greater than that associated with larger numbers of fishermen. Some studies have shown that illegal fishing may deplete young stock (small fish size) and cause damage to fishing ground ecosystems as well as leading to decline in the fish stock as a whole (Sergi, 2004).

4.2.1 Development of system dynamics modeling approach

The model used in this study was developed based on two fundamental models: a dynamic population and a resources-users population model. These two models provide the basic knowledge about interactions within a system and the linkages between two systems. Each of these models, unfortunately, is very generic. To deal with this limitation, this thesis research integrated and modified the two models to design an approach that can help understand the fishery stock decline and also enhance the benefits for poor fishermen in the study site.

The model as created consists of two main sub-systems. The first sub-system examines fish population dynamics, including stocks of both young fish and adult fish. The second sub-system explores fishermen population dynamics; it contains potential and actual fishermen from both non-poor and poor households).

4.2.2 Modeling the fishery sub-system

4.2.2.1 Feedback loops in the fishery sub-system

Figure 4.2 displays a complete causal-loop diagram for the fishery sub-system model.

Breeding depends on the size of the adult fish stock; in turn, breeding replenishes the young fish stock. As the fish life cycle continues, the young fish grow mature and add to the stock of adult fish. Interactions between breeding, mature, young fish and adult fish stocks are the positive relationship in the model (Loop 1). However, death rates for both young fish and adult fish introduce a negative relationship. For instance, death of young fish (Loop 2) decreases the population of young fish. Likewise, death of adult fish depletes the population of adult fish (Loop 3).

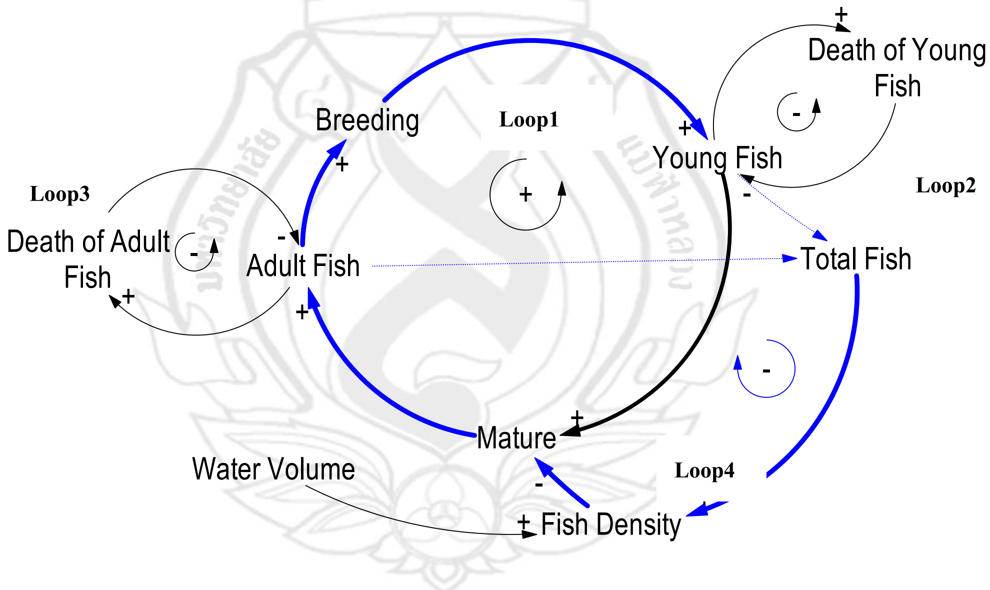

Figure 4.2 Feedback Loops in the Fishery Sub-System

In this fishery sub-system model, the water body is assumed to be a fixed area that remains unchanged throughout the model simulation. Therefore, as fish stock increases, fish density in that fixed water body increases. This results in more competition among the fish population for food. This crowding density may effect a decrease in the mature rate of the fish population. The feedback loop interaction of the fish population system becomes negative, as shown in Loop 4.

4.2.2.2 Stocks and flows in the fishery sub-system

The model diagram presented in Figure 4.3 retains the causal loops of Figure 4.2. The breeding rate is defined as the amount of fingerlings that adult fish produce per year. The normal breeding rate (**Nor_br_fr**) is the average amount of fingerlings produced per year by female adult fish; this equals 0.5 (rate/year) for a relatively low or “normal” fish density. The stock of young fish is increased by the breeding rate and decreased by the mature rate and death rate, both of whihch are functions of a stock (young fish) and other variables with the effects from fish density (**E_den_D_fn** for death rate and **E_den_M_fn** for mature rate). The adult fish stock increases by the mature rate and decreases by the death rate. The death rate is a function of the adult fish population and the normal death rate of adult fish (**No_ D_adf_fr**).

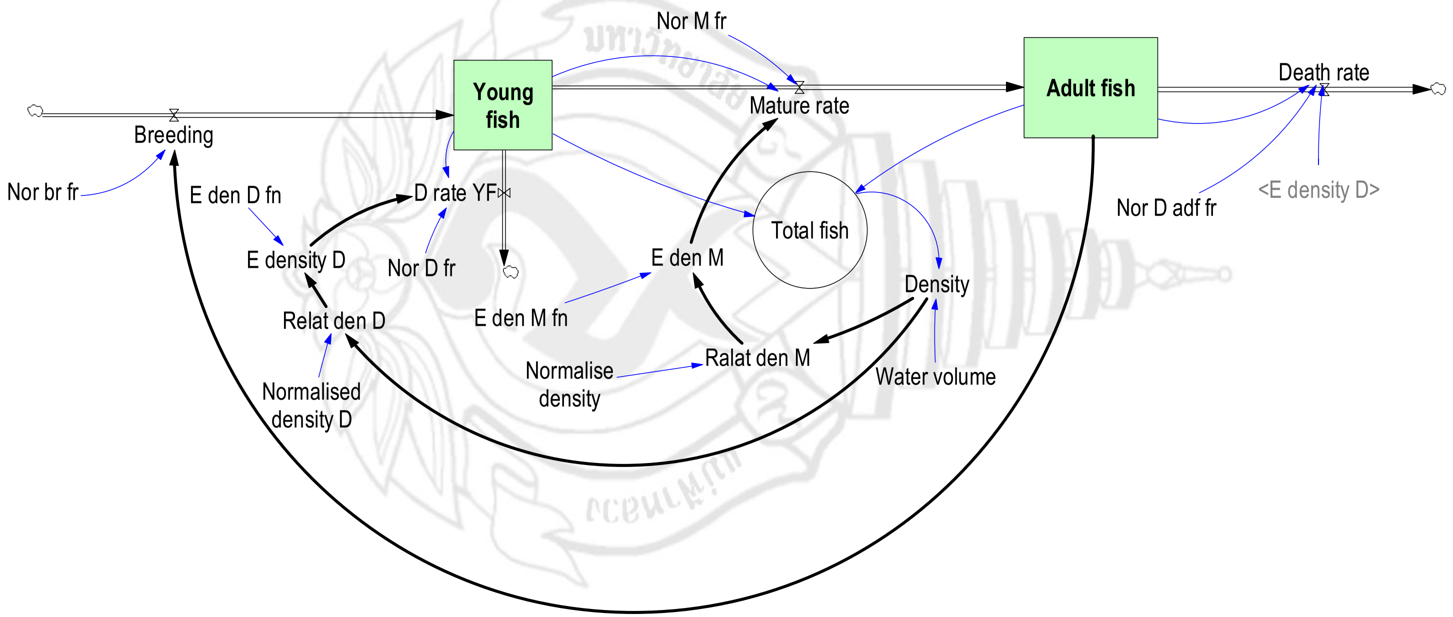

Figure 4.3 Stocks and Flows in the Fishery Sub-System

Equations in the fishery sub-system

Model simulations were run for a period of almost 100 years -- from 1960 to 2050. Key elements of the analysis are captured in the various formulas.

Young Fish stock reflects the stock of fish population at a future time (t+Δt). It is altered by three flow rates: breeding, mature and deaths.

Young Fish (t+ Δt) = Young Fish (t) + {Breeding-D rate YF-Mature rate}*Δt **(1, Stock)**

The initial value for 1960 was: Young Fish (t) = 3,000,00 kg. This value was estimated by back-calculating from recent (2009) catch data from the field survey, since no available data records exist for this specific study site from 50 years ago. This estimate was also based on the assumption of a harvesting rate at 40% of the total fish production, as suggested by McCausland et al. (2005).

D rate YF = Death of young fish

The breeding rate **Breeding** is the product of Adult Fish stock, and the normal breeding rate **Nor br fr**.

Breeding = Adult fish*Nor br fr (2, Rate)

Where Nor_br_fr = Normal breeding fraction (0.5 fraction/year)

The death of young fish rate **D rate YF** is the product of the table function of effects of density on death, normal death, and young fish population.

D rate YF = E_density_D*Nor D_fr*Young fish

Where E_density_D = effect of density on death rate is a table of function (Figure 4.4) and has unit as dimensionless

Nor D_fr = Normal death fraction (0.2 fraction/year)

According to Figure 4.4, a fish population density that equals one has no effect; here death rate equals one. At low population density, the death rate equals its normal death fraction. As fish density increases, the death rate also increases from its prior normal level. This happens due to the higher competition for available food and habitat among the fish population.

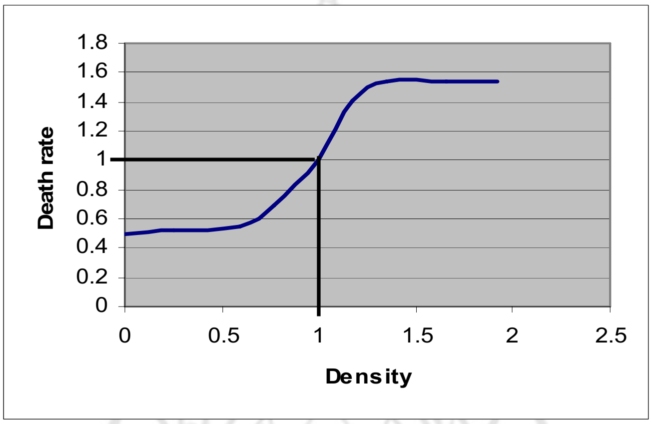

Figure 4.4 Effect of Density on Death

The **mature rate** is the product of the table function of effects of density on mature, normal mature and young fish population.

Mature rate = E_den_M*Nor M_fr*Young Fish **(3, Rate)**

where E_den_M = effect of density on mature rate (Figure 4.6) is a table function and has unit as dimensionless

Nor_M_fr = Normal mature fraction (0.5 fraction/year)

According to Figure 4.5, when fish population density is low, the proportion of mature fish is quite high. However, as density increases, the proportion of mature fish decreases. This assumption reflects a saturation phenomenon. When density equals one and mature also equals one, there is no effect between the two variables.

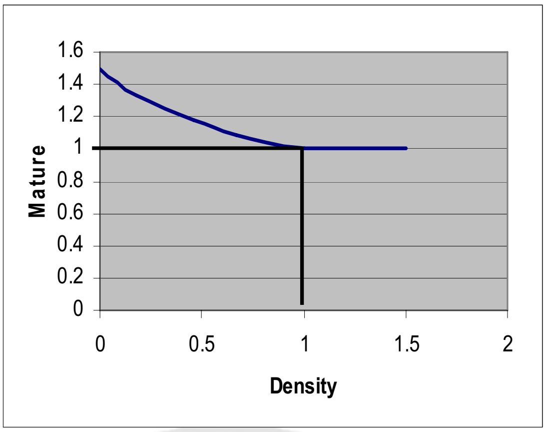

Figure 4.5 Effect of Density on Mature Rate

Adult Fish stock the stock of population is altered by two flow rates mature and deaths.

Adult Fish (t+ Δt) = Adult Fish (t) + {Mature rate - D rate AF}*Δt **(4, Stock)**

Initial value at the year 1960, Adult Fish (t) = 2,000,00 kg (the value also was estimated based on the catch data from field survey in 2009)

where D _rate _AF = Death of adult fish

D rate YF = E _density _D*Nor _D_ fr*Adult Fish **(5, Rate)**

where E_density_D = effect of density on death rate is a table of function (Figure 4.4)

Nor _D_ fr = Normal death fraction (0.2 fraction/year)

Mature rate = E _den_ M*Nor _M _fr*Young Fish (this equation is the same as the equation 3 above)

Figure 4.6 illustrates S-shaped growth in fishery stock, also known as “logistic” growth. This common type of behavior combines both positive (Loop 1) and negative (Loop 4) feedback loops. The shape shows distinct regions. The positive feedback loop produces exponential growth, followed by the negative feedback loop that produces asymptotic growth. At the beginning, births exceed deaths and the stock grows exponentially. However, the excess of births over deaths decreases as the growing fish density regulating acts as the growth-limiting factor.

The system enters equilibrium when the net growth rate (births minus deaths) equals zero. The behavior of this fishery sub-system shares a similar shape with the flowed area model developed by Andrew (1999).

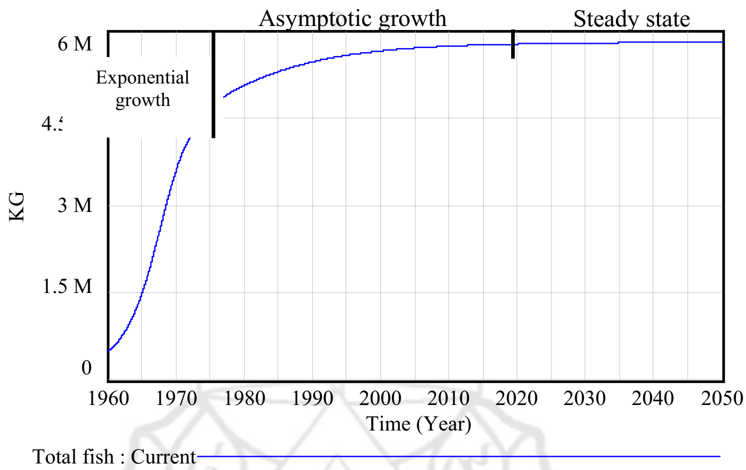

Figure 4.6 Fishery Stock Behavior

4.2.3 Modeling of the fishermen sub-system

4.2.3.1 Feedback Loops in the fishermen sub-system

Figure 4.7 presents the fishermen sub-system. This model focuses on ways by which fishermen can change their economic status from poor to non-poor (Loop 1). We assume that the poor fishermen upgrade their economic status to become non-poor fishermen through status changing. If more poor fishermen, then leads to more status changing and finally add to increase the non-poor fishermen. Loop 2 shows the negative relationship of the population of poor fishermen and the quitting rate. It is perceived that more fishermen will increase quitting rate (the leaving job as fishermen rate), on the other hand more quitting rate will decrease the poor fishermen stock. The same explanation covers the non-poor fishermen and their quitting rate (Loop 4). The stock of both poor and non-poor fishermen increases with each new entrant. In addition, the new entrant increases when the potential fishermen population increases (Loop 3 and Loop 5).

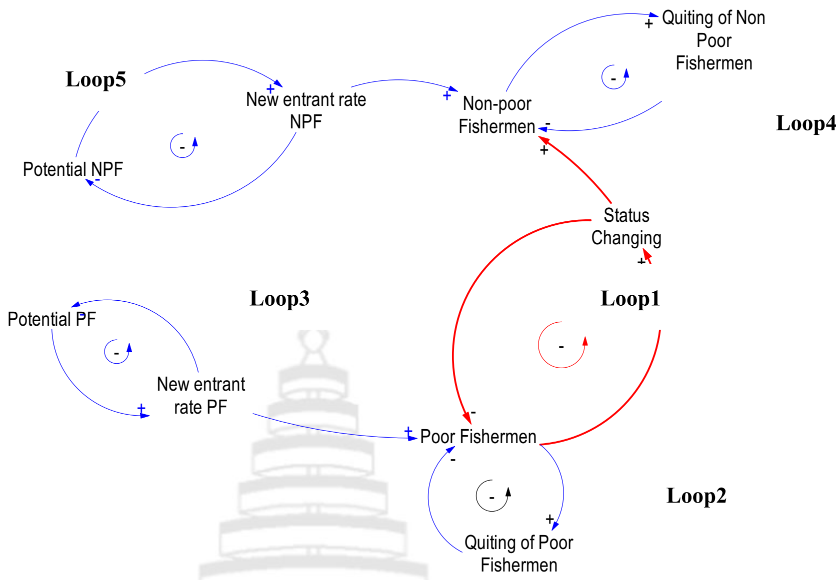

Figure 4.7 Feedback Loops in the Fishermen Sub-System

4.2.3.2 Stocks and flows in the fishery sub-system

Figure 4.8 sets out the fishermen sub-system flow diagram. The net growth rate of poor fishermen **Net_growth of PF_rate** is related to the stock of potential poor fishermen **Potential PF** as affected by the normal growth fraction **Fr_PF**. The poor fishermen stock is increased by the new entrant rate for poor fishermen **Newentrant rate PF** and the normal new entrant fraction **Fr_ NE _PF**. The poor fishermen stock is depleted by the quitting rate of poor fishermen **Quitting rate of PF** and the normal quitting rate of poor fishermen **Fr _Q_ PF**. The non-poor fishermen stock **Fishermen NPF** increases through the changing status of poor fishermen **Fishermen P** and the normal status change fraction **Fr _st_ change**. At the same time the number of non-poor fishermen is increased by new entrant non-poor fishermen **Newentrant rate NPF** and the normal new entrant fraction **Fr _NE _NPF**. In addition, the new entrant rate depends on the potential non-poor fishermen stock. Furthermore, the net growth rate of non-poor fishermen **Net growth of NPF_rate** is related to the stock of potential poor fishermen **Potential PF** by the normal growth fraction **Fr_NPF**. However, the non-poor fishermen stock is decreased by the quitting rate **Quitting rate** of NPF and normal quitting fraction **Fr _Q_ NPF**.

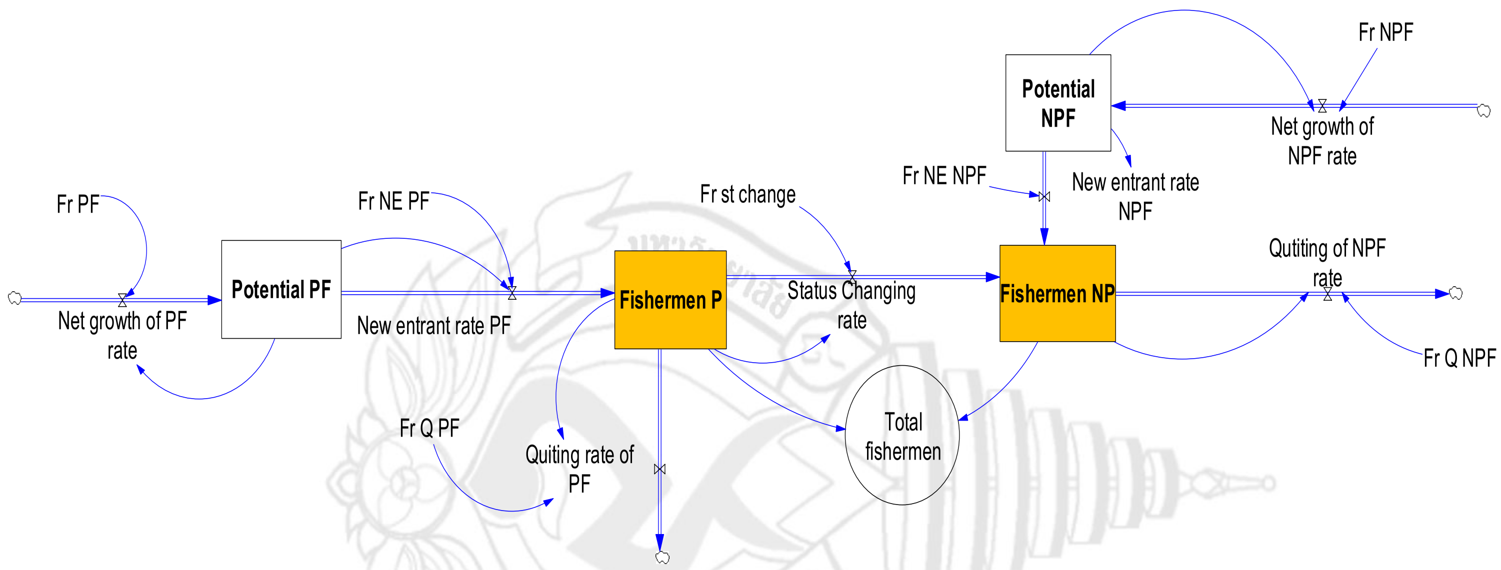

Figure 4.8 Stocks and Flows in the Fishermen Sub-System

Equations in the Fishermen sub-system

The stock of potential poor fishermen reflects the net accumulation over time of the net growth of PF rate and the new entrant poor fishermen rate.

Potential PF (t+Δt) = Potential PF (t) + {Net growth of PF rate – New entrant rate PF}*Δt (**6, Stock**)

Initial value at the year 1960, Potential PF (t) = 150 persons.

The value of this initial stock had been estimated by back-calculating from 2009 field survey data on number of poor fishermen. This estimate is assumed in order to simplify the model simulation.

Net growth of PF rate = Net growth of poor fishermen rate

New entrant rate PF = New entrant of poor fishermen rate

The stock of the fishermen population is altered by three flow rates: New entrants of poor fishermen, status changing, and quitting.

Fishermen P (t+ Δt) = Fishermen P (t) + {New entrant rate PF -Quitting rate of PF-Status Changing}*Δt (**7, Stock**)

The initial value in 1960 = 30 persons

Quitting rate of PF = Quitting of poor fishermen rate

Status Changing = Status changing from poor fishermen to non-poor fishermen rate through application of livelihood improvement interventions

The stock of potential non-poor fishermen reflects the net accumulation over time of the net growth of NPF rate and the new entrant non-poor fishermen rate.

Potential NPF (t+ Δt) = Potential NPF (t) + {Net growth of NPF rate – New entrant rate NPF}*Δt (**8, Stock**)

The initial value in 1960 = 50 persons

Net growth of NPF rate = Net growth of non-poor fishermen rate

New entrant rate NPF = New entrants of non-poor fishermen rate

The stock of non-poor fishermen is altered by two flow rates New entrants of poor fishermen and quitting.

Fishermen NP (t+ Δt) = Fishermen NP (t) + {New entrant rate NPF -Quitting rate of NPF}*Δt (**9, Stock**)

The initial value in 1960 = 60 persons

Quitting rate of NPF = Quitting of non-poor fishermen rate (**10, Rate**)

The rate equations of this fishermen sub-system will be explained in the text describing the interactions between the fishery sub-system and the fishermen sub-system.

Figure 4.9 illustrates the exponential growth of the fishermen population over time. The fishermen stock increases as new entrants continually add to the stock. In this case each new increment (value of rate) to the level is larger than the previous increment because it is proportional to the preceding size of the stock.

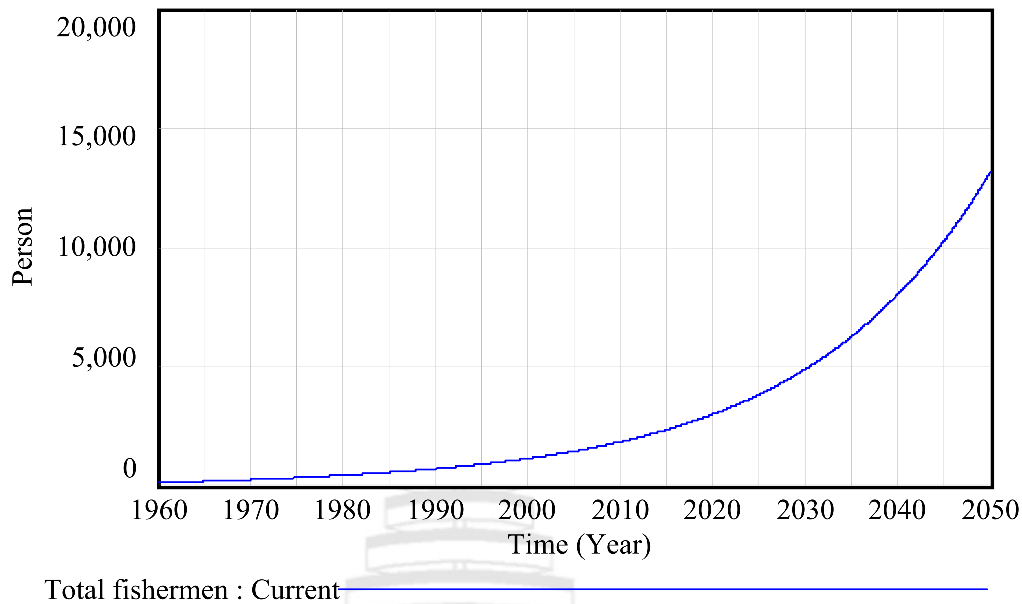

Figure 4.9 Fishermen Stock Behavior Overtime

4.2.4 Interactions between the two sub-systems

Feeback loops and stocks and flows

Figures 4.10 and 4.11 present the completed feedback loops and stocks and flows of the model that now contains both fishery and fishermen sub-systems. These diagrams consist of various linkages that contribute to generate the fishery and fishermen behaviors that mirror in schematic form the actual interactions of the fishery and the fishermen in Trapaeng Rung Channel.

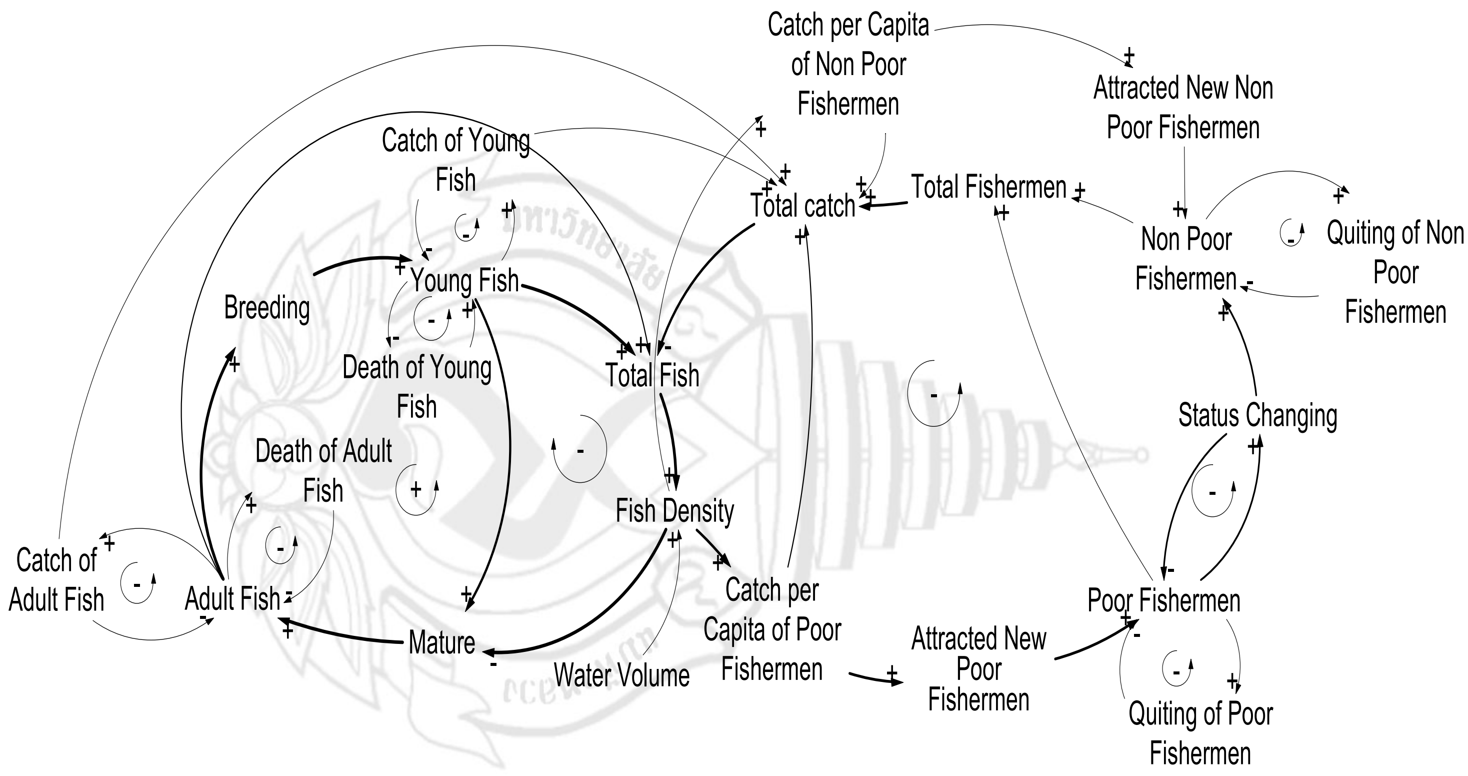

Figure 4.10 Feedback Loops in the Interactions of the Fishery and Fishermen Sub-Systems

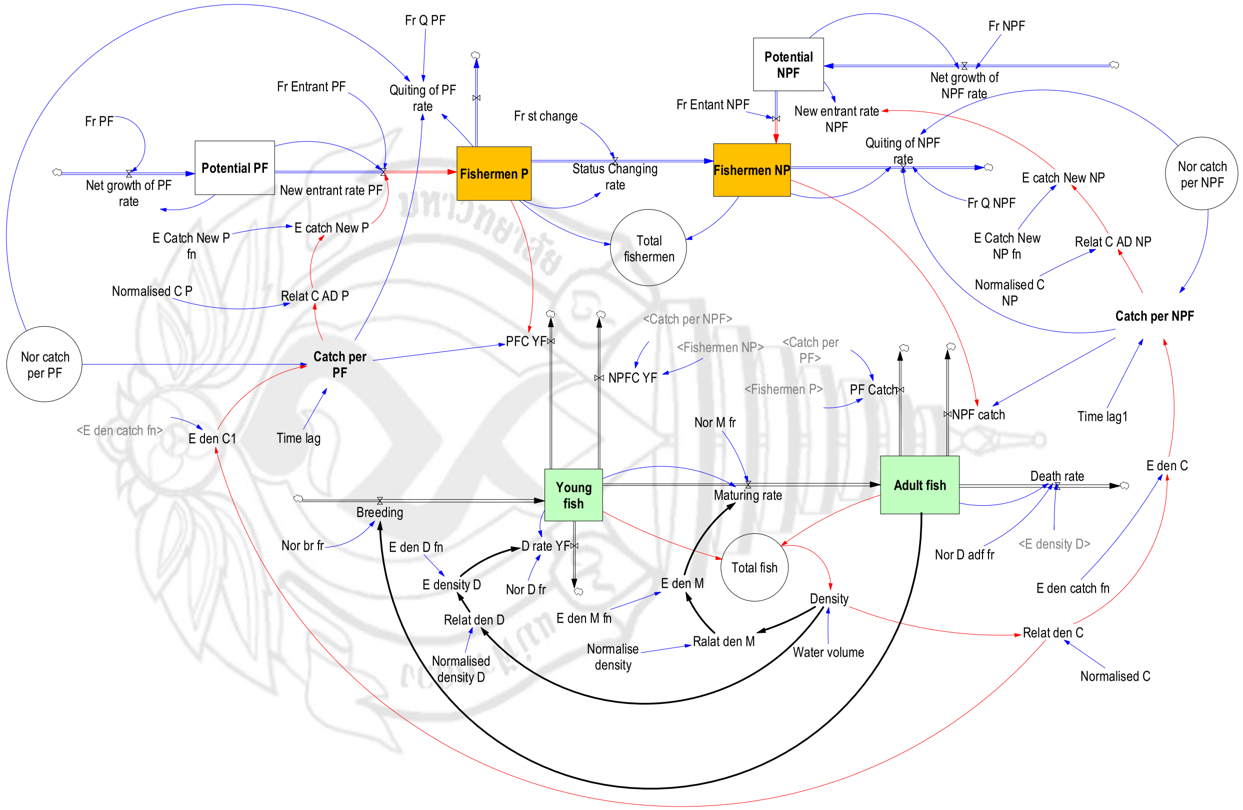

Figure 4.11 Stocks and Flows in the Interactions of the Fishery and Fishermen Sub-Systems

Equations of Fishery and Fishermen sub-systems

1. Net growth of poor fishermen rate, **Net growth of PF rate,** the product of potential poor fishermen stock, and the normal growth fraction Fr _PF.

Net growth of PF rate = Potential PF*Fr _PF **(11, Rate)**

Where Fr _PF = Normal growth of poor fishermen fraction (0.15 fraction/year)

2. New entrant of poor fishermen rate, New entrant rate PF

New entrant rate PF = Fr _Entrant_ PF*E _catch New_ P*Potential PF **(12, Rate)**

Where Fr _Entrant_ PF = Normal new entrant of poor fishermen fraction (0.1 fraction/year)

Potential _PF = Potential poor fishermen

E _catch _New_ P = Effect of catch per capita on new entrant of poor fishermen (Figure 4.12) is a table function and has unit as dimensionless

According to Figure 4.12, catch per capita increases slowly. When catch per capita increases, this attracts new entrants into fishing. However, saturation occurs when catch per capita reaches one and new entrants of fishermen equal one. Therefore, there is no effect between the two variables.

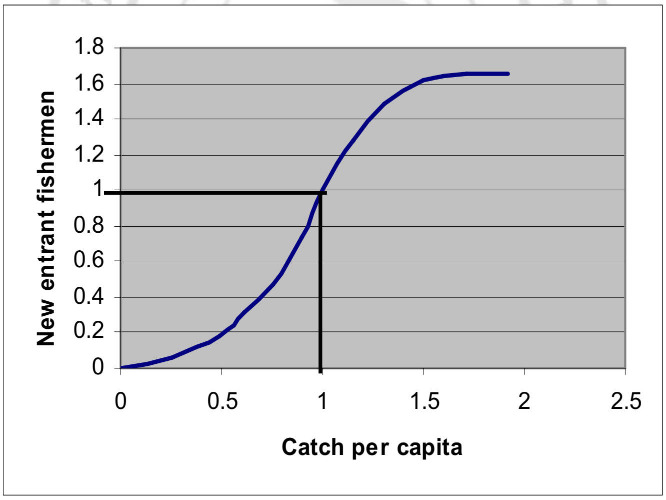

Figure 4.12 Effect of Catch per Capita on New Entrant Fishermen

3. Quitting of poor fishermen rate, **Quitting of PF rate**

Quitting of PF rate = IF THEN ELSE (Catch per PF<Nor catch per PF, Fishermen P*0.1, Fishermen P*Fr_ Q_ PF) **(13, Rate)**

where Nor catch per PF = Normal catch per capita of poor fishermen (53 kg). This value is estimated based on the field survey data in 2009 (details of how the value can be derived are attached in Appendix C).

Catch _per_PF = Catch per capita of poor fishermen (due to the catch per capita is very fluctuate information, the smooth function is used to averaging the value for 5 years)

Catch per PF = SMOOTH (Nor catch per PF*E _den C1, Time lag) **(14, Rate)**

Nor catch per PF = Normal catch per capita of poor fishermen (53 kg)

E den C1 = Effect of density on catch per capita (Figure 4.13) is a table function and has unit as dimensionless

According to Figure 4.13, fish density (as one would expect) definitely affects catch per capita. When density is low, catch per capita is also low; when fish density increases, then catch per capita increases. However, saturation arises when fish density and catch per capita both equal one. At that point, there is no effect between the two variables.

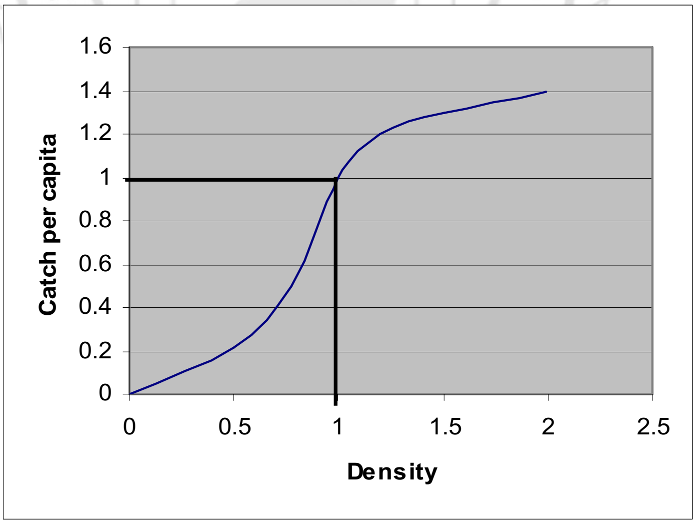

Figure 4.13 Effect of Catch per Capita on New Entrant Fishermen

4. Status changing rate

Status changing rate = Fishermen P*Fr _st_ change **(15, Rate)**

where Fishermen P = Poor fishermen population

Fr_st _change = Normal status change rate (0.01 fraction/year)

5. Net growth of non-poor fishermen rate, **Net growth of NPF rate**

Net growth of NPF rate = Potential NPF*Fr NPF **(16, Rate)**

where Fr NPF = Normal growth of non-poor fishermen fraction (0.1 fraction/year)

6. New entrant of non-poor fishermen rate, New entrant rate NPF

New entrant rate NPF = E_ catch New NP*Fr _Entant _NPF*Potential NPF **(17, Rate)**

where Fr_Entrant_NPF = Normal new entrant of non-poor fishermen fraction (0.1 fraction/year)

Potential NPF = Potential non-poor fishermen **(18, Rate)**

E _catch_ New NP = Effect of catch per capita on new entrant of non-poor fishermen (Figure C) is a table function

7. Quitting of non-poor fishermen rate, **Quitting of NPF rate**

Quitting of NPF rate = IF THEN ELSE(Catch per NPF<Nor catch per NPF, Fishermen NP*0.2, Fishermen NP*Fr _Q_ NPF) **(19, Rate)**

where Nor catch per NPF = Normal catch per capita of poor fishermen (160 kg). This value is estimated based on the field survey data in 2009 (details of how the value can be derived are attached in Appendix C).

Catch per NPF = Catch per capita of non-poor fishermen (due to the catch per capita is very fluctuate information, the smooth function is used to averaging the value for 5 years)

Catch per NPF = SMOOTH(Nor catch per NPF*E den C1, Time lag) **(20, Rate)**

Nor catch per NPF = Normal catch per capita of non-poor fishermen (160 kg)

E den C1 = Effect of density on catch per capita (Figure D) is a table function

4.3 Model simulation

Base case simulation and analysis

Figure 4.14 shows the results of our model's base run of fish stock. Three distinct phases over many years characterize this behavior. The first 20 years are marked by rapid growth. Fish stock behavior at this point indicates a slight abundance of fish. Breeding and maturing rates grow exponentially while deaths and catches are relatively modest. The positive feedback loops involving population without fish density as liming factor dominate in this phase. During the next 10 years we see a marked transition. In this phase, fish population reaches its maximum and remains in a steady state for a short time. Then, it begins to decline as fish density and catches restrict fish population growth. The result is that fish stock declines at an increasing rate. Here the negative feedback loop involving fish density and fishermen catches begin to dominate. Therefore, in the long-run, the fish stock shows decline tendency.

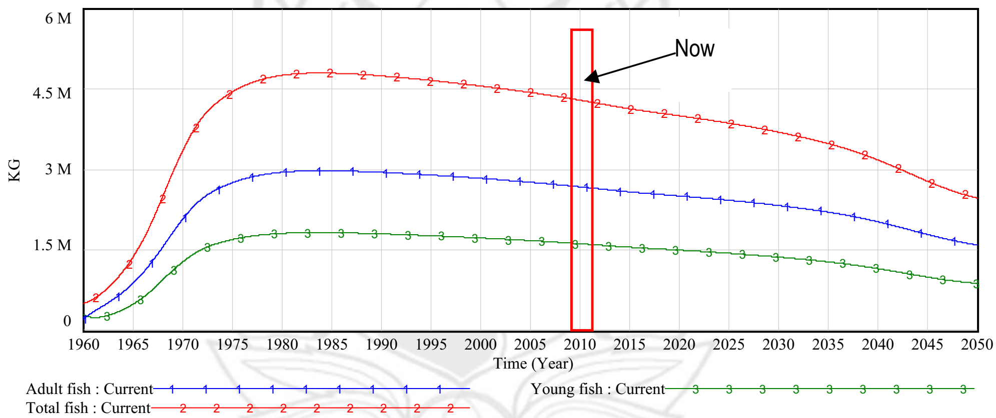

Figure 4.14 Fish Population Change Overtime

According to the information on natural resources utilization pattern that was obtained from villagers during the field research, for about a decade from early 1975 to 1985 not many people stayed in the villages of Trapaeng Rung commune. This was the time of war and killings. Therefore, few fish were being caught. As a result, the total fish population expanded up to its equilibrium level.

However, beginning in late 1990 and continuing to 2002, extensive forest logging took place in this area. As a result, many new migrants moved into the commune. As the result, while the fish population was disturbed to some extent it did not change much because at that time villagers had many job options such as collection of non-timber forest products (NTFPs) and forest logging.

In 2002, the study site was designated as a protected area in which collection of NTFPs for commercial purposes was strictly prohibited. Consequently, most local villagers had to depend on exploitation of available fisheries resources. From that time until the present (late 2009), hence, fish stock has gradually decreased as shown in Figure 4.14 Given our model assumptions, from 2009 until the end of the model simulation runs (2050) fish stock will continue to drop because new fishermen keep entering into this role. Clearly this leads to over-harvesting of local fisheries resources in the long-term.

Figure 4.15 shows changes in fishermen population. From the beginning of our long-term model (1960), the total number of fishermen grew very slowly from the total fishermen of 90 people, with the small number of new entrant fishermen being about the same as the number who were quitting further fishing for some other occupation. However, from 1970 onwards until the end of the model simulation (2050), the fishermen population keeps increasing exponentially because of the incremental growth in new entrant fishermen. This is especially the case for poor fishermen.

The figure also illustrates the rather different shapes of the poor and non-poor fishermen curves. It indicates that while the population of poor fishermen grows gradually, the number of non-poor fishermen population also increases, but more slowly. It seems that the number of poor fishermen entering to fishing job is greater than the number of no-poor fishermen 4 times. According to the data from the field survey, many poor villagers tend to enter into fishing because they do not have any reasonable alternative jobs to pursue. The poor fishermen population increases unabated because every year fishing remains the most attractive job on which they can rely at the moment and in the near future. Other alternatives, including agriculture, are even less attractive. Most of them previously have had combinations of jobs: NTFPs collection or on-demand work as wage laborers in agriculture. However, since the NTFPs collection has faced more stringent regulatory restrictions, they have become more and more dependent on fishing as their primary means of making a livelihood.

In contrast, the non-poor fishermen have various options to acquire their livelihoods and support their families. These alternatives include running a small or mid-sized restaurant or farming because they have the necessary financial capital and other skills besides fishing. Even though not many non-poor households are now engaged in fishing, most of them are equipped with better and more effective fishing gear, which enhance their ability to catch larger amounts of fish compared to the area's poor fishing households.

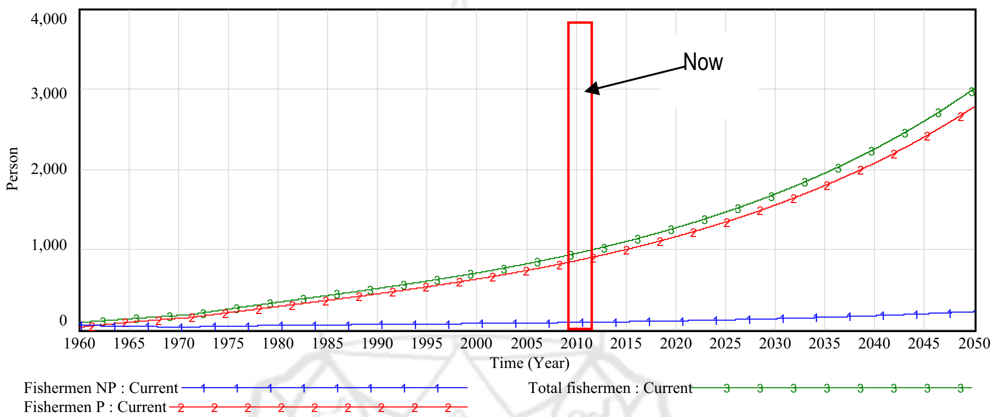

Figure 4.15 Fishermen Population Behavior

Figure 4.16 below illustrates the catch per capita of poor and non-poor fishermen. Their curves are featured in the S-shape growth. Catch per capita is auxiliary that link the fishery sub-system and fishermen sub-system, therefore it depends on those sub-systems. There is the gap between the catch per capita of poor fishermen and non- poor fishermen.

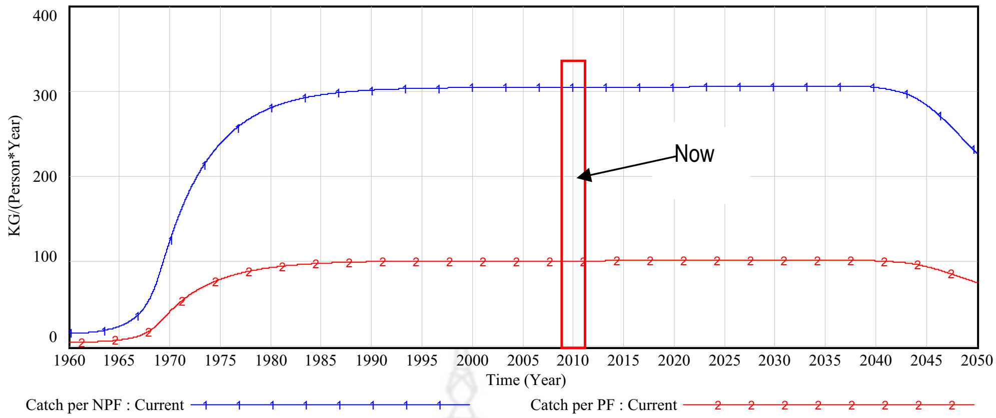

Figure 4.16 Catch per Capita of Poor and Non- poor Fishermen

The catch per poor fisherman is quite far (threefold) lower than the catch per non-poor fisherman. This gap results from catch capacity of each group of fishermen. For instance, non-poor fishermen group have more and better tools (as mentioned in the earlier section on the fishing gears are possessed by different wealth groups) than the poor group because they have their own capital to invest in the fishing job and most often the non-poor fishermen tend to fish for commercial purpose regardless the scale of their fishing operation falls under family scale. In this case, it shows that livelihood capital in terms of financial capital plays an important role in enhancing the accessibility to the free access resources. Observing the individual pattern, the catch per capita of poor and non-poor fishermen characterizes with the steady condition, and then it drops down at the year 2040. This pattern happens because of the increasing of the new fishermen into the fishing job, and then it leads the total population of fishermen increase gradually, therefore more fishes are harvested, which make the fish stock is getting smaller. The increasing of population of the fishermen causes to decrease a proportion of sharing the fisheries resources among those fishermen. In the current situation, the catch per capita is not the crucial influence factor on the new entry fishermen because most of fishermen still can catch at the normal current rate.

4.4 Sensitivity analysis

In this modeling the sensitivity testing was conducted in order to learn the robustness of the fish and fishermen population modeling in terms of generating the behavior.

A variable named catch per capita of the poor fishermen was selected to test the influence on the fish population. Figure 4.17 shows four simulations with different catch per poor fisherman. The simulation with the catch per poor fishermen at 53 kg per year is the base case. The simulation with the catch per poor fishermen at 43 kg per year is the behavior upper the base simulation. The simulations with the high catch per poor fishermen rate of 63 kg/year and 73 kg/year are lower the basic simulation. The four simulations are moderately different when judged in terms of the declined state of the fish population. On the other hand, the four simulations are similar in many respects. For instance, they illustrate identical behavior in the years from 1960 to 1980. Then all four simulations show the declining fish population behavior after their steady states. With this regard, the conclusion can be derived that the model provides the robustness to simulate the over time behavior of the whole system with the variable "catch per poor fishermen" change.

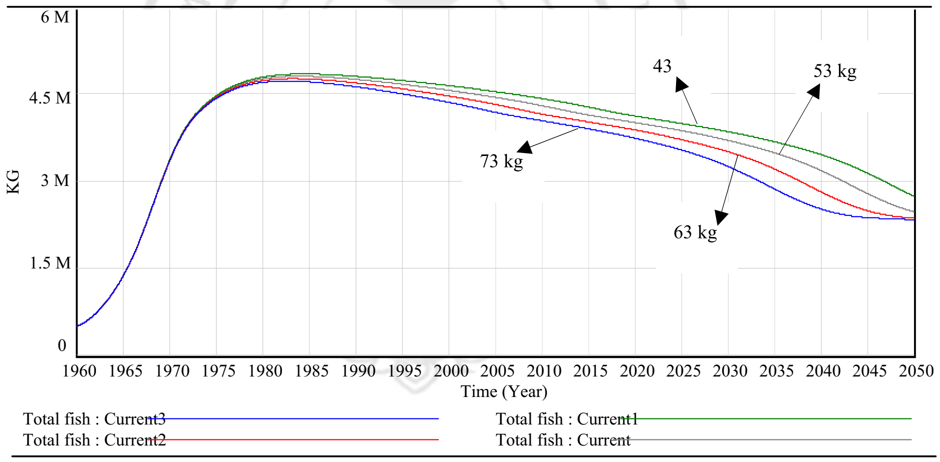

Figure 4.17 Sensitivity of the Fish Population to Changes in the Catch per Poor Fishermen

Here the second sensitivity analysis by using three different causal relationships between density and catch per capita (see in Figure 4.18). The middle graph (Y0) is the base case assumption that used to simulate the in the model for entire research. All three graphs adopt the same assumption when the density reaches reference point 1, there are three effects including weak, strong and no effects. And all three graphs show that the catch per capita will be increasing if the density goes far from 1.

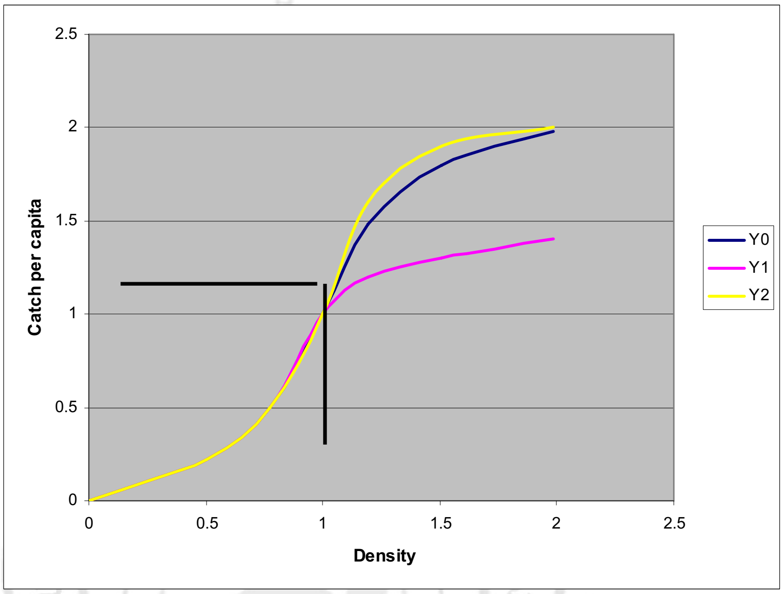

Figure 4.18 Relationship of density on catch per capita

Thear are three possible causal relationships between density and catch per capita.

1. Y0 based relationship
2. Y1 weak effect of density on catch per capita
3. Y2 strong effect of density on catch per capita

Figure 4.19 shows a comparison of the fish population with the three different non-linear relationships assumption. The middle simulation is the result of the using the base case non-linear relationship. The above graph is the result of the simulation of Y1, which is weak effect of density on the catch per capita. It referees that the catch per capita is increasing slowly, when density above reference point 1. The lowest graph portrays the simulation of Y2 that shows density has strong effect on the catch per capita. Here, catch per capita increase shapely when density above 1, then leads to decrease in fish population. In general, the pattern change of this simulation is quite similar to the previous simulation (Figure 4.13).

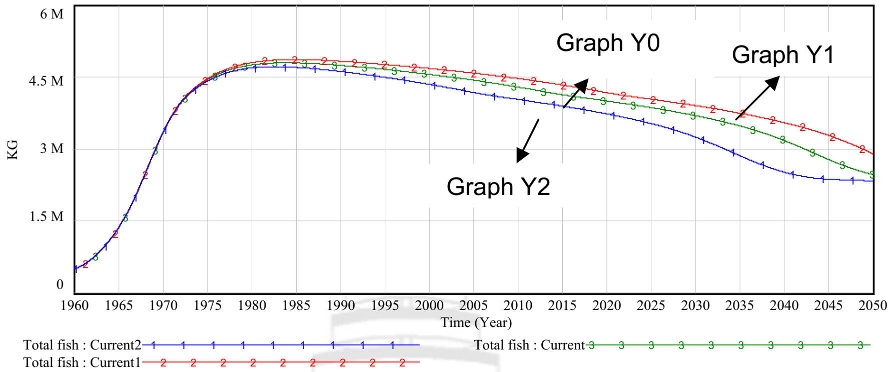

Figure 4.19 Fish Population in Simulation with Three Different Relationships of Effect of Density on Catch per Capita

4.5 Management options for sustaining fisheries resources and enhancing the benefits of the poor fishermen

4.5.1 Available management options

A set of specific management options have been identified based on the specific features that are most compatible with a community-based natural resources management (CBNRM) framework. CBNRM is a well-known legal framework applicable at the grassroots level, with working experience already in Cambodia as a successful, practical approach. The management approaches were chosen to achieve two main purposes: sustaining fisheries resources in the study area, and improving the accessibility to those fisheries resources on the part of local poor fishermen.

The lists below summarize the various management options. Some were derived from various available and relevant documents, especially the *Compilation of Legal Instruments Related to Community Fisheries in Cambodia.* Some others are proposed based on the data available from the fieldwork. Still other options incorporate ideas presented by villagers during the fieldwork (see Appendix D: Perspectives of local villagers toward CBNRM).

The five management options identified through this research effort, along with key impacts, are summarized in Table 4.6.

Table 4.6 Management Options to be Examined

No.	Management Options	Key impacts Impact on sustaining fisheries resources	Impact on improving better access for poor fishermen	Impact on overall economic status of fishermen
Individual case				
1	**Regulate use of specific fishing gear (control fishing efforts)**	- Decrease pressure on fisheries resources	- Help reduce catch rates of non- poor fishermen, making more fish available for poor fishermen. This approach can provide an indirect way to improve access for poor fishermen	- Some fishermen who currently use intensive fishing gear to catch fish may face a reduction in their catch rate, with subsequent economic loss. However, this should be a short term negative impact on their income because after 2-3 years of implementing this measure some fisheries stock will increase. At that point, even fishermen using less gear would be able to harvest an acceptable total amount of fish.

Table 4.6 (continued)

No.	Management Options	Key impacts Impact on sustaining fisheries resources	 Impact on improving better access for poor fishermen	 Impact on overall economic status of fishermen
Individual case - Proposed limits on allowable fishing gear: - Gill Nets: Not more than 7 sets of gill nets (sized not less than 1.5 cm) per fishing household - Crab Traps: Not more than 20 crab traps (mesh size not less than 6 cm) per fishing household - Hooks: Not more than 100 long-line hooks per fishing household - Prohibit use of any explosive or electrode devices				
2	**Limit the numbers of new fishermen allowed**	- Reduce the excess demand now being placed on the fisheries resources, and maintain the area's fisheries resources for sustainable long-term utilization	- This option may not be favorable for those poor households who intend to engage in fishing in the future, but may be precluded from doing so. However, those poor households who already have been fishing for their livelihoods will be more likely to keep fishing even longer.	- Existing fishermen will benefit from this regulation because they can catch fish at the same rate or even higher, and can remain as productive fishermen for longer.

Table 4.6 (continued)

No.	Management Options	Key impacts: Impact on sustaining fisheries resources	Impact on improving better access for poor fishermen	Impact on overall economic status of fishermen
3	**Replenish and enrich fisheries resources**	- Replenish fisheries resources in the natural channel, thereby increasing the stock of fish available over time	- The approach does not provide significant focus on improving the access of the poor to the fisheries resources. However, with more fish available this can reduce the conflict of interest between poor and non-poor fishermen.	- Implementing this approach will improve long-run resources utilization of all fishermen.
- Provide community-based fingerlings nursery and support center				
4	**Prohibit fishing in defined breeding areas (no-entry zone)**	- Protect the primary fish breeding areas, providing a better habitat for juveniles and breeders with high survival rates.	- This measure does not enhance the lot of poor fishermen.	- The option will provide benefits for all fishermen because over time there will be more available fisheries resources in the fishing grounds.

Table 4.6 (continued)

No.	Management Options	Key impacts		
		Impact on sustaining fisheries resources	**Impact on improving better access for poor fishermen**	**Impact on overall economic status of fishermen**
5	**Provide loans to improve poor fishermen's access to fisheries resources and increase their catch per capita**	- Accelerate the destruction of fisheries resources	- This option specifically emphasizes enabling poor fishermen to have better access to fisheries resources	- The measure will benefit fishermen as a whole through better access to loans; poor fishermen can generate more income from their fishing activities.
- Establish commune-level savings group and provide priority to poor fishermen to access the fund for buying more effective fishing tools				

4.5.2 Evaluating and comparing alternative fisheries management options

The preliminary results presented in Table 4.6 each deal with only a single baseline scenario. To extend the analysis further, the same sub-model was used to simulate the differences in fish populations and in catch per fisherman of non-poor and poor fisherman under baseline and policy scenarios. This allows quick examination of a number of situations with minimal modification to the model. Table 4.7 presents our assessment of the five management options, based on the modeling.

Table 4.7 Structure for Assessment of Policies with Specific Management Targets

Measurement Variable	Policy and Management Targets
	Policy Option 1. Regulate use of specific fishing gear
Catch per capita rate for non-poor fishermen	- Target #1: Reduce 25% of current catch rate (160 kg) - Target #2: Reduce 50% of current catch rate (160 kg) - Target #3: Reduce 75% of current catch rate (160 kg) Brief explanation of policy option: Use regulatory measures to ban use of specific fishsing gear (poisonous substances and electrode devices) and reduce the number of gill nets allowed from the current rate (some fishing households own and use 10-12 sets) to a maximum of 5-7 sets per fishing household.
	Policy Option 2. Limit the numbers of new fishermen allowed in the fishing grounds
Entry rate	- Reduce the number of new entrant fishermen by 50% of the current entry rate for non-poor fishermen (5 persons per year) and by 20% of the current entry rate for poor fishermen (22 persons per year) Brief explanation of policy option: Take steps to prevent the entrance of new fishermen into fishing through providing better access to other income generation activities and expanded opportunities to improve their skills in order to obtain better jobs. The policy aims to reduce 50% of non-poor new entrant fishermen because this group has more ability to mobilize their resources to invest in the other alternative jobs.
	Policy Option 3. Replenish and enrich fisheries resources

Table 4.7 (continued)

Measurement Variable	Policy and Management Targets
Adding rate of fingerling in to natural channel	- Replenish fisheries resources through establishing a community-based fingerlings nursery to help regenerate resources more quickly. In the simulation, expand the current young fish stock (2.66e+006) by 15% to reach a level of 399,000 kg of young fish (small fingerlings) added to the natural fish stock. Brief explanation of policy option: Build a cage for regeneration of fingerlings in the upper part of the watershed
	Policy Option 4. Prohibit fising in defined breeding areas (establish a "no-entry zone")
Additional number of fingerlings in the natural channel	- Create a no-entry zone in the small stream at the upper part of watershed and strictly enforce entry restrictions. This area would be used by some fish with its favorable conditions for breeding. It is assumed that about 5% (1,330 kg) of current young fish stock will be added every year into the current fishing grounds through their movement out of the new no-entry breeding zone. Brief explanation of policy option: The new no-entry zone is an area protected for the purpose of conserving the fish breeding zone and rehabilitating local fisheries resources.
	Policy Option 5. Provide loans to improve poor fishermen's access to fisheries resources and increase their catch per capita
Catch per capita rate for poor fishermen	- Increase poor fishermen's catch rates to 80 kg/year from the current rate of 53 kg/year. Brief explanation of policy option: Establish a savings group in the commune level and provide priority to poor fishermen to obtain loans to buy more effective fishing tools and thereby increase their catch rates.

4.5.2.1 Analysis of policy option #1: Regulate use of specific fishing gear

Reducing the use of destructive fishing gear through regulating allowable types, mesh sizes, and quantity of fishing gear is one of options that have been implemented under community-based fisheries management systems in other locales. In addition to adopting a community-based management approach as the preferred institutional framework in Trapeang Rung commune, one obvious policy initiative is to regulate the fishing gear operations that are employed here, doing so differentially by different income groups of fishermen. By influencing the fishing gear being deployed by different groups one can alter (reduce) the capacity of the better-off group to access the fisheries resources. This in turn allows the poorer group to catch more fish.

In the system dynamics models we reduced the capacity of fish catch of non-poor fishermen at three different target levels: (#1) reduce the current catch rate of non-poor fishermen (160 kg) by 25%; (#2) reduce the current catch rate of non-poor fishermen (160 kg) by 50%; and (#3) reduce the current catch rate of non-poor fishermen (160 kg) by 75%. In the modeling we tested each option to assess its impact on the fish population and on catch per capita of both poor and non-poor fishermen.

With respect to actual implementation of such a regulatory approach in the community, this strategy can only be enforced throughout the fishing grounds located within the community's boundaries. A good example already exists in Cambodia: the community-based fishery management system (CFi) named Phneat Kohpongsat Community Fisheries located in Banteay Meanchey Province (CFMP, 2006). This CFi is recognized for its outstanding results as a community fishery. Its internal by-laws include regulation of fishing gear use and zoning of a conservation area (no-entry zone). With regard to the law enforcement the CFi formed a patrol group that monitors the fishing practices of community members. The CFi members recognized that fisheries resources in their fishing grounds had started to increase after only a few years of CFi regulatory operations.

Based on these promising results, the impact of regulating fishing gear in a new community-based fisheries management system in Trapeang Rung commune can be expected to produces positive results. Trapeang Rung can learn from the experience of CFi's outstanding community-based management system in enforcing regulations on fishing gear, The target locality can integrate the proposed management options into its own internal rules/regulations. In establishing its new management area, the community has to inventory and assess all kinds of fishing gear that local fishermen currently use -- their number, size, and length. Obtaining this information, and determining its allocation among the different income groups, will be useful for monitoring the effectiveness of regulatory enforcement. The following illustrations were generated based on the results from simulation of each option in the model.

1. Target #1 Reduce current catch rates of non-poor fishermen (160 kg) by 25%

Figures 4.20, 4.22 and 4.21 illustrate the impact of regulating fishing gear under the assumption that this regulatory policy reduces catch per capita of non-poor fishermen by 25% from current levels. The three main variables here are fish stock, catch per capita and fishermen population.

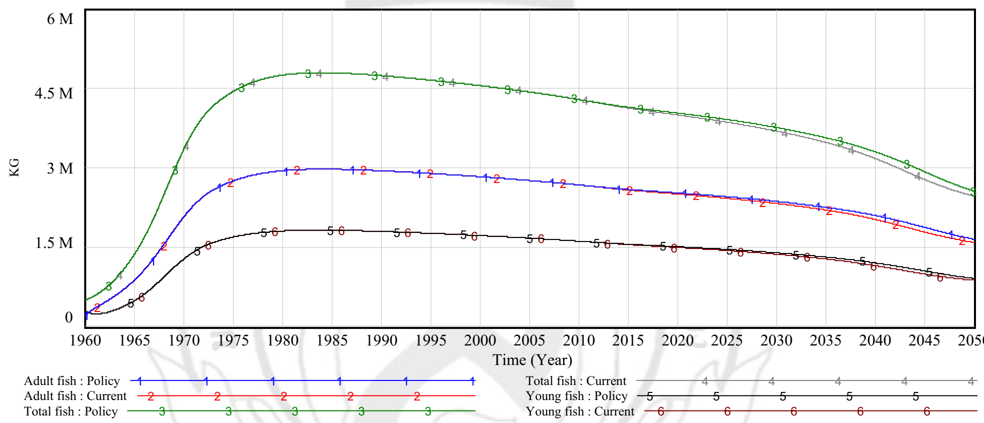

Figure 4.20 Impact of Regulating Fishing Gear on Fish Populations (25% reduction scenario)

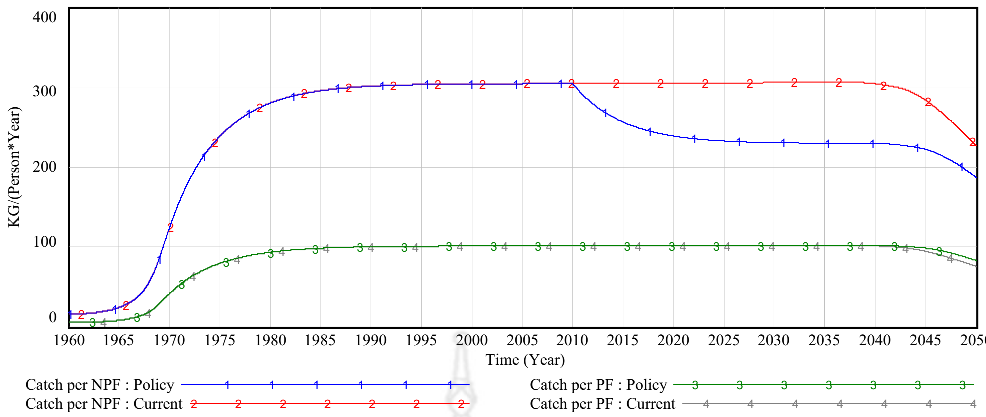

Figure 4.21 Impact of Regulating Fishing Gear on Catch per Capita of Both Poor and Non-poor Fishermen (25% reduction scenario)

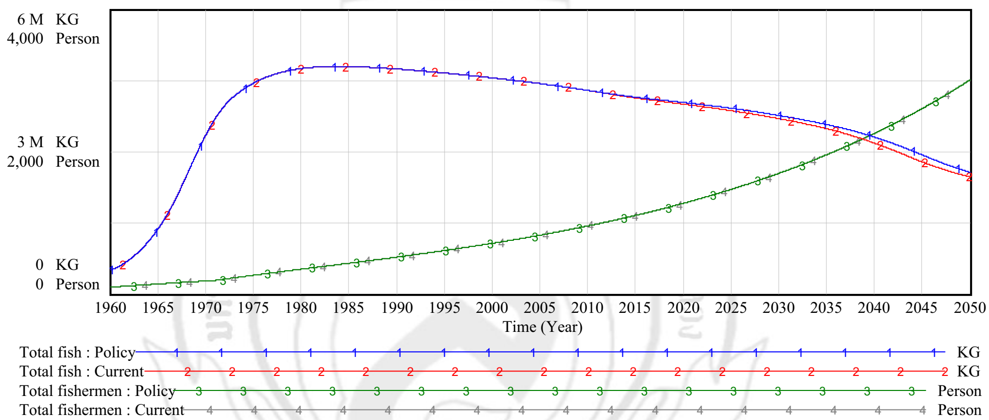

Figure 4.22 Impact of Regulating Fishing Gear on Both Fish and Fishermen (25% reduction scenario)

Under the assumed target by which regulating use of fishing gear reduces catch rates of non-poor fisherman by 25% from their current levels, only a slight change occurs in fish stock production. The fish population can be sustained at a little bit larger level than under the baseline scenario. Catch per poor fisherman is not influenced by implementing the new regulations. Since they do not have access to the larger amounts and better types of fishing gear, they continue to catch fish in generally the same amounts as in the baseline simulation. However, reducing catch per capita rates for non-poor fishermen does reduce somewhat the pressure on fisheries resources in the channel.

2. Target #2 Reduce current catch rates of non-poor fishermen (160 kg) by 50%

Figures 4.23, 4.24, and 4.25 show the different results from the model simulations when we reduce by half the current catch rates of non-poor fishermen. Here the result still does not show a major improvement in terms of maintaining the fisheries resources because the fish stock keeps declining gradually over time. In addition, both poor and non-poor fishermen can catch fish just a little bit longer than under the base line model simulation.

In practice, reducing current catch rates of non-poor fishermen by 50% would be a very big task for the community members responsible for enforcing the regulation. This may be beyond their realistic capabilities.

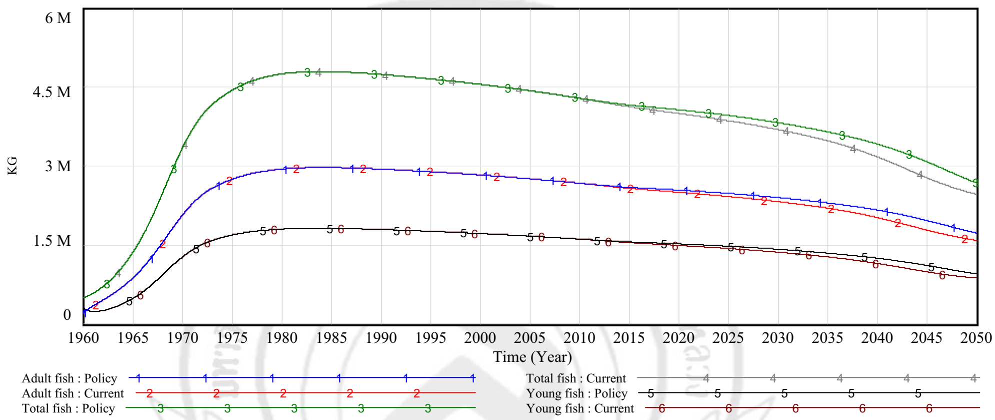

Figure 4.23 Impact of Regulating Fishing Gear on Fish Populations (50% reduction scenario)

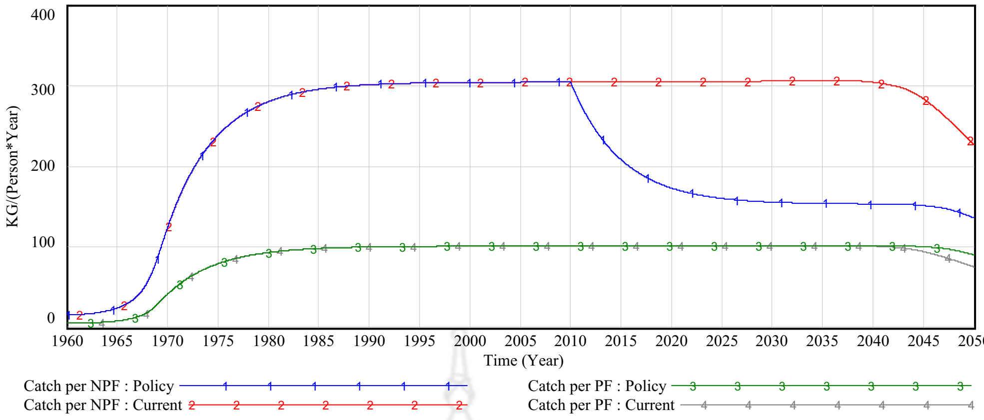

Figure 4.24 Impact of Regulating Fishing Gear on Catch per Capita of Both Poor and Non-poor Fishermen (50% reduction scenario)

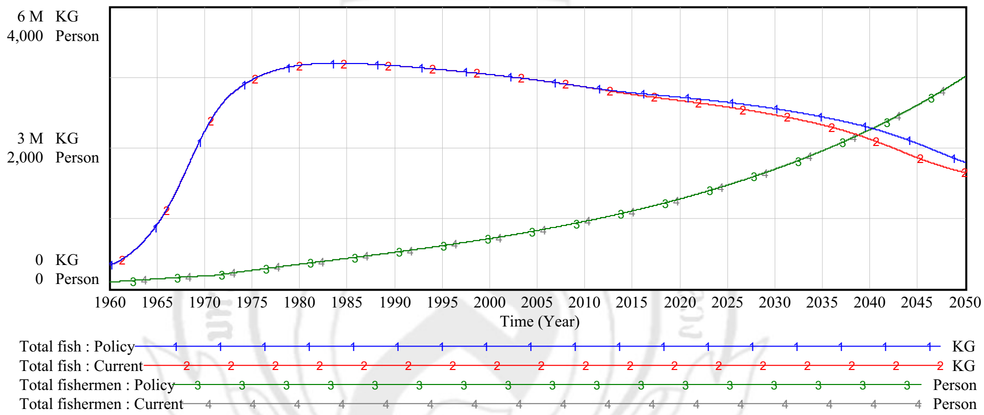

Figure 4.25 Impact of Regulating Fishing Gear on Both Fish and Fishermen (50% reduction scenario)

3. Target #3 Reduce current catch rates of non-poor fishermen (160 kg) by 75%

In this model simulation, catch per capita of non-poor fishermen was assumed to be reduced by as much as 75%, a very large reduction. However, even this policy simulation shows no significant impact. As shown in Figure 4.26, the fish stock demonstrates the same trends as in the smaller reduction levels. The fish stock drops down eventually, though catch per capita of non-poor fishermen drops nearly to levels below the current rate catch of poor fishermen

(Figure 4.27). Figure 4.28 illustrates long-term relationships between fish and fishermen under these assumptions. Even though fish stock declines, fish are available for fishermen to harvest a bit longer than in the baseline simulation.

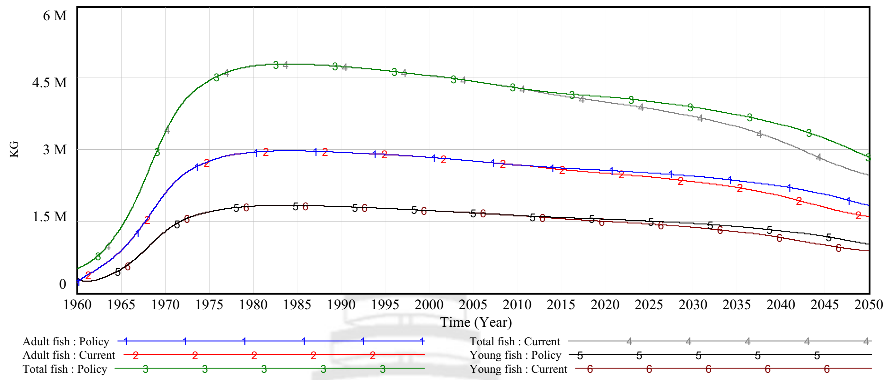

Figure 4.26 Impact of Regulating Fishing Gear on Fish Populations (75% reduction scenario)

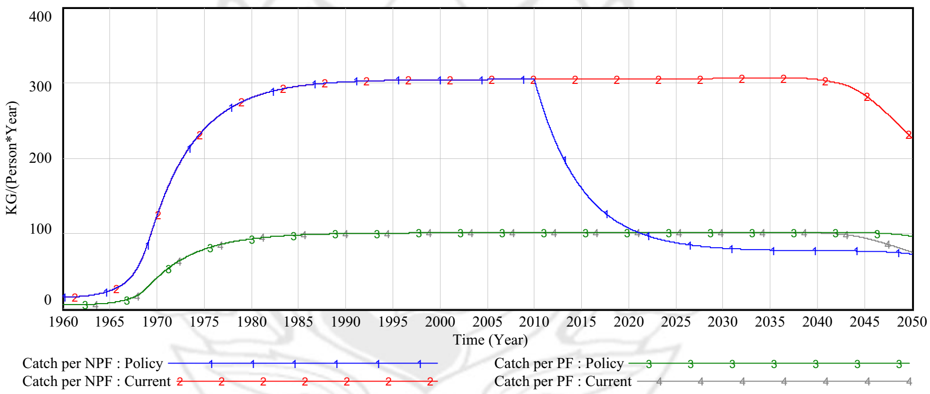

Figure 4.27 Impact of Regulating Fishing Gear on Catch per Capita of Both Poor and Non-poor Fishermen (75% reduction scenario)

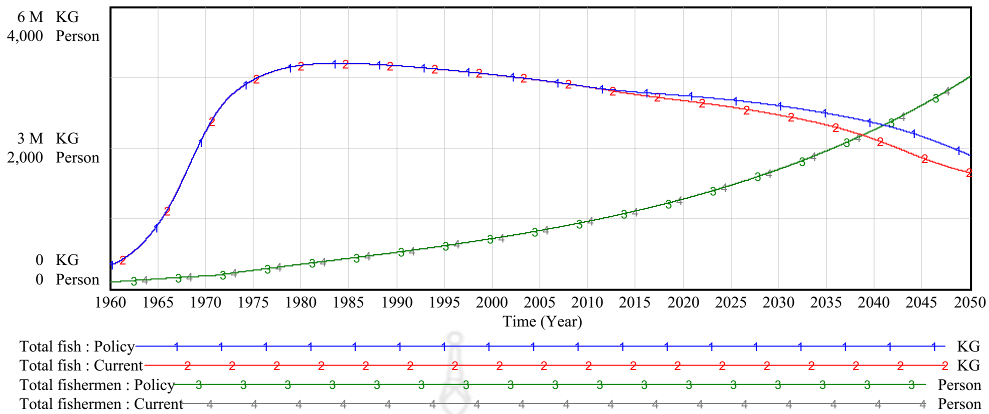

Figure 4.28 Impact of Regulating Fishing Gear on Goth Fish and Fishermen (75% reduction scenario)

In conclusion, even though regulation of the types, sizes, and amounts of fishing gear allowed for use in a certain fishing grounds is well known as a basic way to control fisheries resources, it does not have major impacts (according to modeling results) because decline in catch per capita leads to attempt to deploy more labor in fishing job rather than leaving the job since there is a few alaternative job available in the area. Moreover, this is a very challenging regulation to enforce, especially in an area like Trapeang Rung commune where fisheries resources are already seen as scarce. Most local fishermen tend to want to increase their fishing efforts as much as possible in order to enhance its effectiveness in catching fish (and thus in sustaining their incomes).

4.5.2.2 Analysis of policy option #2: Placing limits on the numbers of new fishermen allowed in the fishing grounds

As mentioned in the problem statement of this study, the increased of the number of fishermen is one main cause of the over-harvesting of fisheries resources in this area. Addressing this problem directly, one solution would be to reduce the number of fishermen by focusing specifically on new entrants into fishing. The specific management options explored would reduce the numbers of new non-poor entrant fishermen by 50% of current entrant rates (5 persons per year) and by 20% for poor fishermen (22 persons per year current rate). By simulating these two policy options, the figures below show the impacts on the main components in the overall system: fishermen population, fish stock, catch per capita, and fishermen and fish populations.

Figure 4.29 shows that the fishermen population grows more slowly under these policy assumptions as compared to the baseline situation. However, the fishermen population keeps increasing at a steady rate, which shows that fishing is still an attractive occupation for some people in the commune.

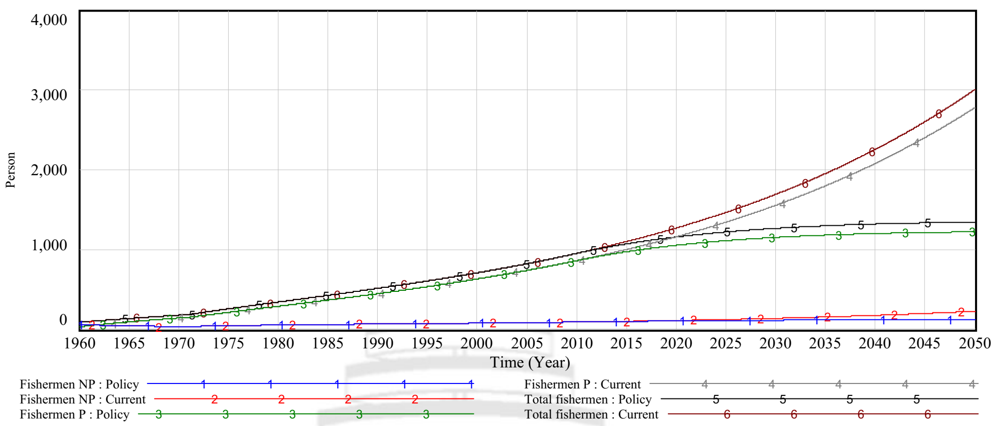

Figure 4.29 Impact of Limiting the Number of New Poor and Non-poor Fishermen on the Fishermen Population

With regard to the impacts of this policy option on fish stock, Figure 4.30 shows that the fisheries resources do not drop as they do under the baseline simulation. Instead, they grow at a steady rate. This fish stock behavior indicates that the pressure on the commune's fisheries resources from increasing the number of fishermen is very an important factor in sustaining the resources. This has obvious policy implications.

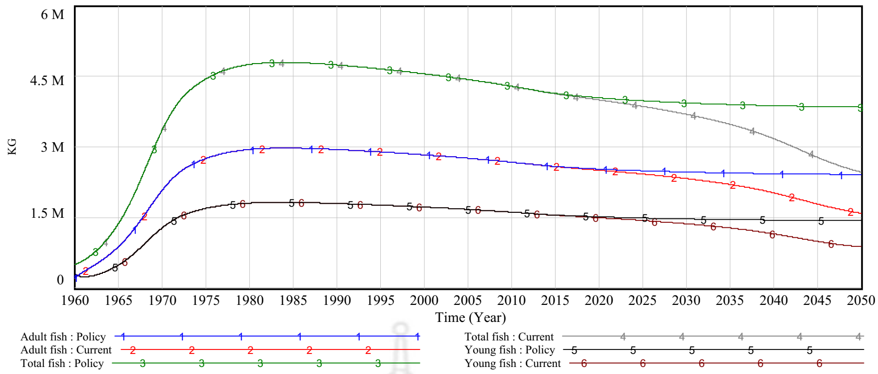

Figure 4.30 Impact of Limiting the Number of New Fishermen on Fish Stock

Figure 4.31 portrays catch per capita of both poor and non-poor fishermen. In this policy simulation their individual catch rates do not increase. However, reducing the numbers of new entrants contributes to sustaining the fish available for catching for a long time.

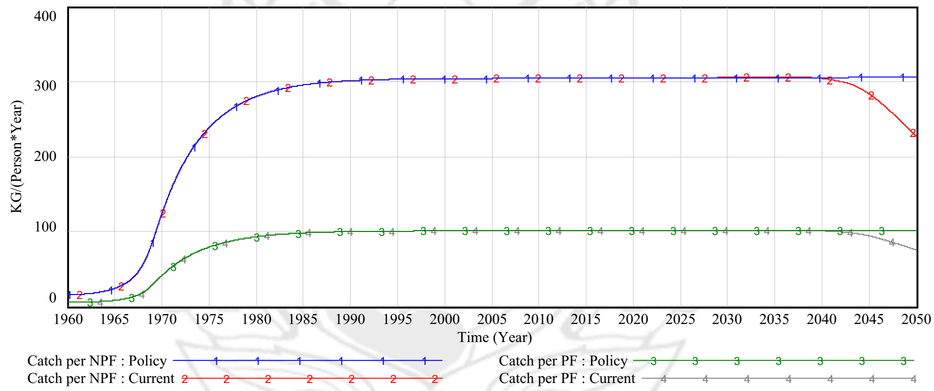

Figure 4.31 Impact of Limiting the Numbers of New Fishermen on Catch per Capita

Figure 4.32 shows the parallel patterns of fishermen and fish stock under this policy option. Compared to the baseline situation, the number of fishermen in the area declines and grows stablely from the year of policy application onward. There is a commensurate sizeable increase in the available fish population. Again, the policy implications here are quite compelling.

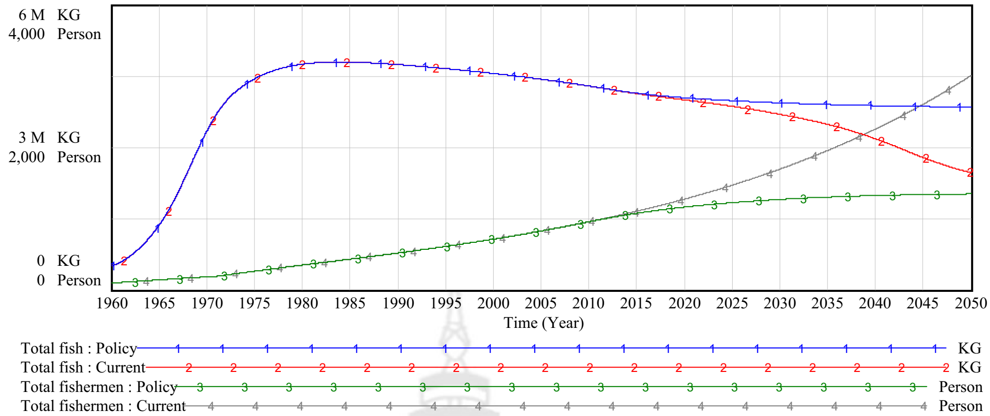

Figure 4.32 Impact of Limiting the Numbers of New Fishermen on Fish and Fishermen Populations

Given the limited alternative livelihood options beyond fishing in the commune, implementation of this management option seems to face a lot of challenges. Effective implementation would seem to require development of alternative diversified job options that could support those people who would not enter fishing as their primary occupation.

4.5.2.3 Analysis of policy option #3: Replenish and enrich fisheries resources

Aquaculture development would involve extensive nursing activity to supply large numbers of fingerlings into small sections of Trapeang Rung channel, allowing them to grow naturally every year. In the policy scenario, 399,000 kg of fingerlings would be released into those areas of the channel capable of supporting a survival rate high enough to replenish the catch size stock. The fingerlings species would be selected based on the native species in the primary local sections of the channel.

There are a few appropriate ways to implement extensive fish nursery activities at the commune level without resulting negative impacts on the surrounding environment. For instance, the most common practice is cage culture, known to be the most important fish hatchery system in Cambodia accounting for over 80% of national production from aquaculture (Food and Agriculture Organization, 1991 and Peter, E., 2008). Traditionally, the cages are made out of either split bamboo supported by a wooden frame or mainly of wood, supported by floating rafts made of bundles of bamboo tied to the long axis of the cage (Peter, E., 2008).

Figure 4.33 shows that the fish stock will indeed increase eventually if the extensive nursing program works well. This happens because of the increased number of young fish stock over time and the recruitment of fishes also increases. However, the fish stock tends to drop down slowly after 2025. This may happen because catch per capita increases slightly when more fish are available in the channel, allowing fishermen to catch them more readily.

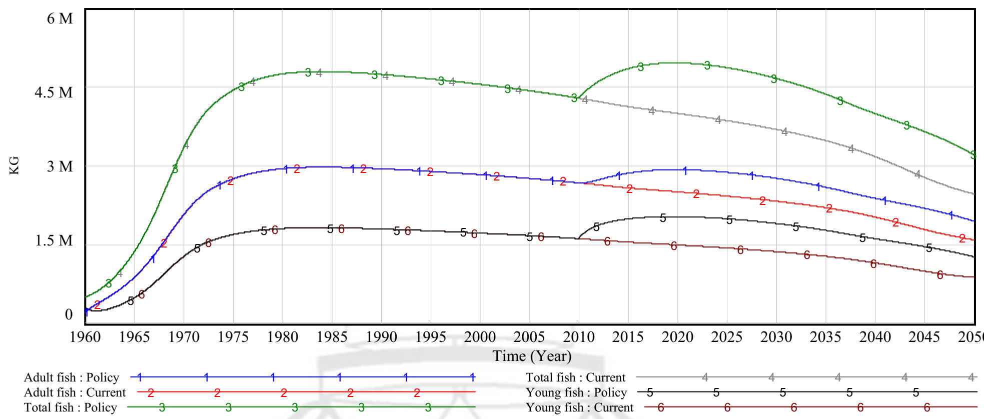

Figure 4.33 Impact of Extensive Fishery Nursing on Fish Stock

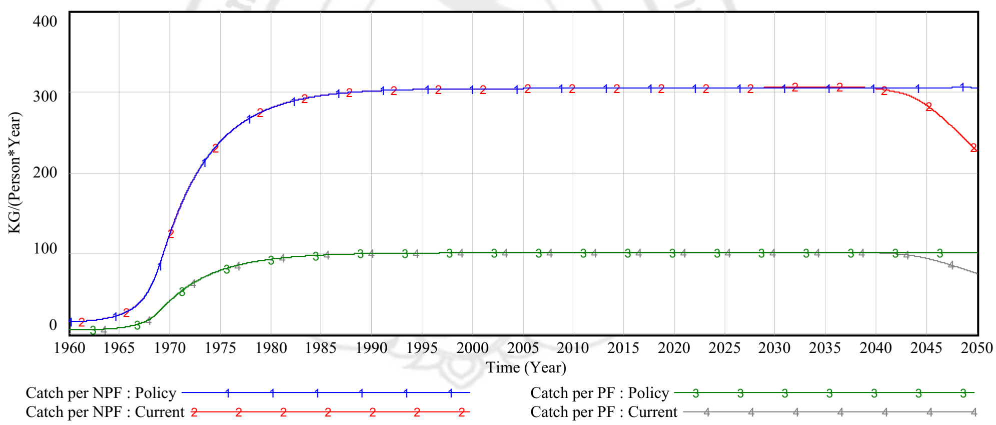

Figure 4.34 Impact of Extensive Fishery Nursing on Catch per Capita

Figure 4.34 indicates that fishermen under this policy scenario would be able to continue to catch fish at current rates from 2010 onwards. In this sense, the proposed extensive nursing program would indeed produce positive results in terms of sustaining the area's fisheries resources and enhancing livelihood options for fishermen.

Moreover, it certainly seems feasible that this policy intervention could be implemented at the local level by community residents themselves, especially by the fishermen who are involved the most in using these resources and have a great deal of basic knowledge related to fisheries resources. However, even though it seems possible to implement an extensive nursing program locally, capacity building for the local people in terms of fish hatchery management would seem to be required.

4.5.2.4 Analysis of policy option #4: Prohibit fishing in defined breeding areas

One more resources conservation option would be to prohibit access to a defined area. In the marine fisheries management context, such a no-entry zone is generally known as a marine protected area. However, in an area like Trapaeng Rung commune -- especially for the brackish water fishing grounds -- an area in which access is prohibited is called a "no-entry zone."

The area to be protected should be isolated and characterized by a good habitat conditions in which the fish can breed and survive. In this case, it is assumed that an upper part of the Trapaeng Rung channel's watershed can be identified as a no-entry zone. This area would be used to allow some of the fish to have favorable conditions for breeding. We assume that about 5% (1,330 kg) of current young fish stock will be added every year into the current fishing grounds through releases from the no-entry zone.

The model simulation shows that the fish stock slightly increases under these assumptions over that found in the baseline simulation (see Figure 4.35). However, even here the fish stock tends to decline eventually. Similar results appear with respect to catch per capita (Figure 4.36). The fishermen cannot harvest fish throughout the modeling period because the fish stock starts to drop at 2045 (this decline starts 5 years earlier (in 2040) under the baseline scenario. Figure 4.37 illustrates the fisheries resources and the population of fishermen, whose curves cross when the fishermen population reaches 2,300 people in 2040. The relevant conclusion is that the assumed fish stock available in the channel cannot accommodate the increasing rate (10% net growth rate) of fishermen.

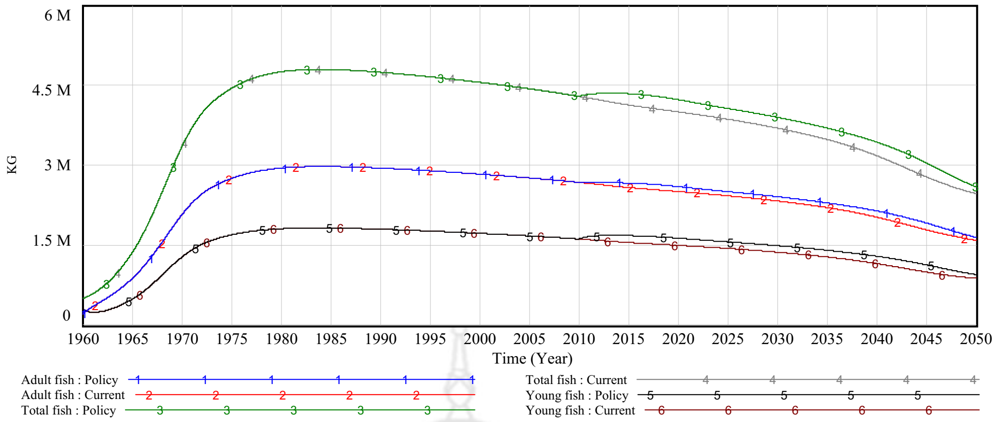

Figure 4.35 Impact of No-entry Zone on Fish Stock

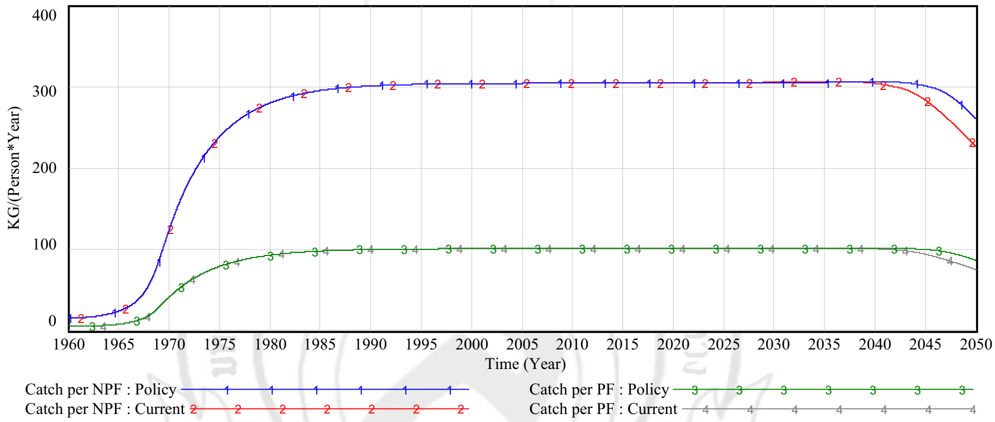

Figure 4.36 Impact of No-entry Zone on Catch per Capita

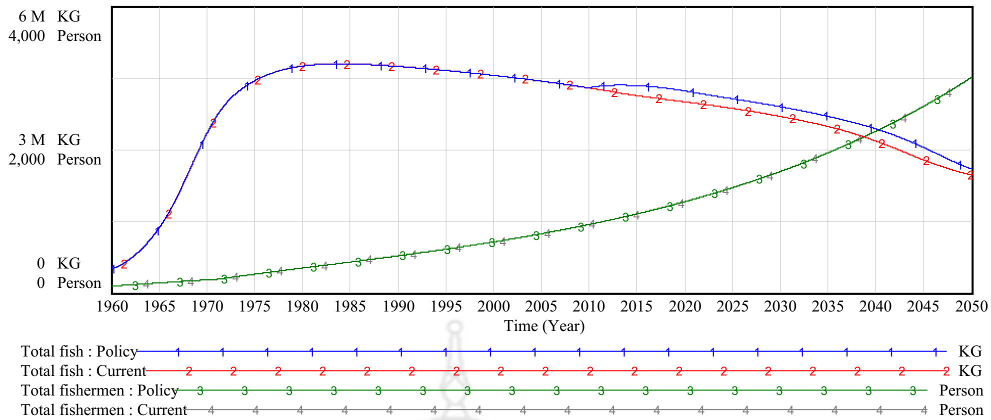

Figure 4.37 Impact of No-entry Zone on Fishermen Population

4.5.2.5 Analysis of policy option #5: Provide loans to improve poor fishermen's access to fishery resources and catch per capita

One of the primary objectives of this study was to assess the options available to assist poor fishermen gain better access to local fisheries resources as a way to reduce their poverty. In response, the study has come up with the idea of providing loans to improve the effectiveness of poor fishermen's fishing gear in order to increase their catch per capita. Establishing a new savings fund at the commune level and providing priority to poor fishermen to access this fund in order to buy more effective fishing tools seems feasible. Because most community fisheries are supported by NGOs, this new loan program could seek NGO support as well.

This study has found that in order to improve the situation of the poor, we need to increase their catch per fisherman to 80 kg per year from the current catch rate of 53 kg. This proposed larger amount equals half of the current catch rate of each non-poor fisherman.

As shown in Figure 4.38, under these new conditions (indicated by the green line) the poor fishermen would catch more than they did in the baseline scenario. The catch rate of non-poor fishermen can be maintained at current levels (160 kg/capita/year) for a short time after adoption of the loan policy. However after year 30 the catch rates of both poor and non-poor fishermen drop dramatically. This shows clearly that the increasing catch of the poor fishermen puts more pressure on the fish stock and accelerates its rate of decline. Therefore, unless steps are also taken to expand the fish stock, increasing the catch of the poor seems to be the short-term policy. They cannot enjoy their increased catch for long (in fact, their catch drops earlier here than it did under the baseline scenario).

This phenomenon emerges due to overuse of the area's overall fisheries resources (at more than its rate of natural regeneration). The available stock of fish cannot regenerate fast enough to keep up with the demand from the fishermen. Figure 4.39 shows that fish stock in the loan policy scenario declines more rapidly than in the baseline scenario. Interestingly, in the out years the fishermen population also decreases as the result of large numbers of fishermen quitting fishing when their catch per capita diminishes.

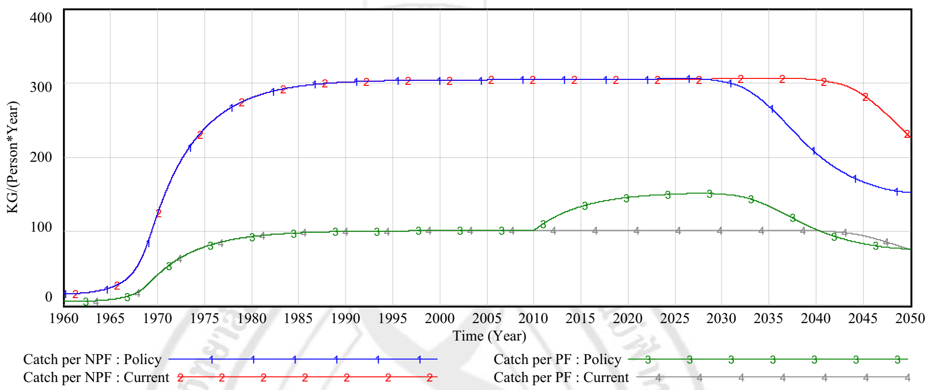

Figure 4.38 Catch per Capita of Poor and Non-poor fishermen

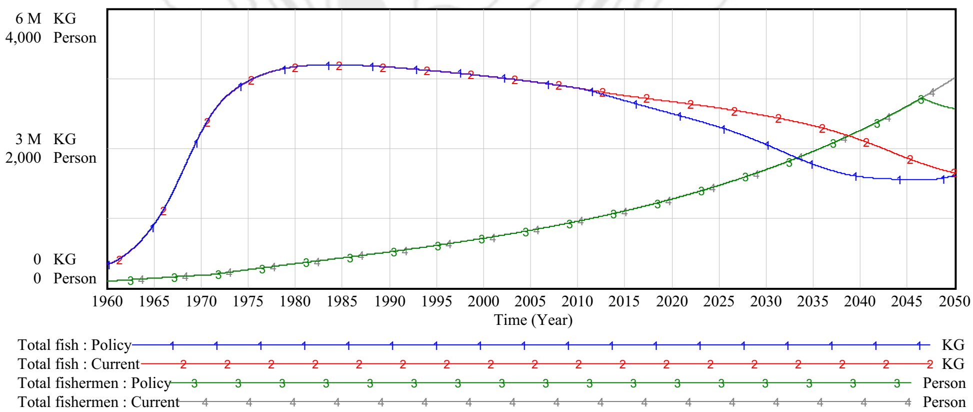

Figure 4.39 Fish Stock and Fishermen Population Assuming an Increased Catch per Capita of Poor Fishermen

4.5.3 Analysis of combinations of management options

4.5.3.1 Analysis of a combination of three policy options

The previous policy options were considered individually, each being related in turn to only a single component of the complex overall system structure. To examine policy options more fully, we turn next to analysis of combinations of the most effective individual policies in the hope of finding the most promising results that could comprise an integrated environmental policy approach.

As can be seen from the modeling results presented above, radical policy changes in each separate area were able to provide impressive results in regard to achieving individual objectives. For instance, regulating fishing gear and introducing an extensive fish nursery program were each able to sustain fisheries resources; but neither could help poor fishermen catch more fish. Conversely, increasing the catch of poor fishermen causes the fish stock to decline dramatically. To deal with these contradictions, the study explored a possible combination of policies that might yield a more encouraging outcome that would meet both of the core fisheries management objectives.

The model simulation of combined policies first explored a package of three specific policy initiatives:

1. Reduce the catch rate of non-poor fishermen to half of its current level (that is, to 80 kg/year/person)
2. Develop a community-based fingerlings nursery and release 15% of the current young fish stock (399,000 kg of fingerlings) annually
3. Increase the catch rate of poor fisherman up to twice its current level (that is, to 80 kg/year/person)

Such relatively moderate changes in these three system components may prove feasible of effective implementation in the context of the commune capacity, since none of these management options are new in the realm of fisheries management. Indeed, all three are recognized in community-based fisheries management programs in Cambodia today.

The long-term results generated by this combination of policy changes are better than the individual policy performance (see Figure 4.40). Fisheries stock could remain at a sustainable level for 10 years after implementing the nursing program. However, fish stock starts to decrease again after 2020. This pattern follows a decreasing trend (Figure 4.41) despite the introduction of a nursing program to regenerate fisheries resources, because while catch remains steady the number of fishermen keeps increasing.

The catch of the poor fishermen could increase for more than 30 years after providing loan support for them to buy better equipment. However, catch per capita of both poor and non-poor fishermen starts to decline eventually after 2040 because the fisheries resources decline while the fishermen population keeps increasing. Therefore, the share of the resources among all these competing fishermen gets smaller from year to year.

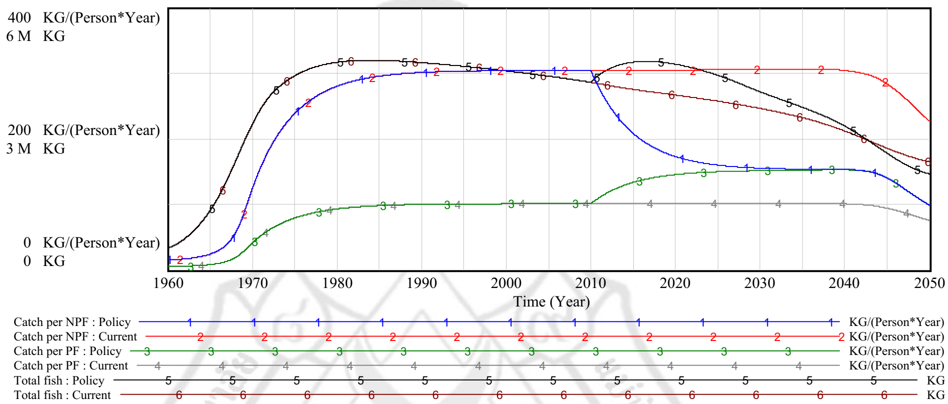

Figure 4.40 Fish Stock and Catch per Capita under a Combination of Three Policy Options

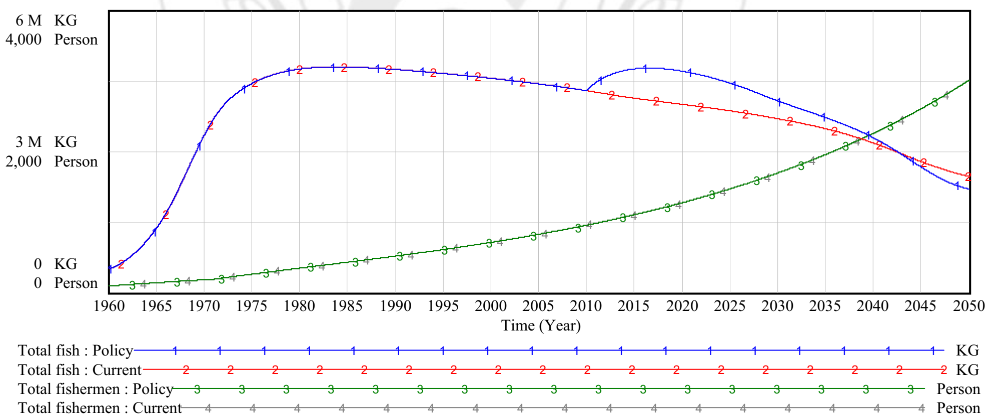

Figure 4.41 Fish Stock and Fish Population under a Combination of Three Policy Options

4.5.3.2 Analysis of a combination of four policy options

The second combination model simulation explored a unique set of four appropriate policies:

1. Limit the number of new fishermen by reducing entry of non-poor fishermen by 50% (5 persons per year) of the current entry rate and by 20% for poor fishermen (22 persons per year).

2. Reduce the catch rate of non-poor fishermen by 25% from its current level (that is, to 120 kg/year)

3. Establish an extensive fish nursery program for the community with the expectation that 5% of current young fish stock (1,330 kg of fingerlings/year) will be released into the Trapeang Rung channel

4. Increase the catch rate of poor fisherman to 80 kg/year from its current level of 53 kg/year (that is, it would go up to half the current catch rate of non-poor fishermen)

Figures 4.42, 4.43, and 4.44 portray the results of the model simulation of these four combined policies. These results show clearly the significant impact of reducing the number of fishermen. As can be seen, Figure 7.42 shows that the area's fisheries resources can be sustained for a long period of use even in the absence of other regulatory policies such as regulating fishing gear. Positive results are also achieved by the two related policy initiatives of reducing by 25% the catch of non-poor fishermen while increasing poor fishermen's catch rate to 80 kg/year (Figure 4.43).

Even though there is a positive result from reducing the number of new entrants into fishing, yet the consideration on the number of the populations (Figure 4.44), implementation of such a policy would require the community to provide other non-fishing jobs to those who are being prevented from fishing. They will have to find other livelihood options such as fish processing, improved agricultural skills (crop production and raising poultry and livestock), and agricultural processing. Improved market access for different locally produced products is also needed. Similarly, the non-poor fishermen will not readily accept the reduction in catch per capita being proposed for them. To respond, other livelihood options need to be found for them, too, in order to sustain their income levels. Most such alternative jobs for those non-poor fishermen are likely to found in post-harvesting value added activities. This might also offer an opportunity for some poor villagers to work as new wage laborers for the non-poor.

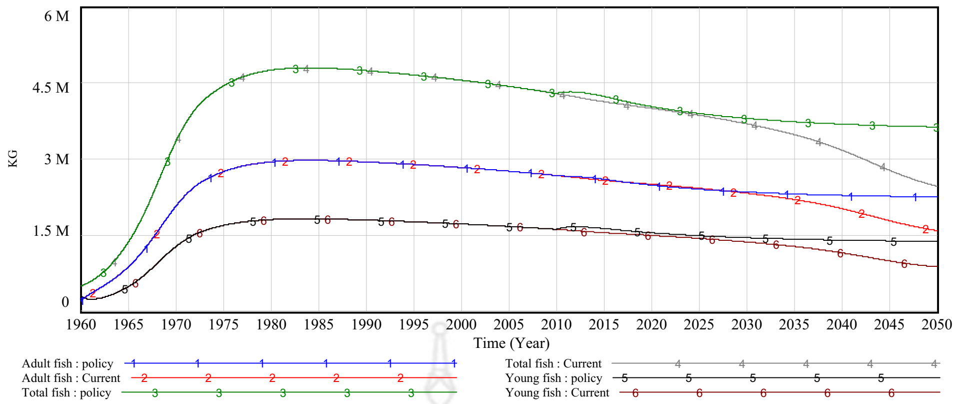

Figure 4.42 Fish Stock under a Combination of Four Policy Options

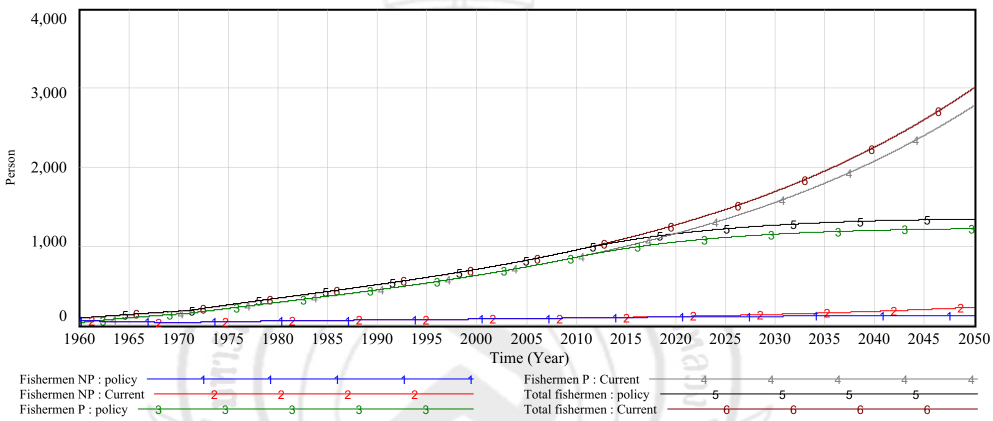

Figure 4.43 Fishermen Population under a Combination of Four Policy Options

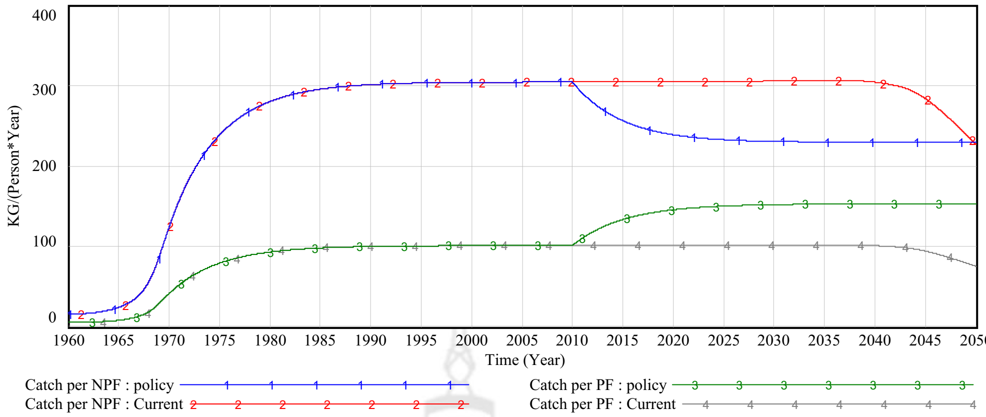

Figure 4.44 Catch per Capita Combination of Four Policy Options

4.5.4 Development an appropriate management system for the Trapeang Rung commune

There is a rising recognition that many small-scale fisheries need community-based fisheries management as the key to their sustainable resources use. Community participation in the management process is widely accepted and encouraged in the policy of countries in Southeast Asia (Nopparat & Charles, 2009). In Trapeang Rung commune, a broad segment of community residents, including local fishermen, see community-based fisheries management as an option to sustain their heavy dependence on these resources and thus allow for their continuing livelihood.

Despite the fact that the people in this commune would like to develop an effective management system for their fisheries resources, no management actions have yet been carried out to date. Inertia prevails over effective action. Therefore, setting up a new community-based fisheries management system in the commune is the highest priority task.

Local community residents (including fishermen, especially) are vital stakeholders in such a process, since they bring extensive knowledge of the local environment. Their participation is essential to ensure that the problems and weaknesses as well as the strengths of their own community are incorporated into the new management system. In addition, they may well be willing to share information, participate in identification of enforceable boundaries and appropriate management measures, help with implementing plans, and be involved with monitoring to detect any future illegal fishing activities emerging in their area.

Even though the community possesses a great deal of potential to manage its resources by itself, assistance from the responsible government body (the Provincial Fisheries Administration), NGOs and research institutes is required to establish a feasible and appropriate management system. In the initial stage, the local authorities, community residents and fishermen with support from the Provincial Fisheries Administration can devise their own organization, structured according to the guidelines of the Fisheries Administration (FiA) of Cambodia. Furthermore, they can combine the knowledge of local fishermen with the authority of local government to demarcate the boundaries of their new community-based fisheries management system, drawing on their knowledge of the local environment in terms of fish-related behavior (spawning and migrating) and fishing grounds.

It is widely known that, in most cases, a new community-based fisheries management will start with only a few management activities that are effective and enforceable in the community. Community members themselves may eventually see a need to expand their scope of activities to meet their own changing goals.

Table 4.8 provides a few management options that can be implemented by the community. These measures were already examined in this research project through use of system dynamics modeling. However, in order to set forth an appropriate overall management system, some actions that have not been tested in the model were also included in this management plan.

Table 4.8 Management Plan

Objectives	Actions	People & Institutions Involved	Outcomes
1. Sustain fisheries resources in Trapeang Rung channel 2. Improve access of poor fishermen to the fisheries through enhanced catch rates	- Conduct research, collect data, and prepare an inventory	- Research institute - NGOs - FiA - Local community (fishermen)	Sustainable fisheries management and poverty reduction at the local level
	- Raise awareness to the whole community about the regulations	- Research institute - NGOs - FiA - Local community	
	- Implement management options (enforcement)	- Local community	
	- #1 Regulate the fishing gear being used by reducing the numbers of fishing gear allowed per fishing household	- Local community - FiA	

Table 4.8 (continued)

Objectives	Actions	People & Institutions Involved	Outcomes
	- #2 Reduce the number of new entrants to fishing through providing job diversification	- Local community - NGOs	
	- #3 Establish restricted no-entry zone combined with enactment of extensive nursing program	- Local community - NGOs - FiA	
	- #4 Establish savings group in the commune and provide priority to the poor fishermen to access the fund to buy more effective fishing tools (meeting requirement of management option #1)	- Local community - NGOs	

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This section presents some concluding and remarks on the research and some final policy recommendations. The research employed system dynamics modeling as a tool to assess the impacts of a variety of potential policy initiatives and management options under the overall rubric of a community-based fisheries resources approach. The management options selected for proposed implementation were based on their positive impacts on sustaining fisheries resources and improving accessibility of poor fishing households, as indicated by the modeling results.

5.1 Conclusions

Small-scale fishing is a significant contributor to the livelihoods and incomes of the local people in Trapeang Rung commune. Current trends include the increasing number of fishing-dependent households, increased use of effective fishing equipment, and the increasing disturbance of the fishery habitat. All these phenomena are combining to cause a clear decline in fisheries resources in the commune's fishing grounds, Trapeang Rung channel. Meanwhile, it is increasingly evident that poor and non-poor fishermen in this area have vastly different accessibility to the local fisheries resources. Specifically, the catch per capita rates of poor fishermen are three times lower than those of non-poor fishermen. The field research identified, perhaps not surprisingly, that the primary accessibility constraint affecting poor fishermen comes from their own limited investment capacity; they simply do not have enough money to buy better, more effective fishing equipment (boats, motors, nets, hooks, lines).

The current fishery utilization system contributes to the decline in available fisheries resources and to the weak livelihoods of the poor fishing households. However, at the same time this situation can offer evident clues allowing us to trace back to the underlying causes of the problem. Such insights can encourage the local people themselves to be aware of the problems and look for appropriate local-based resolution. Clearly, no management scheme exists in the commune at the moment. The way in which local fisheries resources are being exploited (rather than being managed) affects their sustainability. This, in turn, has unavoidable impacts on the economic situation of local fishing households, especially the poor fishermen. It is evident from the research that the area's lack of an adequately structured management system is causing many unnecessary problems that have to be solved in the future.

The new community-based fisheries management system being proposed as the outcome of this research certainly does not represent a total solution to all the area's problems. Nevertheless, it can play a key role in helping the local people --especially the poor fishing households -- to organize themselves to use the resources in the wise way, improving their incomes while sustaining the fisheries resources at the same time.

In addition to its ability to empower local resources users to be responsible for care of the local resources, a community-based fisheries management approach is already legally supported by the nation's fishery law. Cambodia has specific legal frameworks designed to assist community-based fisheries management processes emerge and become successful.

People participating in managing fisheries resources to sustain their own livelihoods might not be fully aware of the overall economic benefits of their actions. The research shows that they are aware, however, of the extent to which they are personally affected by declines in local fisheries resources. This encourages them often to make correct management decisions, for their own benefit.

Local people, especially the fishermen, have to consider many factors before becoming activists in sustaining and protecting local resources. They have to allocate time and energy to start becoming involved in community activities. This is not easy for poor villages. The field research found that their desire to sustain vital local fisheries resources was the motivational factor most often cited for them to become involved. Sustaining or improving their incomes was second, followed by an expressed desire to conserve biodiversity and maintain nutrient sources from fish protein. These are all interrelated action categories in this area.

With regard to the specific options for community-based fisheries management in Trapeang Rung commune; many relevant and appropriate measures have already been implemented in various countries across the globe. For instance, some common management options include fishing gear restrictions, area and time-based restrictions, access limitations, and input (effort) and output controls. The model developed in this study has demonstrated that fish catch is basically an extractive action, which leads inexorably to fisheries resources decline. Increasing the number of fishermen can be seen as a fundamental driving force behind this process.

Through experimenting with the model, a few specific management options emerged that in combination are designed to both sustain fisheries resources and improve accessibility of the poor fishing households. These key policy initiatives are as follows:

1. Limit the number of new fishermen
2. Restrict the types and amounts of fishing gear used
3. Establish an extensive fish nursery program in the community
4. Establish a commune savings group to provide finances for poor fishing households to improve their investment capacity to enhance their ability to catch fish

Implementing this set of combined measures can bring the local natural resources system into balance, one which can be sustained for a substantial period of time.

The research intended to answer two main research questions:

1. What management options would work best to maintain/increase fisheries resources available for long-term harvesting?
2. What practical ways exist to help poor households get more benefits from local fisheries resources?

Different community-based fisheries management options were tested by simulation through system dynamics modeling to identify and assess the best options that would actually be appropriate for the managing fisheries resources in the Trapeang Rung channel. Observations and data from the filed survey, including insights contributed by many different local stakeholders who were asked to give their opinions and views on the management issues, were incorporated into the analysis.

5.2 Recommendations

The fisheries resources in Trapeang Rung commune were studied closely in order to demonstrate potential ways to balance the often-competing goals of natural resources conservation and poverty reduction. Such new balance is imperative in rural areas within the Biodiversity Conservation Corridor Initiative site, where natural resources are the population's major source of livelihood.

System dynamics modeling was used to capture the complexity of the interactions of fisheries resources and their users in order to provide an analytical framework that can be used to examine the effects of various community-based fisheries management policy options. As mentioned in the conclusions section, such potential community-based fisheries management options include limiting the number of new fishermen entering fishing, restricting the types and amounts of fishing gear used, establishing a fish nursery program for the community, and establishing a savings group to provide financing for poor fishing households to improve their capacity to catch more fish.

A set of specific recommendations are presented below to overcome perceived challenges and barriers that stand in the way of implementing the recommended management options. The recommendations are grouped into certain main areas in which effective action can be taken.

5.2.1 Recommendations for involvement of local community residents

It would be very important for all stakeholders in the area, especially fishing households, to develop their own agendas for managing local fisheries resources and communicate those ideas in one or more special commune meetings. The primary policy recommendations emerging from this research could also be presented to the entire community at that time. Hopefully such group discussions could help reach consensus on ways to resolve the fisheries decline, including immediate actions to be taken. Regular commune activities, like the needs assessment of the people in the commune conducted annually in order to update the commune development plan, offer good opportunities to raise awareness related to this community initiative. Clearly, but more frequent open meetings are needed to build a strong basis for effective community action.

5.2.2 Policy and legal recommendations

5.2.2.1 Incorporate the fisheries management issue in the commune development plan

Currently, at the commune level, insufficient attention has been paid to managing fisheries resources and improving the fisheries stock. Since the area's infrastructure such as roads is so poor, the commune development plan has emphasized rehabilitation of roads. Moreover, to date the commune authority has not been sufficiently aware of available, practical ways to solve the area's fisheries decline. As a result, action by the local authority with the support from the provincial FiA is necessary to initiate community-based fisheries management here. The commune authority plays a key role in the development process, and have has the power to make a real difference at the local level. Authority members along with heads of some fishing households should participate in training programs in which the benefits of fisheries management are highlighted. With such information in hand, fisheries management schemes should be formally incorporated into the commune development plan.

5.2.2.2 Create an activist group to carry out the fisheries management option

A group of fisheries management activists should be established. Members should include men and women from the local authority, both fishing and non-fishing households of poor and non-poor groups, non-governmental organizations, and the provincial FiA office. This group should be granted power from the local governing authority to develop and enforce appropriate rules and regulations. Their role is to devise action plans that will foster sustaining of fisheries resources and enhance the accessibility of the poor fishing households to those resources.

5.2.2.3 Create a new loan fund in the commune availability to poor fishing households

Cash is required to improve the effectiveness of the fishing gear available to the commune's poor fishing households. Similarly, financial investment is needed to develop the proposed extensive fish nursery effort and to diversify local livelihood options besides fishing. Local authorities and government bodies as well as NGOs should realize the importance of establishing a new local fund and allocate it to ensure that the monies actually reach the households that most need it. Small grants should be allocated for immediate assistance to the most-needy fishing households. These grants could be non-repayable gifts or loan with low or even zero interest rates.

5.2.3 Educational and skill improvement recommendations

Local people, especially members of the fishing households, are not ready on their own to lead the management practice in their commune. Management skills are needed. Demonstration of the details of successful cases elsewhere in Cambodia and sharing of lessons learned through excursion to visit those sites should be established, perhaps with the help of NGOs. These actions will help local activists learn about effective management techniques and also about the implications of operating a workable management system, including conflict resolution. Workshops could take place in the commune to expand both levels of interest and technical knowledge. These workshops could be conducted by NGOs or FiA. Through education the negative mindsets of certain people could be diminished and fisheries management system models could be fostered.

In addition, education could be provided to members of fishing households and to other potential new entrant fishermen about innovative ways of adopting diversified alternative jobs. Some sectors that are related to agriculture such as promoting livestock raising through providing credit will contribute both to household welfare and to fertilizing land for agriculture inputs as well as the feed for fish nursing.

The integrated management scheme that has emerged from this research has a significant potential to enhance the accessibility of the poor fishing households to available resources while also fostering sustainability of those resources. Such local, grassroots initiatives need support from other community members (non-fishing households), NGOs, local authorities and government agencies. First and foremost, proactive local initiative, action, and leadership (plus critical resources) are prerequisite to starting a community-based fisheries management system. Immediate management options such as establishing a warning sign to prohibit illegal fishing activities and indicate that local fisheries are already in decline.

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APPENDICES

APPENDIX A

Questionnaire form

Individual Interview

1. Personal information

1.1 Name	

1.2 Age		
1.3 Ethnicity	1. Khmer	2. Muslim

1.4 Education

1.	Illiterate	4.	Upper secondary
2.	Primary	5.	Higher
3.	Lower secondary	6.	Other

1.5 Type of HH

1.	Poor
2.	Non poor

1.6 # of dependents in the HH	

1.7 What are the main occupations of the HH?	1. Fishing; 2. Agriculture; 3. Sale fish; 4. Business (other); 5. Other
1.8 What is the monthly income of the HH?	
1.9 What is the daily expenditure of the HH?	- Food ……………..……………………………………………… - Rice ……………..………………………………………………... - Children' education …………….………………………………… - Other …………………………………………………………….

2. Participation in Fishing Activities

2.1 Did you go fishing?

YES ☐ NO ☐

2.2 When have you been involving in fishing?

Year

……………………………………………………………………………………………….

2.3 Why did you begin fishing?

……………………………………………………………………………………………….

……………………………………………………………………………………………….

2.4 How did you learn to fish?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2.5 Do you consider yourself as?

Small scale fisher ☐ Medium scale fisher ☐

2.6 How do you get there? *Circle*

1. Own boat, traveling by self
2. Own boat, traveling with others
3. With others, on their boat
4. Other (specify) ________

2.7 On what basis do you decide where and why you fish a particular species? *Circle*

1. Family tradition
2. Seasonality
3. Advice from friends / neighbors
4. Personal experience and knowledge of the fish and water
5. Market demands / profitability
6. Ease of harvesting
7. Other (specify) ________

2.8 Do you own a fishing boat?

YES ☐ NO ☐

2.9 If yes, how many boats do you have and what type?

Type of boat	Specification	Number of boats
Motor boat		
Row boat		
Small wooden boat with engine		
Big boat with engine		
Other (specify)		

2.10 Type of boat/gear?

Type of boat	Gear	Size of gear
Motor boat		
Row boat		
Small wooden boat with engine		
Big boat with engine		
Other (specify)		

2.11 How much did you spend per fishing trip?

Spending items	Unit	Quantity
Gasoline		
Food		
Fishing gear		
Boat repair		
Other pay		

2.12 Do you have enough money to spend for one trip? ( ) Yes / ( ) No

2.13 If no, what would you do to?

Borrow items	Lenders	Return means
Money		
Gasoline		
Fishing gear		
Other		

2.14 Do you think you get reasonable price from selling your fisheries products?( ) Yes/( ) No

2.15 If no, what would be the reason? …………………………………………………………..

2.16 Do you want to change this situation? ( ) Yes / ( ) No

2.17 How? ……………………………………………………………………………………….

3. Catch assessment

3.1 Where did you go fishing?

Places of fishing	(#)& types of boat	When (year)	Location	Frequency (Times/dry season)	Frequency (Times/rainy season)	Time	Gear used	Caught species	Weight (kg)	Post-harvesting use	Amount of use
	………. ……. ………. …….	…….. …….. …….. ……..	GPS …………… … HD	………… …………	………… …………	…….. . …….. .	………… ………… ………… …………	1. ………….. 2. …………..	……… …	……… …	……… ………

Codes for places of fishing

1. Stream (specific name)
2. Trapeang Rung channel
3. Pond
4. Other (specific name)

Codes for time

1. Morning
2. Afternoon
3. Evening
4. Night

Codes for post-harvesting use

1. Self-consumption
2. Sale
3. Gift
4. Processing

3.2 Current catch assessment what kind of boat/gear?

Date ……………………………………..Time …………………………………………..

Location 1. Middleperson's house 2. Port 3. Other……………….

Places of fishing	(#)& types of boat	Location	Frequency (Times/dry season)	Frequency (Times/rainy season)	Time	Spending hour on catch	Weight (kg)	Post-harvesting use	Amount of use (kg)
	……… …. ……… ….	GPS ………………. ………… HD …………	………… …………	………… ………… …….	……... ……...	From …… ……………. …………… …	………… ………… ………	……… ……… ……	…… …… …………… …………

4. Knowledge/ perspectives on fisheries resources management

4.1 What do you think about the fisheries resources?

Areas of change per season	How?
	…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………

Codes

1. Increase to what extent compare to previous years?
2. Decrease to what extent compare to previous years?

4.2 Does the change impacts on your livelihoods?

Areas of impact	How?
	…………………………………………………………………………………… ……………………………………………………………………………………
	…………………………………………………………………………………… ……………………………………………………………………………………

Codes

1. HH's income

2. Nutrition of HH's members
3. Workload of household members
4. Conflicts within the households
5. Conflicts between households
6. Others

4.3 What kind of benefits of fisheries resources that you gain? (pls, Circle)

a. Income generation
b. Nutrition for HH
c. Employment
d. For ecotourism
e. Others (please specify)……………………………………………………...

4.4 Is there outsider (not a commune member) fishing in the fishing ground of the commune?

YES ☐ NO ☐

4.5 If yes, where are they from?

a. Other province
b. Other near by commune (specify the name)…………………………………………….

4.6 What kind of fishing boat/gear do they use?

Type of boat/gear	Gear	Rainy season	Dry season
Motor boat			
Row boat			
Small wooden boat with engine			
Big boat with engine			
Other (specify)			

4.7 Is there fisheries resources development activities occurred in the commune? ( ) Yes / ( ) No

4.8 If yes, what are they? (pls, Circle)

a. Individual fish pond raising
b. Restoration of natural pond for fish breeding
c. Training on aquacultures
d. Other (pls, specific)……………………………………………………….

4.9 Do you agree to manage fisheries resources? ( ) Yes / ( ) No

4.10 If you agree, why? (pls, Circle)

a. To sustain fisheries resources
b. To sustain income
c. For biodiversity conservation
d. To sustain nutrition
e. Others (please specify)…………………………………………………….

4.11 If you don't agree, why? (pls, Circle)

a. It is not my responsibility
b. Lack of knowledge to manage the fisheries resources
c. Lack of resources for conducting the management scheme
d. People need to catch fisheries
e. Others (please specify)………………………………………………………

4.12 If you agree to the idea of fisheries management, what efforts do you think that need to be taken place? (pls, Circle)

a. The local authority should be a leader for management the resources
b. Establish community based management
c. Establish fish breeding zone
d. Protect the mangrove forest and other forests that grow along the TPR channel
e. All people should involve in the management process
f. All people should create rules for protect the fisheries resources

g. Involved in patrolling

h. Involved in combating illegal fishing gears use

i. Others (please specify)……………………………………………………………

4.13 Do you think it is feasible to form the collective activities to manage the fisheries?

Notion	Reasons
Yes	…………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………
No	…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………

4.14 If yes, who should join the activities?

Who?	Why?
	…………………………………………………………………………………… ……………………………………………………………………………………
	…………………………………………………………………………………… ……………………………………………………………………………………
	…………………………………………………………………………………… ……………………………………………………………………………………
	…………………………………………………………………………………… ……………………………………………………………………………………

4.15 Are you willing to participate in the activities? ( ) Yes / ( ) No

4.16 If yes, what activities would you like to do?

Activities	Reasons
1.	
2.	
3.	
4.	

4.17 What impact do you think this participation may bring?

Good (To)	Reasons
Your HH	
Community	
Fisheries	
Forest along the TPR channel	
Bad (To)	**Reasons**
Your HH	
Community	
Fisheries	
Forest along the TPR channel	

APPENDIX B

Sample study and socio-economic assessment data

Table B1: **Sample study and socio-economic assessment data**

Village	Number of HH	The well-off HH	Sample of HH	The marginal poor HH	Sample of HH	The moderate Poor HH	Sample of HH	The very poor HH	Sample of HH	Percentage distribution of each different wealth group
Veal Taphou	76	3	0	43	8	27	5	3	0	0 percent of the well-off household and 15 percent of household that classified as the marginal, moderate and very poor households.
Dei Tumniep	125	6	0	56	10	38	10	25	4	

Table B1 (continued)

Village	Number of HH	The well-off HH	Sample of HH	The marginal poor HH	Sample of HH	The moderate Poor HH	Sample of HH	The very poor HH	Sample of HH	Percentage distribution of each different wealth group
Praik Angkoinh	40	2	1	18	5	12	5	8	2	50 percent of the well-off household and 30 percent of household that classified as the marginal, moderate and very poor households

Table B1 (continued)

Village	Number of Household	The well-off HH	Sample of HH	The marginal poor HH	Sample of HH	The moderate Poor HH	Sample of HH	The very poor HH	Sample of HH	Percentage distribution of each different wealth group
Koh Kong Khnong	52	2	2	8	3	16	5	26	7	100 percent of the well-off household and 30 percent of household that classified as the marginal, moderate and very poor households.
Total			3		26		25		13	

Table B2 The main data required for a whole research

Research questions	Data inputs	Methodologies	Data outputs	References
	Socio-economic and Biological parameters for stock assessment		**Socio-economical and Biological parameters for stock assessment**	
1. What management options would be acceptable to maintain/ increase fisheries resources and harvesting in the long term?	- Average fresh weight - Main fisheries species caught in different seasons - Seasonal capture rate (kg day)-1 - Catch per capita - Fishing location - Total days for capture - Initial month for capture (Month) - Duration of fishing season (Months) - Existing management approaches in the province as well as at the commune level	- Questionnaires and interviews (data collection technique) - Focus group discussions (FGD) - Apply system dynamic modeling to simulate the management options	- Total capture (kg) - Catch per unit effort - Fisheries species composition - Seasonal average captures - Initial month for captures - Capture season duration (months) - Capture periodicity	- Fishermen (small-scale fishermen and medium -scale commercial fishers) - Fishery experts consultation - Documents and relevant reports

Table B2 (continued)

Research questions	Data inputs	Methodologies	Data outputs	References
	Socio-economic and Biological parameters for stock assessment		**Socio-economical and Biological parameters for stock assessment**	
2. How to enhance the extent to which fishing can benefit the poor?	- Number of HHs involved in fish catching - Fishing contribution to total HH livelihood (percentage of fisheries share in subsistence and cash income) - Education level - Involvement of women in fishing - Areas where fish are caught in different seasons - Years started fishing, and where is the location - Catch from fished location, no. of days on fishing trip, - Frequency of trips to the fishing location,	- Questionnaires and interviews - Focus group discussions - Semi-structured interviews - Apply system dynamic modeling to simulate the management options	- Fishing location - Season - No. of HHs involved in fishing - Fishing contribution to total HH livelihood Property owned by fishermen - Awareness of relevant regulations	- Fishermen (small-scale fishermen and medium scale commercial fishers) - head of commune and village - Documents and relevant reports

Table B2 (continued)

Research questions	Data inputs		Data outputs	
	Socio-economic and Biological parameters for stock assessment	**Methodologies**	**Socio-economical and Biological parameters for stock assessment**	**References**
	and regular length of fishing trip - Species targeted, gear type used, crew size - Where fish are sold, and each type fish species price - Personal description of condition of fisheries 5 years ago vs. today, - Perception of cooperative spirit, interest in supporting management team in the commune - Ownership of various assets including land, house, fishing equipment and boats - Investment cost per fishing trip per season - Awareness of fishery-related rules and regulations - Feelings about cooperation with fisheries management		-	

Table B2 (continued)

Research questions	Data inputs		Data outputs	
	Socio-economic and Biological parameters for stock assessment	**Methodologies**	**Socio-economical and Biological parameters for stock assessment**	**References**
3. Identify and evaluate different possible management options	All relevant data -- both biological and socio-economic -- from the current assessment stage	- Apply system dynamic modeling to simulate the management options	- Appropriate /preferred management option for fisheries and poverty reduction	

Table B3 Educational Levels of Different Age Groups

Age group	Education obtained (%) Illiterate	Primary School	Lower secondary school	Know how to write and read some	Total
10-20	30.00	70	0.00	0.00	100
20-30	36.84	31.58	0.00	31.58	100
30-40	52.63	31.58	5.26	10.53	100
40-50	60.87	17.39	4.35	17.39	100
50-60	16.67	16.67	16.67	50.00	100
>60	50.00	25.00	25.00	0.00	100

Source. Results from calculation from fieldwork data, 2009.

Table B4 Major and Secondary Income Generation Sources

Income sources	Number of HHs involved	(%)
- ***Major income sources***		
Fishing	58	86.57
Agriculture (fruit trees plantations)	7	10.45
Middleman/trader	1	1.49
Wage labor	1	1.49
Total	67	100.00
- ***Secondary income sources***		
Fishing	10	14.93
Agriculture (Fruit tree plantations)	29	43.28
Business	5	7.46
Wage labor	11	16.42
Collecting and selling NTFPs	11	16.42
No response	1	1.49
Total	67	100

Source. Results from calculation from fieldwork data, 2009.

Table B5 Household Monthly Income

Household monthly income (1USD=4110 Riel)	Households (in percentages)			
	Well-off	Marginal poor	Moderate poor	Very poor
50,000-100,000 Riel ($12.16-424.33)	0	23.08	32	38.46
100,000-150,000 Riel ($24.33-$36.49)	0	23.08	20	30.77
150,000-200,000 Riel ($36.49-$48.66)	0	7.69	24	30.77
200,000-250,000 Riel ($48.66-$60.81)	0	0	8	0
250,000-300,000 Riel ($60.81-$72.99)	0	11.54	12	0
350,000-400,000 Riel ($72.99-$97.32)	0	7.69	0	0
400,000-450,000 Riel ($97.32-$109.48)	0	7.69	0	0
450,000-500,000 Riel ($109.48-$121.65)	33.33	11.54	0	0
More than 500,000 Riel ($121.65)	66.67	7.69	4	0
Total	100	100	100	100

Source. Results from calculation from fieldwork data, 2009.

Table B6 Household Average Daily Expenditures

Household Average Daily Expenditures (1USD= 4110 Riel)	Household Status			
	Well-off	Marginal poor	Moderate poor	Very poor
Less than 5,000 Riel ($1.21)	0	19	28	23
5,000-10,000 Riel ($1.21-$2.43)	0	27	32	53
More than 10,000 Riel ($2.43)	100	54	40	23
Totals	100	100	100	100

Source. Results from calculation from fieldwork data, 2009.

Table B7 Key Features of Fishing in Trapeang Rung Commune Compared to Characteristics of Small-Scale Fisheries

Key features of Fishing	Local Area Compared to Small-scale Fisheries' Characteristics
Direct employment in fishing	About 48% of total population involved in fishing (971 people in the commune out of a total 2008 population of 2,023, 90% classified into the poor group).
Fishing household dependents	10% of those involved in fishing
Have 5-HP motorized boat	85% of fishing households own motorized boat
Use row boat for fishing	15% of fishing households use row boat for fishing
Catch distance	Most fishermen go fishing 2-3 km from home (sometimes up to 10 km)
Labor and fishing time	Most fishermen stay out 1-3 nights on each trip
Total time in fishing occupation	30-40 years
Fuel oil consumption per fishing trip	On average, 2.54 litters
Fishing gear	Set of gillnets, long-line hooks, and fish fork

Table B7 (continued)

Key features of Fishing	**Local Area Compared to Small-scale Fisheries' Characteristics**
Fishing gear	Set of gillnets, long-line hooks, and fish fork
Capital cost per fishing trip	About 19,324 Riel ($4.70)
Catch per fishing trip	On average, 3- 6.3 kg
Number of fishing months per year	8 months - Rainy season 4 months (May to November or December) - Dry season 4 months (January/February to April/May)

Source. Results from calculation from fieldwork data, 2009.

Table B8 Gross Income Earned per Trip of Fishermen in Different Wealth Groups

Amount earned per trip (1USD=4110 Riel)	**Household status (%)**			
	Well-off	**Marginal poor**	**Moderate Poor**	**Very poor**
Less than 10,000 Riel ($2.43)	0.00	11.54	4	38.46
10,000-20,000 Riel ($2.43-$4.86)	0.00	30.77	56	53.85
20000-30000 Riel ($4.86-$7.29)	33.33	11.54	12	7.69
30000-40000 Riel ($7.29-$9.73)	0.00	15.38	12	0.00
More than 40000 Riel ($9.73)	66.66	30.77	16	0.00
Total	100	100	100	100

Source. Results from calculation from fieldwork data, 2009.

Table B9 Expenses per Fishing Trip by Different Wealth Groups

Expenses per fishing trip (1$=4110 Riel)	Household Status (%)			
	Well-off	Marginal poor	Moderate poor	Very poor
Less than 5,000 Riel ($1.21)	0	11.54	12	61.54
5,000-10,000 Riel ($1.21-$2.43)	0	15.38	4	23.08
10000-15000 Riel ($2.43-$3.64)	0	26.92	24	15.38
15000-20000 Riel ($3.64-$4.86)	100	11.54	12	0
More than 20000 Riel ($4.86)	0	34.62	48	0
Total	100	100	100	100

Source. Results from calculation from fieldwork data, 2009.

Table B10 Long line hooks own

Different Wealth Group	Long-line hook					
	From 50 to 80 hooks	From 80 to 110 hooks	Less than 50 hooks	More than 110 hooks	Not own	Total for Long line hooks
Moderate Poor	2	0	10	0	13	25
Marginal poor	4	9	13	1	0	26
Very poor	0	0	3	0	10	13
Well-off	0	0	2	1	0	3
	7	6	30	1	23	67

Source. Results from calculation from fieldwork data, 2009.

Table B11 Gillnet owned by different wealth group

Different Wealth Group	Gillnet				
	From Five to Ten sets	From One to Five sets	From Ten to Twenty sets	Not own	Total for Gillnet
Moderate Poor	4	10	6	5	25
Marginal poor	7	13	6	0	26
Very poor	3	7	0	3	13
Well-off	2	1	0	0	3
	17	31	10	9	67

Source. Results from calculation from fieldwork data, 2009.

Table B12 Fish Fork owned by different wealth group

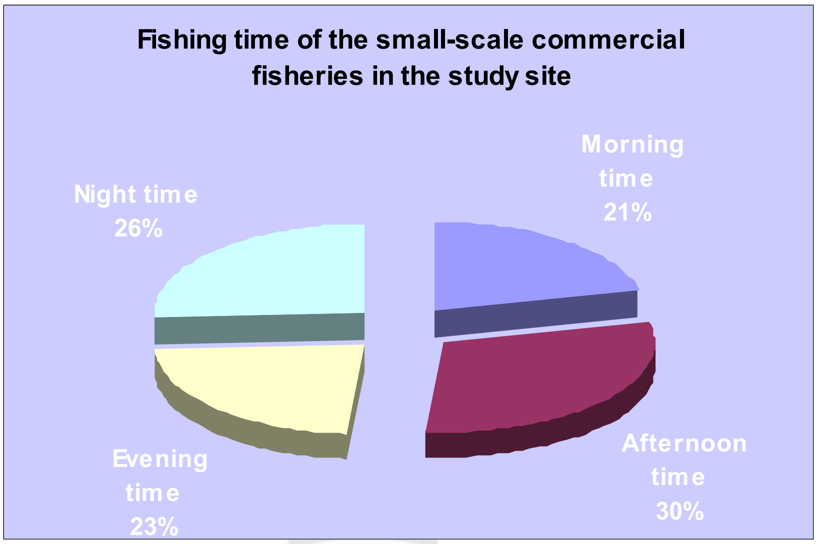
Different Wealth Group	Fish fork owned				
	One Fish Fork	Two Fish Forks	Three Fish Forks	Not own	Total
Moderate Poor	19	4	0	2	25
Marginal poor	8	10	5	3	26
Very poor	10	1	0	2	13
Well-off	0	2	1	0	3
Total	37	17	6	7	67

Source. Results from calculation from fieldwork data, 2009.

Table B13 Number of Fishing Days per Fishing Trip

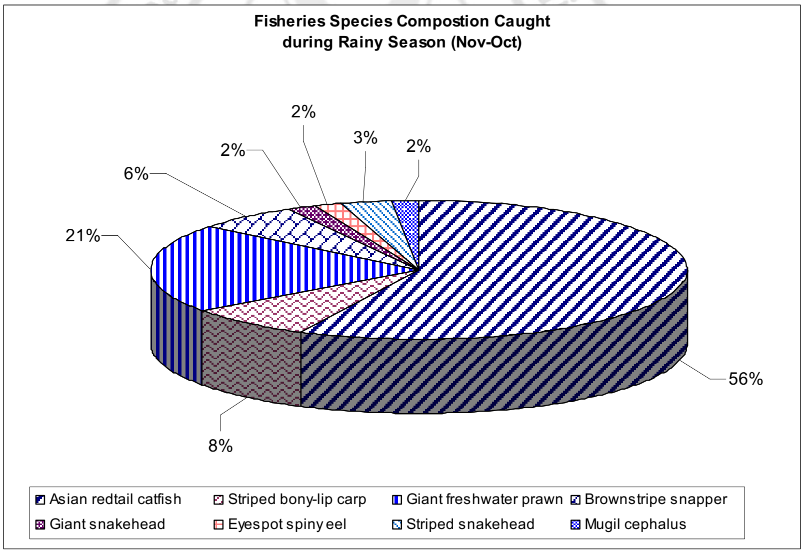
Length of fishing	Frequency	(%)
1 night	44	65.67
1-2 nights	13	19.40
2-3 nights	7	10.44
3-4 nights	1	1.49
Up to 5 nights	1	1.49
No response	1	1.49
Total	67	100

Source. Results from calculation from fieldwork data, 2009.



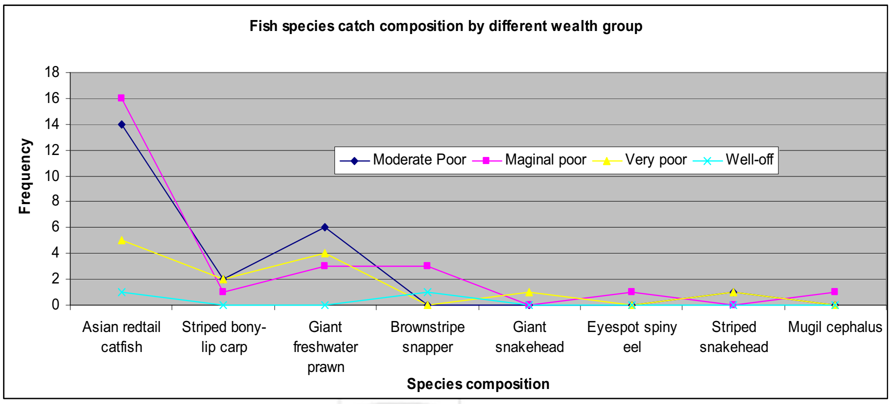
Source. Results from calculation from fieldwork data, 2009.

Figure B1 Fishing time



Source. Results from calculation from fieldwork data, 2009.

Figure B2 Fish Species Catch Composition



Source. Results from calculation from fieldwork data, 2009.

Figure B3 Fish species caught -- composition by Different Wealth Group

APPENDIX C

Assumptions and inputs model

Table C1 Main data inputs used in the model Fishermen Population Dynamic component

Variable	Variable Type	Meaning	Typical value used in the model[4] Initial Value used in the model (1960, assumed)	Reference
Poor fishermen (Fishermen P)	Stock	Those fishermen who own fewer fishing tools; most have no motor boat for fishing	30 (persons)	- Estimated from actual data obtained from survey in 2009.
Non-poor fishermen (Fishermen NP)	Stock	Those fishermen who own better fishing tools and have a motor boat for fishing	60 (persons)	- Estimated from actual data obtained from survey in 2009.

[4] Values shown here are estimations, but, of course, can be changed to examine other scenarios.

Table C1 (continued)

Variable	**Variable Type**	**Meaning**	**Typical value used in the model**[5] / **Initial Value used in the model (1960, assumed)**	**Reference**
Potential poor fishermen (Potential PF)	Stock	Those poor people who intend to become fishermen	150 (persons)	- Estimated from actual data obtained from survey in 2009.
Total fishermen population	Auxiliary	Combination of Non-poor and Poor fishermen	90 (persons)	- Estimated from actual data obtained from survey in 2009.
Status promotion	Rate	Change from poor to non-poor fishermen by having better tools or more effort to catch more fish	- With fraction 0.01 (person/year)	- Estimated from actual data obtained from survey in 2009.
Fractional quitting rate	Rate	The rate at which fishermen (either non- poor or poor) leave fishing as their job	- For poor fishermen 0.05 (person/year) - For non-poor fishermen 0.1 (person/year)	- Estimated from actual data obtained from survey in 2009.

[5] Values shown here are estimations, but, of course, can be changed to examine other scenarios.

Table C1 (continued)

Variable	Variable Type	Meaning	Typical value used in the model[6] / Initial Value used in the model (1960, assumed)	Reference
Total fish stock	Stock	Total volume of young and adult fish stocks. Based on data from interviews, catch per fisherman averages 6 kg, with 8 months of fishing days and about 938 fishermen. In addition, it is assumed that **<u>40%</u>** of total fish stock is harvested. Thus, total fish production volume can be estimated at 3,376,800 kg per year. However, the real production stock may be larger than the estimated figure; therefore; the real figure was manipulated.	5e+005 (kg)	- A substantial proportion of the catch is estimated around 40%. Even though this proportion is not very précised, but it is simple ration that can be applied regardless the variation between species, areas and seasons (McCausland et al. 2005)

[6] Values shown here are estimations, but, of course, can be changed to examine other scenarios.

Table C1 (continued)

Variable	Variable Type	Meaning	Typical value used in the model[7] / Initial Value used in the model (1960, assumed)	Reference
Young fish	Stock	The fish stock that is not yet old enough for breeding	3e+005 (kg)	- Estimated from actual data obtained from survey in 2009.
Adult fish	Stock	The fish stock that has matured enough for breeding and can be harvested for economic value	2e+005 (kg)	- Estimated from actual data obtained from survey in 2009.
Water body	Auxiliary	Carrying capacity to accommodate fisheries resources	3.5e+006	Area that can accommodate the maximum fish, identified as m^3

[7] Values shown here are estimations, but, of course, can be changed to examine other scenarios.

Table C1 (continued)

Variable	Variable Type	Meaning	Typical value used in the model[8] / Initial Value used in the model (1960, assumed)	Reference
Fractional maturing rate	Rate	The rate that young fish grow up to be adult fish, which depends on the time to become mature	- Time to mature is 6 months, so normal fraction 0.5 (dimensionless)	- Pettletier et al. 2005
Fractional breeding rate	Rate	The proportion of female fish that can produce young fish	- With normal fraction 0.5 (dimensionless)	- Pettletier et al. 2005
Fractional death rate of young fish and adult fish	Auxiliary	We assume that young fish have an 80% survival rate and a 20% mortality rate.	- With normal fraction 0.2 (dimensionless)	- Pettletier et al. 2005
Fractional Catch rate	Rate	The rate that fishermen extract fish from the fishing grounds	- Affected by catch per capita rate and population of fishermen (with unit kg/year)	- Estimated from actual data obtained from survey in 2009.

[8] Values shown here are estimations, but, of course, can be changed to examine other scenarios.

Table C1 (continued)

Variable	Variable Type	Meaning	Typical value used in the model[9] / Initial Value used in the model (1960, assumed)	Reference
Catch per person rate for poor fishermen	Auxiliary	The rate that poor fishermen catch fish per fishing trip	- Affected by density, effective tools, and normal catch per time estimated to be 53, which is 3 times lower than the non-poor fishermen (with unit kg/year/fishermen)	- Estimated from actual data obtained from survey in 2009.
Catch per person rate for non-poor fishermen	Auxiliary	The rate that non-poor fishermen catch fish per fishing trip	Affected by density, effective tools, and the normal catch per time is estimated to be 160 (with unit kg/year/fishermen)	- Estimated from actual data obtained from survey in 2009.

[9] Values shown here are estimations, but, of course, can be changed to examine other scenarios.

APPENDIX D

Perspective of Trapeang Rung commune towards community-based fisheries management

During the fieldwork, throughout the discussions with various stakeholders to find ways to better manage the area's fisheries resources that face over-catching and find ways to provide more benefit to the poor, the idea of community-based management frequently came up as a feasible management approach. Many local people are aware of the possible benefits of this approach through their own experience in the neighboring community of Chrouy Pras (see Map A).

To capture and understand more deeply the area's multi-stakeholder perceptions on community-based fisheries management, the author carried out analysis to understand the motivations and reasons why this type of management approach intrigues people. To assess and understand the barriers and opportunities of such practices, different stakeholders were asked to give their views on the issue. Officials from government departments (Fisheries Administration), non-government organizations (NGOs), and local authorities were requested to provide some of their views on the practical experiences related to community-based approach for local fisheries management.

Their opinions on this issue are considered as a top-down perspective. Moreover, the people actually involved in fishing were interviewed as well to gain in-depth understanding toward their thoughts on the issue. The ideas of this group belong to the bottom-up notion. Qualitative methods were used as the basis of the analysis.

The following presents the results of the research on the observations of the different stakeholders. The findings from the officials are organized and integrated with the ideas from fishermen in order to put more emphasis on the possibility of enacting such a management approach. Each group’s views are not presented separately because of differences in sample size between the two and the different methodologies used to obtain the information (i.e. members of the fishermen group were interviewed through questionnaires, while for the officers the researcher used semi-structured interviews through a short checklist)

The first section analyses the motives of people towards fisheries management; the second highlights the difficulties and challenges that such a management approach would face. The last section looks at opportunities and the future of fisheries management in the community that would sustain its fisheries resources and enhance benefits to the poor.

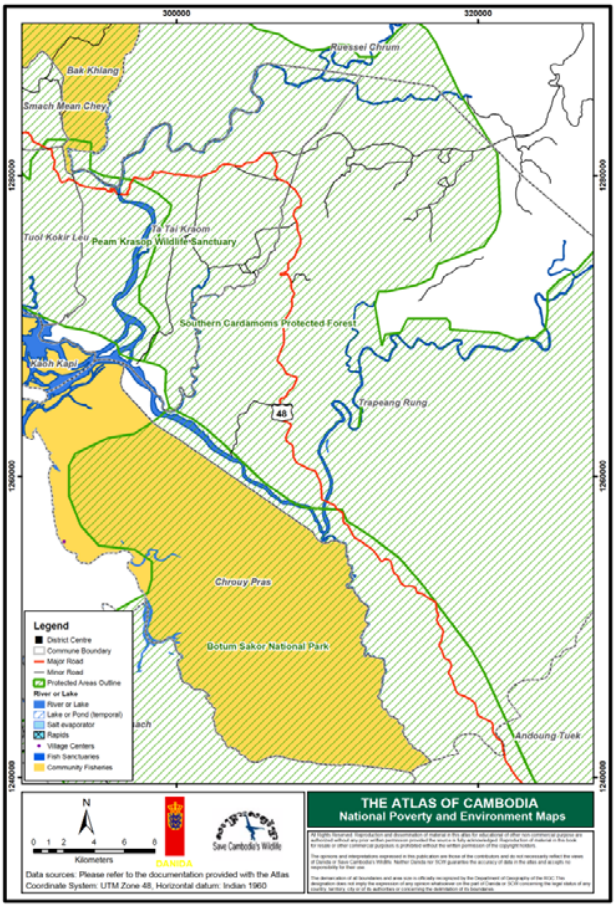


Figure D1 Chrouy Pros community fisheries

- Motivational factors

People who provided information on fisheries management come from different backgrounds and have had different relationships with fisheries resources. Fishermen use resources while fisheries officers are resources managers. This also means that they have various concerns about the issue and have different understandings towards community-based management in Trapeang Rung commune.

Figure A shows the various indicated reasons that are considered to be the motivational factors for fishermen to participate in establishing community-based fisheries management in the commune. The desire to sustain fisheries resources was the most-cited factor (41%); sustaining incomes was second (30%). Desire to conserve biodiversity (20%) was also important, but less so. Maintaining nutrient sources from fish protein accounts for only 9%. The following provides an explanation toward the difference of motivating factors raised by the fishermen.

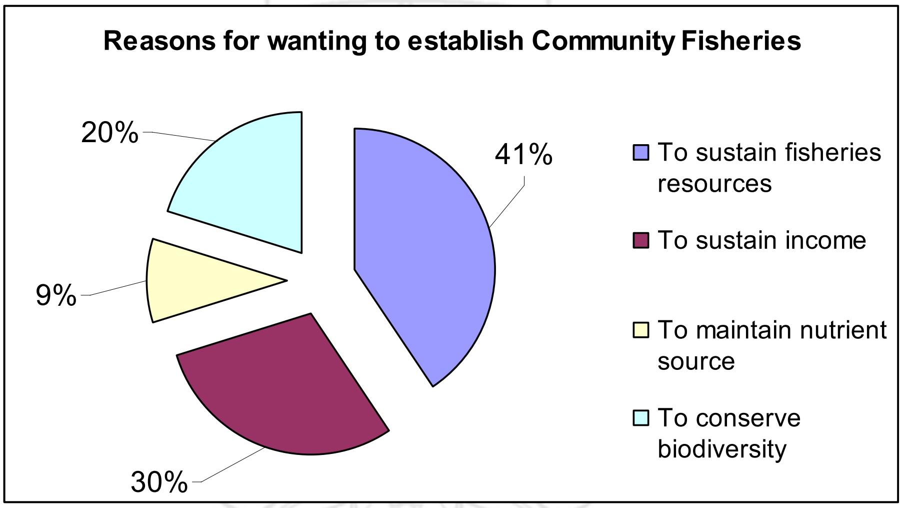


Figure D2 Reasons for wanting to establish Community Fisheries

Source. Results from calculation from fieldwork data, 2009.

- Sustainable resources utilization as a motivation

In this section sustainable resources use refers to the intention to sustain fisheries resources as well as conserving biodiversity that are presented in Figure A. In this context, the fishermen defined biodiversity as involving flooded forests as well as mangrove forests that support fisheries habitats. Some of them also thought of it as involving other NTFPs or wildlife in the forests near their villages.

According to Figure A, two factors accounted for over 70% of the total share of all those reasons cited the hope to sustain the fisheries resources and income in the future. Clearly, at some core level these villagers understand deeply the value of the natural resources that provide them their livelihood. This also is a possible sign of their willingness to cooperate voluntarily in the protection and management process rather than being treated solely as a beneficiary group.

The officers also emphasized this set of viewpoints. Typically, these resource management-oriented people see the potential for community-based natural resources management to sustain biodiversity either directly or indirectly.

However, through talking with local fishermen, a special emphasis was evident within the poor group since they are the ones now disadvantaged in terms of accessing resources. In their view if a community fisheries system was formed in their commune, they hope that they can gain more fish just by fishing near their own houses (some of which are located near the bank of Trapeang Rung channel). They do not want other fishermen who have better fishing gear to come here to fish. This opinion seems to reflect the intention that this new management system would allow local poor groups to exercise some version of true ownership of the fisheries resources within their own territory.

- Economic and nutrition motivation

Economic motivation covers the intent to sustain income and nutrition. According to Figure A, these motivated factors contribute about 39% of all the reasons for establishing a community fishery system, slightly less than the motivation focused on sustainable use of resources. This reflects the intense awareness of fishermen towards the resources on which they depend for their livelihood.

Based on observations during fieldwork, most fishermen have also participated in the other related community activities that have been carried out by other institutions like NGOs and government offices. For example, the Wildlife Alliance has established and been implementing a community-based eco-tourism project in the commune. Therefore, most of them understand and realize the importance of biodiversity for their community. However, it is interesting to note that some fishermen who did not emphasize sustaining income as a motivational factor to establish community fisheries thought that establishing a community fishery in their commune will require them to obey new community rules and regulations that they see as a constraint in accessing the fisheries resources. Therefore, to them, putting fisheries resources under community ownership will more or less reduce their fishing capabilities, and then may reduce their income. Because they experienced signs of fisheries decline through recent decreases in their fish catch, this group saw conservation biodiversity and maintaining fisheries resources as their main motivational factors. So maintaining and improving fisheries resources will at least provide them a chance to catch more available fish, which to them is better than having fewer fish available in the channel because it will reduce time and expenses on gasoline to go fishing compared to the current situation.

- Challenges and Barriers

Fishermen intend to establish a community-based fisheries management system in their commune for various reasons. These include sustaining fisheries resources, conserving biodiversity, and improving economic opportunity simply by sustaining income generation sources. But these motivating forces never stand alone. They are interlinked so that one supports the other. For instance, sustaining fisheries resources will make more fish available, allowing the fishermen to catch more fish. That result, in turn, allows these individuals to support other biodiversity issues like NTFPs or wildlife continuing to grow and flourish without any disturbance from humans.

However, it is true that many reasons come together before an initial establishment of any management approach that would convert today's open free access resources into limited access resources. This also means that the fishermen have to face different everyday challenges when they are operating the approach. For instance, fishermen see a real problem in participating on their own in some of the particular actions required to operate a community management system — for example, patrolling activity. In this regard, they felt that they would have to rely heavily on technical support from outsiders, especially from the provincial fisheries officials who seems to be able to help them organize and facilitate the process. Without that kind of support, the fishermen are worried that they would not know what to do not when to do it. Officials view the barriers from a different perspective, because they have knowledge about different systems and can see the inter-relations of the work done by governmental bodies and other actors. They can be powerful actors in fostering policy changes and following up implementation procedures.

During the interviews with the different stakeholders the following barriers and challenges were outlined in relation to emergence of various community initiatives.

- Non-availability of resources

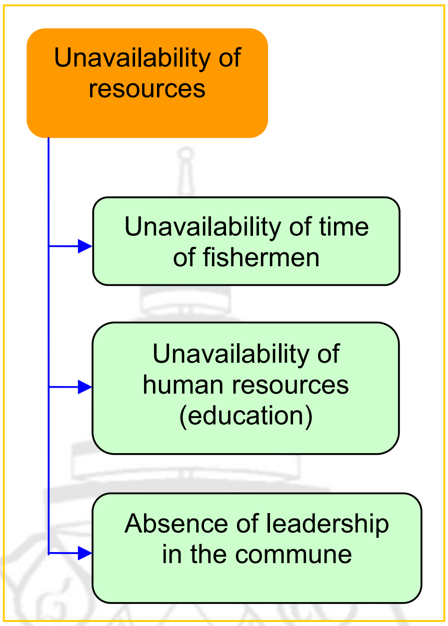


Figure D3 Non-availability of reasons

Fishermen commonly saw the adequacy of resources available to them as the greatest constraint that has to be taken into consideration. Key resource constraints are time for fishermen to work on helping protect fishery resources, and education and leadership among the local people.

Time availability was raised as the main challenge among the fishermen, especially the poor fishermen who depend on fishing for their basic daily survival. Therefore, if the new fisheries management approach were to make enormous demands on their time to participate, the system would simply not work. If that happens, the poor will be automatically excluded from the management scheme, a result that does not reflect its main purpose of building a bottom-up management approach.

Another constraint involves having enough literate people among the fishermen groups. Even though basic fishing skills are not influenced by literacy, the proposed local management regime needs local people to handle many important actions from paper work (regulations, planning of resources utilization, penalty schemes and fisheries laws) to practical work.

Similar to the educational constraint, absence of leadership in the commune to initiate this kind of management approach counts as an important barrier. It is crucial in terms of revealing motivations as well as participation in voicing the community concerns to be heard by outsiders who can support them in terms of technical and financial aspects. Likewise, the officers emphasized the importance of proactive action by the local people. Since the management approach being considered is bottom-up, it requires collective action by the community to make it happen.

- Possibility to engage external actors

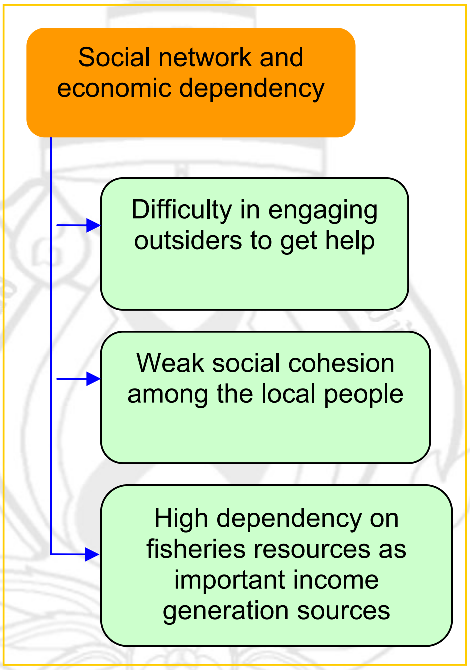


Figure D4 Possibility to engage the external actors

Another perceived constraint mentioned by the local people related to social networks with outsiders as well as among their own group. Some of them said that it is really difficult to contact outsiders. The local people often do not know who to contact; it is hard to reach even those who provide existing support.

In this regard, local authorities highlighted their expectation that establishing a community-based management system in the commune would help protect fisheries resources for better long-term utilization. However, they are not sure whether local people can participate in this mechanism since, as they experienced often during commune meetings, only a few people are willing to spare their time to join in. In their opinion, the social cohesion of people in the commune is still weak even though, traditionally, local people always help each other during difficult times. (For example, when some poor households need cash urgently to pay a hospital bill, they can borrow from their neighbors without having to pay interest on the loan).

Another factor also has influenced the motivation of the local villagers to participate in the community fisheries management approach their high economic dependence on fisheries resources. Few alternative jobs are available in the commune; most are labor intensive jobs such as wage labor or NTFPs (rattan) collecting. Moreover, it seems to be especially difficult for those local people who live in villages inaccessible by road (Koh Kong Knog and Veal Taphou) to mobilize themselves to get to available jobs in the center of the commune. Therefore, it is important to bear people's livelihood limitations in mind when developing rules or regulations for the locals to act upon. Clearly, any intervention that converts open access fisheries resources into community property ownership will add some stress on the livelihoods of the people in the short term. Hence, the leader or the local authority will need to work harder to raise awareness of the long-term benefits that are possible from implementing the management approach in the face of existing constraints.

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